EPDE

Engineering and Product Design Education

2022

Disrupt, Innovate, Regenerate and Transform

Proceedings of the 24th International Conference on Engineering and Product Design Education

8 - 9 September 2022

Hosted by
London South Bank University
United Kingdom

Editors

Deborah Andrews

Elisa Puccinelli

Erik Bohemia

Hilary Grierson

Lyndon Buck

Robin Jones

Susana Soares

DISRUPT, INNOVATE, REGENERATE AND TRANSFORM

Editors: Deborah Andrews, Elisa Puccinelli, Erik Bohemia, Hilary Grierson, Lyndon Buck, Robin Jones, Susana Soares.

PROCEEDINGS OF THE 24TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8-9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, London, UNITED KINGDOM

DISRUPT, INNOVATE, REGENERATE AND TRANSFORM

Deborah Andrews
London South Bank University

Elisa Puccinelli
London South Bank University

Erik Bohemia
Shandong University of Art and Design

Hilary Grierson
University of Strathclyde

Lyndon Buck
Aston University

Robin Jones
London South Bank University

Susana Soares
London South Bank University

Cover credit: Deborah Andrews.

Institution of Engineering Designers
Courtleigh, Westbury Leigh, Westbury, Wiltshire, BA13 3TA, United Kingdom.
+44 (0)1373 822801.
www.ied.org.uk

The Institution of Engineering Designers is a charitable body, incorporated by Royal Charter registered in the UK No: 1145678.

The Design Society
University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ, United Kingdom.

The Design Society is a charitable body, registered in Scotland, No: SC031694.

Published by:

The Design Society
Institution of Engineering Designers

ISBN: 978-1-912254-16-3

The Design Society is an international non-governmental, non-profit making organisation whose members share a common interest in design. It strives to contribute to a broad and established understanding of all aspects of design and to promote the use of results and knowledge for the good of humanity.

The Design Society was founded in 2000, taking on the previous activities and responsibilities of the Workshop Design Konstruction (WDK) Society, especially the organisation of the International Conference on Engineering Design (ICED) series of conferences, which had been running since 1981. Since 2000 the Society has organised ICED conferences in Stockholm, Melbourne, Paris, Stanford, Copenhagen, Seoul and Milan. The upcoming 2017 conference will be hosted in Vancouver.

The Society has members from over forty countries and it organises very popular events such as the Engineering and Product Design Education conferences and the International Conference on Design Creativity among many other activities. The Society is very active in publishing papers and proceedings on design topics, and it has a developing portfolio of other design resources available to members including a repository of theses and collaborative agreements with a number of design research journals.

The Design Society concentrates on activities that transcend national boundaries, and, where possible, will seek to complement national activities. The objects of the Society are to promote the development and promulgation of understanding of all aspects of design across all disciplines by:

- Creating and evolving a formal body of knowledge about design
- Actively supporting and improving design research, practice, management and education
- Promoting co-operation between those in research, practice, management and education
- Promoting publications and their dissemination
- Organising international and national conferences and workshops
- Establishing Special Interest Groups and other specialist activities
- Co-operating with other bodies with complementary areas of interest

The Design Society is a charitable body, registered in Scotland, number SC031694. Registered Company Number: SC401016.

The Design Society is open to new members.
www.designsociety.org

Established in 1945, Incorporated by Royal Charter in 2012, the Institution of Engineering Designers is the premier organisation in the UK to represent those working in the many fields of engineering and product design.

Our members enjoy a range of benefits, including mentoring and guidance to professional registration, exclusive access to our job board and newsletters to keep members up to date with relevant developments and events. We host regular events which offer our members the chance to network with other professionals and members receive the Institution's bi monthly journal – Engineering Designer.

We are committed to encouraging CPD for all our members and support ongoing training and skills development.

We offer a wide range of professional registrations: our own register for professional product designers includes the exclusive Chartered Technological Product Designer (CTPD) which is on a par with all other Chartered registrations and exists to provide professional recognition and standing to those suitably qualified and competent persons working in Product Design, with the sister grade of Registered Product Designer (RProdDes) for those not working at Chartered level.

We are licensed by the Engineering Council to assess candidates wishing to join the register of Professional Engineers and Technicians and we also accredit academic and training courses, for registration with either the Institution or with the Engineering Council. Those members who achieve the appropriate academic and competence standards receive Chartered Engineer, Incorporated Engineer or Engineering Technician status.

We are also a licensed body of the Society for the Environment and are able to register suitably qualified and competent members as Chartered Environmentalists (CEnv).

We welcome members from any organisation that has a design function and employs design engineers and we have many academic teaching staff in membership. To find out more about becoming a member of the IED and a professional registered designer go to http://www.ied.org.uk

AGEING COLLABORATIONS: CO-DESIGNING FUTURE TECHNOLOGY OPPORTUNITIES

Linda SHORE[1], Shika HURRYDASS[2], Richard THOMPSON[2], Rachel SALZANO[2], James MARSH[2], Zuzanna MARCHEWKA[2], Thelma BABBS[2], Sharon JACKSON-KERR[2], Marta LIS[2], Reece LESLIE[2] and Michael ELLIS[3]
[1]Edinburgh Napier University/Glasgow School of Art, Scotland
[2]Edinburgh Napier University, Scotland
[3]TapintoIT, Edinburgh, Scotland

ABSTRACT
The Ageing experience and increased longevity presents innovation opportunity for emergent technology, e.g., mobile and wearable. In turn, these technologies can enhance quality of life and independence as we age; however, they can also increase social inequalities and exclusion. The Covid-19 pandemic affected how we interact, communicate engage and interact with people and also technologies. People – across the generations were impacted and disrupted, motivating new behaviours in how they conducted everyday tasks and activities. Co-Design approaches have previously revealed successful collaborations between older adults, students, researchers, designers and other disciplines as a means to define unmet needs. Edinburgh Napier University provided funding to the PI (Principal Investigator) as a means to mobilise a 'Creative Cross-Education Team' (CCET) consisting of undergraduate students, research assistants (post-graduate researchers) and other staff colleagues of the University. The CCET worked with members from 'Tap into IT' (a local charity based in Edinburgh with a remit and focus on enhancing and enabling digital technology access for older adults). Two Co-Design workshops were conducted online titled 'Express' & 'Create.' The aim of these workshops was to explore, identify and define unmet needs/gaps expressed by older adult participants as a catalyst to create and generate future conceptual technology opportunities. The workshops were framed around Instrumental Activities of Daily Living (IADLs). The team were broken into groups whereby they were encouraged to collectively collaborate, Express and Create with the participants. This multi-generational and transdisciplinary approach created a democratized outlook where each contributor added value through expression, commentary and creativity. The findings have generated themes which are the basis for new opportunity through education and research with a focus on future technology opportunities.

Keywords: Creative cross-education teams, UX design education, ageing experience, speculative design, co-design

1 INTRODUCTION
Increased longevity and new lifestyle approaches to ageing offers innovation opportunity for emergent technology (Barclays Bank, 2021; Marston et al., 2022).
Emerging technologies including mobile and wearables can offer benefits to quality of life and independence as we age (Shore et al., 2018a, Barbosa Neves & Vetere, 2019); however they can also increase social inequalities and exclusion. In addition, technological applications including Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR), Mixed Reality (MR), connected services/systems e.g. healthcare, offer research & innovation opportunity (McLaughlin et al., 2018).
Previous research has demonstrated how multi-generational and transdisciplinary approach creates a democratized outlook where each contributor adds value through expression, commentary and creativity. Furthermore, Co-Design methods can enhance successful collaborations between older adults, students, researchers, designers and other disciplines as a means to define unmet needs (Shore et al., 2018b). A research project funded by Edinburgh Napier University facilitated a new collaboration with a local charity in Edinburgh, Scotland that provides ongoing support to enable older adults to access and experience positive interactions with IT and online services.

2 CO-DESIGN IN A PANDEMIC

The Covid-19 pandemic, impacted generations, economies and personal freedoms (Shevlin et al., 2020), with digital technology offering access and connection across various community sectors. In addition, opportunity to innovate can be harnessed and driven through approaches of collaboration, co-creation, universal design and speculative design in order to optimise physical and digital spaces and experiences for all (Marston et al., 2020). Co- Design methods offer rich, democratised and collaborative outputs that are realised through the creative activity, conversations & interactions (Sanders & Stappers, 2008; Shore et al., 2018; Sakaguchi-Tang et al., 2021). Initial Discussions began in March 2021 between the PI at Edinburgh Napier University and the lead contact at 'Tap into IT'. A call was put out to the University community, including undergraduate students, inviting their participation and collaboration to forge a CCET. Despite the pandemic and current lockdown restrictions at that time, there was a positive response and the creative coalition (Manzini, 2015) was mobilised for further development and communications to work with the lead at 'Tap into IT'. The planned workshops were discussed over digital meeting technology (Microsoft Teams) as a means to collectively plan a course of action. MacDonald et al., (2021) discuss the importance of real world contexts and opportunities through a number of tools (e.g., Brainstorming, Design, Messaging, Productivity, Project Management) as important factors to develop students' communication skills and competencies. UX Design by its very nature relies on understanding and communicating with people, as we define unmet needs. The workshops and the nature of communication, creativity & collaboration would enable the students involved to refine and develop skills with communications, particularly with other team member as well as participant interactions (MacDonald et al., 2021).

3 METHODOLOGIES

It was envisaged that Co-Design and research through design approaches would identify research opportunity by defining new concept directions. This collaborative coalition of academic, charity and older adult participants engaging in the co-design workshops would act as a catalyst to innovation opportunity. Students can benefit from collaborative activities as a means to enhance education and learning (Nel, 2017). Two interactive/digital Co-Design workshops were devised with objectives aimed at exploring, identifying and defining unmet needs/ gaps expressed by older adult participants. The workshop topic and headers were framed around IADLs – Instrumental Activities of Daily Living (Lawton & Brody, 1969). In addition, there was a planned timeline of delivery agreed collectively by the CCET (see Table 1).

Table 1. Planned timeline of delivery and activities

Day 1	meet with the team to strategize and develop the programme of the workshops.	01.06.2021 @2pm (2-5pm)
Day 2	launch information session to 'Tap into IT' members to promote and discuss the workshops. This will be online and possibly over Zoom	08.06.2021.2021 @ 2pm (meet/available 1-4pm)
Day 3	Administration re information and consent documents	17.06.2021 perhaps a one hour meeting that day).
Day 4	Day one of the Co-Design workshop titled: Express	21.06.2021: 2-4/4.30pm (some admin time that day)
Day 5	Day 2 of the Co-Design workshop titled: Create (this will be hosted three days after the Express workshop)	25.06.2021: 2-4/4.30pm (some follow up admin wrap up)
Day 6	brainstorming and debrief to develop themes collectively	28.06.2021: one hour and plan research and analysis for Tri 3

Table 1 highlights the themes and tasks as required, to prepare workshops and also debrief and interpret findings. In addition, Day 2 was significant as we launched and discussed our plan for the Co-Design workshops with the members of 'Tap into IT'.

The areas of enquiry (IADLs) were introduced and discussed, groups were formalised and encouraged to collaborate, express, and create. The discussion and workshops presented opportunity for the CCET to collate experiences and future perceptions by the older adult participants. This project intended to familiarise the PI, undergraduate students, and research assistants of unmet needs by older adults in relation to IADLs Instrumental Activities of Daily Living (Lawton & Brody, 1969)

Managing Finances, such as paying bills and managing financial assets.

Managing Transportation, either via driving or by organizing other means of transport.

Shopping & Meal Preparation. This covers everything required to get a meal on the table. It also covers shopping for clothing and other items required for daily life.

House Cleaning & Home Maintenance. This means cleaning kitchens after eating, keeping one's living space reasonably clean and tidy, and keeping up with home maintenance.

Managing Communication, such as the telephone and mail.

Managing Medications, which covers obtaining medications and taking them as directed.

There was identified research opportunity to understand and engage with the older adult members of 'Tap into IT' as a means to collaboratively consider the present challenges with technology and envisage solutions for the future.

3.1 Digital Co-Design Workshops

The workshops were attended by up to 18 participants plus the CCET. There were sections of the workshops that the whole group would discuss and then dispatch to breakout rooms. Each group of approx. 7 older adults would also include student volunteers and research assistants (at least one of each to each older adult group). Students who were involved and chose to pursue and develop research based on the workshop themes were given an opportunity to gain 20 credits to undertake research with a defined strategy that could be utilised and converted to post-grad, post-doc or external funding research (as identified in project overview) opportunity with collaborative partners such as the groups and members who engaged with the initial workshops or others. Each of the sessions would provide intervals with accompanying easy listening jazz type music e.g., Sam & Max season 1 OST (https://www.youtube.com/watch?v=YJrYs6pPYtw). This was a pleasant surprise observing the reaction and comments to the pleasant easy music and timeout opportunity from the screens. It offered light laughter and a refresh moment to make tea or look out to the garden etc.,

3.2 Express

The first of the two workshops was titled 'Express' this was designed to offer opportunities to the participants to express current and share experiences relating each of the IADLs. The participants entered breakout rooms, whereupon there were minimum of two team members from Edinburgh Napier University. Many stories were shared relating to the IADLs and participants everyday experiences.

3.3 Create

The second workshop was scheduled for three days later, and as per the latter part of the Express workshops, participants were encouraged to reflect and put together some thoughts as part of preparation for the Create session. The team members met after the initial workshop to de brief, discuss and evaluate the merits of what was highlighted/discussed by the participants and the commonalities or not between the various groups.

4 FINDINGS

Despite the digital space of interaction on Microsoft Teams, there was also a reliance on Miro boards to assist creativity and collaboration. In addition, there was consideration to taking breaks as opportunities to make tea & reflect with some specially selected music. In addition, the students involved at undergraduate level were invited to share reflection on the experience and how if any it may benefit their learning, as noted below:

"From the perspective of an undergraduate student, the possibility to take part in the project was a very exciting opportunity. My input and preparation before workshops included writing open-ended questions, taking part in the meetings and sharing ideas with my colleagues. Taking part in the project and collaborating with experienced researchers was an outstanding experience, that positively impacted my education and growth. By the end of the project, I feel much more confident as a student and future designer. The workshop was a beautiful experience where designers found a universal language with participants, a space where we freely shared and talk about new ideas and everyday struggles." (Student voice).

4.1 Express

The groups worked within the breakout rooms, and during the first day/session focussed on expressing current experiences as per each of the IADLs. The findings are summarised below:

Managing Finances: Participants noted the impact of the pandemic and how observations such as the physical interactions and services in a bank had been affected not only as a result of 'lockdowns' but also as a business practice witnessed in recent years. In addition, there was commentary relating to cashless transactions with one participant commenting: "*It's amazing how I can pay for milk with my card now*". Other discussions related to managing finances related to trust, security, online apps and how 'Age-Friendly' some banks were – or not.

Managing Transportation: focussed on ability to move from A-B. Participants expressed reasons to use public transport – enjoying bus trips locally to reasons they disliked public transport access - particularly with assistive technology (wheelchairs) or hybrid – walk to the shops and take the bus home "*Buses only allow one wheelchair at a time; this can prompt a long wait till the next bus*".

Shopping & Meal Preparation: The Covid-19 Pandemic again was a focus with some participants who expressed the adaptation to shopping and food preparation. Batch cooking was commented on as was 'garden to microwave' approaches by those who took an interest in growing their own vegetables and/or fruit. Accessibility with some packaging was expressed as challenging – "*packaging can be a hassle, especially milk cartons*" as was online shopping, particularly in the first lockdown (Spring 2020) with issues expressed regarding location and post code errors by delivery drivers and supermarkets not advising or updating customers of shop issues until the last minute.

House Cleaning & Home Maintenance: Some participants noted how the pandemic had influenced cleaning behaviour around the home with some stating how they cleaned less as they were no longer receiving visitors – "*since lockdown and no visitors, I clean a little less*". There was positive expression towards community supports, however some services such as 'Care & Repair' presented difficulties to accessing tradespeople due to long waiting lists.

Managing Communications: This section generated interesting conversations regarding past experiences and again the current pandemic. Technology and digital communication tools such as Zoom or Microsoft Teams were discussed with lack of trust raised by some, ease of use by others and hearing capacity when interacting with others on these platforms. Participants shared how despite hearing challenge; they sometimes find further support on the 'chat' options - "*I have a hearing problem;* [the] *chat box on Zoom works really*".

Managing Medications: Pill and medication packaging was discussed with participants expressing difficulty opening blister packaging. There was expressions of satisfaction with some healthcare professionals, e.g., additional supports/reliance on pharmacists. Participants also shared numerous ways medications are accessed – online prescription requests to reminders as per 30 day pill planners, or technology reminders such as Alexa or smart-phone, or "*Getting text when prescription is ready to collect*".

These themes highlight research opportunity that could be developed, particularly in a real and face to face time post-pandemic. There was at times some reluctance or discomfort expressed during the Create sessions which was mainly considered relating to the uncertainty or doing something that wasn't correct or might be perceived silly. Previous experience of this activity in a face to face event type would appear to have offered more comfort with the design activity.

4.2 Create

The Create workshop was opened three days later with no change to attendees, however one was unable to attend due to illness. There was a positive energy, and perhaps a small amount of uncertainty to what was expected for the session ahead. Again, there was a reliance to assign groups to breakout rooms and Miro boards. This session mixed attendees from the previous session to offer collaboration, creative expression & ideation. A selection of the ideation and creative opportunity are summarised below, initially as a point of view (POV) statement to a how might we (HMW) as displayed on Table 2:

Table 2. POV & HMW samples for the Create session

IADL type	Point of view (POV)	How-Might-We (HMW)
Managing Finances	In the future cash and coin may remain as a digitalised asset to support transactions, but how do we educate understanding of coin	HMW apply money management and awareness education to students in order to minimise security, trust and risk in a digital space?

	'value' and crypto currency to children/students in formative years	
Managing Transportation	British roads are deemed not suitable for self-driving cars with limited consideration to other users such as pedestrians in city environments	HMW create a shared safe environment for pedestrians who select walking as their preferred access to city spaces?
Shopping & Meal Preparation	As we age, conditions like diabetes may manifest as a result of poor diet attention to nutrition and portions	HMW develop lifespan guides to nutrition that are interesting and invitation to optimise nutrition curiosity to adults and older adults?
House Cleaning & Home Maintenance	Adults who live independently may be at risk of becoming dependent due to illness or physical limitations as a result of reduced autonomy and/or ability	HMW retrofit and apply building principles to incorporate lifespan design and technology/robotic assistance to support housecleaning and home maintenance?
Managing Communications	Interfaces and new technology can be a challenge to learn 'by keyboard'	HMW create a design principle to include accessible tutorial sections in a variety of formats (e.g., video, book, digital, slides)?

5 DISCUSSIONS

The capacity to collaborate and research through design despite a pandemic has been demonstrated through the Express and Create workshops. The themes presented in this paper offer detailed insights to progress conceptual innovation opportunity. The CCET worked well together, accepting responsibilities and roles to deliver experience and expression through the planning and preparing sessions before the workshops, and the integration and working together with the members of 'Tap into IT'. The Student experience is optimized when experiential learning is facilitated in supported settings as demonstrated in this paper.

REFERENCES

[1] Barbosa Neves B., and Vetere F. (2019). Ageing and Emerging Digital Technologies. In B. Barbosa Neves and F. Vetere (Eds.), *Ageing and Digital Technology* (1 ed.). Springer Nature.

[2] Barclays Bank. (2021). *Active Ageing: Maximising the demographic dividend*. Retrieved 06/04 from https://www.investmentbank.barclays.com/our-insights/Active-Ageing-Maximising-the-demographic-dividend.html?cid=paidsearch

[3] Lawton M. P. and Brody E. M. 1969. Assessment of older people: self-maintaining and instrumental activities of daily living. The gerontologist, 9(3_Part_1), pp.179-186.

[4] MacDonald C. M., Rose E. J. and Putnam C. (2021). How, Why, and with Whom Do User Experience (UX) Practitioners Communicate? Implications for HCI Education. *International journal of human-computer interaction*, 1-18. https://doi.org/10.1080/10447318.2021.2002050

[5] Manzini E. (2015). *Design, When Everybody Designs: An Introduction to Design for Social Innovation*. MIT Press.

[6] Marston H. R., Shore L. and White P. J. (2020). How does a (Smart) Age-Friendly Ecosystem Look in a Post-Pandemic Society? *International journal of environmental research and public health*, *17*(21), 8276. https://doi.org/10.3390/ijerph17218276

[7] Marston H. R., Shore L., Stoops L. and Turner R. (Forthcoming-2022). Transgenerational Technology and Interactions for the 21st Century: Perspectives and Narratives. *Emerald Publishing.* ISBN 9781839826399.

[8] McLaughlin A. C., Matalenas L. A. and Coleman M. G. (2018). Design of human centered augmented reality for managing chronic health conditions. In *Aging, technology and health* (pp. 261-296). Academic Press.

[9] Nel L. (2017). Students as collaborators in creating meaningful learning experiences in technology-enhanced classrooms: An engaged scholarship approach. *British journal of educational technology*, *48*(5), 1131-1142. https://doi.org/10.1111/bjet.12549

[10] Sakaguchi-Tang D. K., Cunningham J. L., Roldan W., Yip J. and Kientz J. A. (2021). Co-Design with Older Adults: Examining and Reflecting on Collaboration with Aging Communities. *Proceedings of the ACM on Human-Computer Interaction*, *5*(CSCW2), 1-28.

[11] Sanders E. and Stappers P. (2008). Co-Creation and the new landscapes of design. CoDesign, 4, 5-18.
[12] Shevlin M., McBride O., Murphy J., Gibson Miller J., Hartman T. K., Levita L., Mason L., Martinez A. P., McKay R., Stocks T. V. and Bennett K.M. 2020. Anxiety, depression, traumatic stress and COVID-19-related anxiety in the UK general population during the COVID-19pandemic. *BJPsychopen*, *6*(6) https://doi.org/doi:10.1192/bjo.2020.109
[13] Shore L., Power V., De Eyto A. and O'Sullivan L. W. (2018a). Technology acceptance and user-centred design of assistive exoskeletons for older adults: A commentary. Robotics, 7(1), 3.
[14] Shore L., Kiernan L., DeEyto A., Nic A Bhaird D., White P., Fahey T. and Moane S. (2018b). Older adult insights for age friendly environments, products and service Systems. Design and Technology Education: an International Journal, v. 23, n 2,, p. 40-58,. Retrieved Date accessed: 10 oct. 2018., from < https://ojs.lboro.ac.uk/DATE/article/view/2327 >.

DESIGN WITH A CRITICAL LENS TEACHING STUDENTS HOW TO FIND, RATHER THAN SOLVE, DESIGN CHALLENGES USING INTERDISCIPLINARY WORKSHOPS

Kristof Romain Victor VAES[1], Anne Britt TORKILDSBY[2] and Muriel DE BOECK[1]
[1]Department of Product Development, Faculty of Design Sciences, University of Antwerp, Belgium
[2]The Norwegian Research Laboratory for Universal Design, NTNU Norwegian University of Science and Technology

ABSTRACT
The Critical Design Workshop series aimed to give students experience of designing for social emancipation and cohesion. In times where extreme circumstances and polarization are hardening the social debate, transferring this power to design students can enable them to identify various ethical issues, such as guilt, fear, stigma or social gaps, early in the design process. Through four, five-day interdisciplinary workshops – conducted from 2018 to 2021 – approximately 60 students from disciplines including design, architecture and engineering were encouraged to generate critical design examples shedding light on assistive technology, product-related stigma, empathy and human augmentation, respectively. By first making the students believe they were approaching the design challenge using a traditional problem-solving approach, they gained hands-on knowledge about the fundamental difference between affirmative and critical design. The first three workshops were conducted face-to-face, but due to COVID-19, the fourth workshop was held online. Despite the different format, the hybrid version managed to maintain both the pedagogical content and the spirit of the earlier workshops and, furthermore, the students reported that the 'upside-down' methodology was liberating, engaging and effective no matter what format. This paper presents the structure, content and results of the four workshops, and discusses the inevitable transition from a physical to a hybrid-learning environment.

Keywords: Critical design, stigma-free design, design methods, educational practices, workshops

1 INTRODUCTION
Traditionally, designers apply affirmative design[1] approaches in the design process, providing answers or solutions to questions or design challenges, reinforcing the current situation rather than rejecting it and thereby encouraging critical thinking [1],[2]. This is simply how we are trained to perform as 'problem-solvers' (and 'solution-focused') [3]. Critical and speculative design has been around since the late 1990s and it has proven to be effective as a medium for inquiry into present social, cultural, ethical, technical and economic implications of design and practice for decades [1],[2],[4]. However, our collective experience from conducting critical design workshops for more than 10 years in various higher education institutions in Europe [5–8] is that more emphasis could be put on this alternative way of thinking through design to, in short, open the minds of students.

The importance of teaching students about existing stereotypes and prejudices also needs to be emphasized, given that products can be embedded with qualities and attributes, which directly cause social rejection and stigma among users and bystanders – even when nobody else is around. According to [9], the power of public stigma can make users of certain products experience discrimination,

[1] According to Dunne and Raby, 'Affirmative design' reinforces predominant social, technical or economic values, while 'Critical Design' strives for an alternative form of product design, positioned as a medium for inquiry [2, 16, 17].

alienation and inequality, rejecting the products altogether and, in the worst-case scenario, leading to a stigmatized condition that triggers further inequality and exclusion from society.

For this case study, we explored the above-mentioned critical/affirmative dichotomy through four interdisciplinary one-week workshops focusing on, for example, how to design stigma-free products, environments, systems and services with respect to equality, diversity and inclusion using the stigma-free design toolkit [9, 10] but with a ‘critical twist’. This involved generating ‘stigma-free design’ (SFD) [10] during the first two-and-a-half-days, with the students spending the latter half of the week developing critical design (CD) examples[2] [5], which helped them to let go of traditional problem-solving methods and instead tap into the power of problem-finding (exposing).

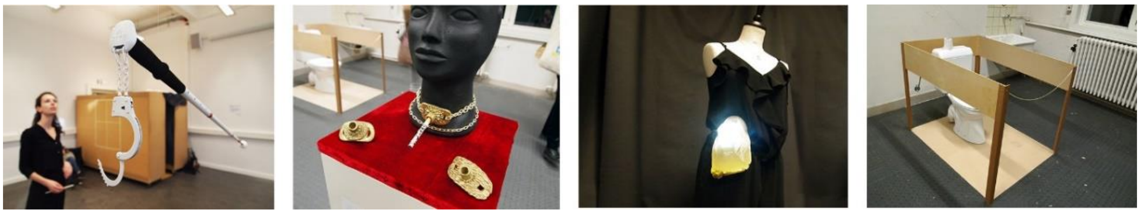


Figure 1. Some of the CD examples generated in WS1-WS2, shedding light on (from left to right) what life might look like when dependent on: a cane for the blind (#Can'tYouSee?); tracheostomy covers (#SmokingHot); or a colostomy bag (#Carry-on); or when suffering from Paruresis/‘shy bladder’ syndrome (#Exposed)

We believe that by enabling students to identify various moral and ethical issues, as discussed above, the next generation of designers, architects and engineers will be better equipped to be ‘problem-finders (exposers)’ as well as ‘problem-solvers’ and, thus, far better suited to dealing with twenty-first-century challenges whatever they might be [11].

2 METHOD

2.1 Critical twist

Authors Vaes and Torkildsby conducted four workshops (WS1-WS4) as part of the International Design Workshop Week, at the Faculty of Design Sciences at the University of Antwerp. While WS1-WS2 were merely about how to illustrate universal design [6] and empathic design through CD, respectively [7], WS3-WS4 were divided into two parts: a stigma-free design challenge (i.e. SOLVING), followed by a critical design twist (i.e. EXPOSING) (see Figure 2) [11]. It should be noted that there were 15 students in total in each of the workshops, and they were divided into four teams by the tutors with both genders represented.

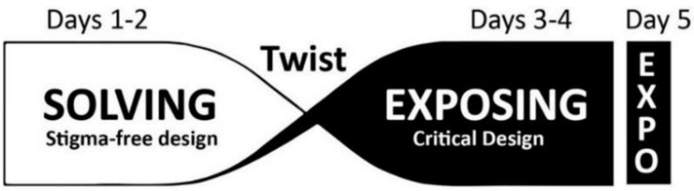


Figure 2. Visualization of the workshop layout, including the ‘critical twist’

2.1.1 Step 1 – SOLVING

In this step, we exposed our students to two expeditious exercises. The students were first challenged to explore the context of a specific stigma-eliciting product, e.g., a hearing aid, identifying the main sensitivities for both the product, the user, people they engage with and society at large. To facilitate this, they used a checklist of 27 questions (PAMS - Products Appraisal Model for Stigma) [9] to ‘unveil’ stigma pitfalls and social conflicts embodied in the specific product. The tutors requested the students to synthesize this exercise into a selection and description of the six most socially challenging and stigmatizing aspects. In a second exercise, we provided our students with 17 inspirational stigma-reducing design cards (PIMS - Product Intervention Model for Stigma) [9], which aimed to inspire them to develop concepts that could not only solve the six stigma challenges they defined, but could also increase consumer product attachment, user empowerment and collective wellbeing. In this way, the

[2] CD example is the result of employing critical design in a design process [5].

students try to solve the social problem(s) of stigma elicited by a product in an affirmative manner of design. The combination of PAMS and PIMS helped the students to produce stigma-free concepts, which they presented in the afternoon on the second day. This activity also included feedback and assistance from tutors and other students. They went home that day thinking they were going to elaborate on the chosen stigma-free design concept towards a solution over the coming three days.

2.1.2 Step 2 – EXPOSING

While the 'solving-phase' aimed to provide solutions to stigma-sensitive problems, the 'exposing-phase' was all about using critical design to identify and reveal the exact same problems that the students had attempted to solve in Step 1. They had two and a half days to turn the design process 'upside-down,' and generate CD examples[3] that embodied critique of or commentary on the design challenge chosen (i.e., product-related stigma, WS3; and human augmentation, WS4).

From lunch on Wednesday to Friday afternoon, the students diligently followed a miniature version of the traditional design process (i.e., inspiration, ideation and implementation), using the above-mentioned six stigma challenges as requirements or 'guidelines.' They presented their results in a plenary session as milestones during the process and used the critiques of their peers and the teachers to make decisions about which concept to choose and continue developing. The various teams were free to choose whatever means they wanted to present their concepts, including text scenarios, drawings, storyboards, paper or other material mock-ups, role-play or film.

2.2 Face-to-face and hybrid learning

In this section, we present the hands-on method of WS3 and the hybrid approach (i.e., face-to-face and online teaching) used in WS4 separately, before comparing them in the subsequent discussion section.

2.2.1 Workshop Series #3 (WS3) – Generating CD examples and preparing for the exhibition

During the last phase of the workshop, it was interesting to see how quickly the students adapted to their new roles as 'problem-finders.' As expected, the 'critical twist' generated some head-scratching at first, followed by an interesting 'aha moment' (by the end of Wednesday), but from then on, they quickly turned their 2D concepts into 3D models. Using all kinds of materials, artefacts and props available from the various workshops at the university and from their private homes or shops nearby, they brought their CD examples to life by the end of Thursday. It should be noted that all the teams in WS3 ended up making full-scale models, simply because the students decided that, among other things, they would 'make an impact' or 'shock people' (to quote two of the students) during the planned exhibition [8]. On Friday, the students generated titles and graphics to complement their groups' CD example in the exhibition. As shown in Figure 3, some teams went the extra mile and put the CD example in an authentic context before they documented it on camera or video as a way of showcasing the model. In doing so, they were living up to Dunne and Raby's take on CD, which advises that the viewers should experience a dilemma and makes them decide for themselves what they are experiencing and whether it is serious or not and real or not [12].

Figure 3. Impressions from Step 2 of WS3 - students working on physical models

2.2.2 Results

On Friday afternoon, the classroom was cleared and set up like a gallery, and at 6 pm the first guests – a mix of peers, partners, relatives, teachers, researchers and anyone else who had seen the advertisements for the exhibition on posters and on social media – arrived to view the five CD examples (see Figure 4). The students took turns manning the exhibition and generally attempted to avoid explaining the CD

[3] Please note that the point of the CD examples, as well as the process of designing such a CD example, is identical to that of critical design as such, namely, to raise awareness, expose assumptions, provoke actions, spark debate, etc. Or in the words of Dunne and Raby, 'to make us think' [12].

examples, instead allowing them to, in the words of Dunne and Raby, ‘make up their own mind’ [12], which is, according to them, the mark of strong critical design.

Figure 4. CD examples generated during WS3, shedding light on (from left to right): life when dependent on a fall alarm (#Fallnerable); the stigma associated with braces (#Embrace); the fear of being close to another individual (#Don’tHugMeI’mScared); the dominant role of social media in our life (#Megapixel); and Nosophobia, the irrational fear of contracting a disease (#Outbreak)

2.2.3 Workshop Series #4 (WS4) – Generating CD examples through digital means

Due to the global COVID-19 pandemic, online collaboration was the main tool during International Design Week 2021. An adjusted setup was thus organized so that the workshops could take place partly online and partly on campus. The students were only allowed on campus during predefined timeslots of a maximum of 1.5 hours per day. In total, the students spent only 6.5 hours on campus during the entire week. The online method of working was enabled by two collaboration platforms. We used Miro as a team collaboration whiteboard to share images, brainstorm and ideate, and Blackboard Collaborate to communicate and provide online consultation. Because COVID-19 also restricted the use of our craft workplace and hands-on work, students were asked to present their results in 2D posters instead of 3D artefacts. As such, they explored the critical twist through digital means, and they creatively manipulated photographs by using drawing tablets or graphic design software such as Adobe Photoshop or Illustrator (see Figures 5 and 6).

Figure 5. Impressions from Step 1 of WS4 - students’ output using graphic design software

2.2.4 Results

As shown in Figure 6, the four groups of students created 2D CD examples that, like the 3D artefacts of previous years, were meant to speak for themselves. During the exposing phase, we noticed that the hybrid way of working did not inhibit the students in making the critical twist and that the ‘aha moment’ took place just as quickly as in the preceding workshops. Furthermore, the immersion in critical design – even though it was mostly done online – made the students feel they had ‘a more critical view of the world’ and realize that they could ‘use critical design to understand a problem better’ (to quote two of the students).

Figure 6. CD examples generated during WS4, shedding light on (from left to right): city safety for vulnerable road users (#OneLessCar); the dependency of blind people (#WhoLetTheBlindOut); the feeling of endless waiting and alienation due to the COVID-19 pandemic (#Waitinglist) and stigma regarding the appearance of someone with a visual impairment (#MagnifEYEd)

Instead of an exhibition with a live audience, a virtual exhibition was presented in Mozilla Hubs, which is an avatar-embodied space that allows people to meet in a 3D environment. Four virtual exhibition rooms were created in which the posters of all twelve workshops could be found. Students, supervisors and guests were free to visit each room, view the posters and leave digital comments on the work presented.

3 DISCUSSIONS

Comparing WS3 and WS4, the difference was more than simply one between a face-to-face and a hybrid workshop. Here, we aim to elaborate on how the 'SFD + CD' applies to teaching and learning design and to further develop the workshop layout for use beyond the lifetime of the critical workshop series and towards an integration of critical design within the design curriculum. The following comparison of the two workshops provides material for both these aspects.

In each of the years, we presented students with a questionnaire at the end of the workshop. The reflections from all workshops indicate that the pedagogical shift from an affirmative (solving) to a critical (exposing) approach is generally well received and seems to work well to help students break free from their traditional thinking. To quote one of the students from WS3 [8]:

- *"By first looking for solutions to the problem, we briefly researched the chosen issue. But by totally changing direction on Wednesday, we were able to make even better and more focused critical designs, I think."*

Furthermore, students were surprised by what they had achieved by the end of the week. As a participant from WS3 said [8]:

- *"Stigma-free design will always be useful when you are working with any kind of stigma. Critical design will be used more to make a statement and maybe also to open your mind and think differently in the idea-generation phase*."

This positive attitude towards 'SFD + CD' from WS3 did not seem to change because of the shift of the hybrid teaching and learning environment. Although it is plausible that students may have been less motivated due to these unconventional times, we did not notice this in their performance throughout the week, nor in their responses to the questionnaire. Moreover, according to some of the students in WS4, when asked the following question after the workshop: 'What is the most important thing you learned from this workshop?' the responses included:

- *"By first focusing on understanding the real problem (instead of an existing solution), you can come up with more far-reaching and unique solutions."*
- *"To dwell a little longer on what problem and its social consequences you actually want to tackle with your design..."*
- *"What critical design entails and how it can be used to make people think and look at the world with a more critical eye."*
- *"[for CD] to convey a message, it should be as simple as possible, to-the-point design."*

The purpose of our pedagogic method – which entails the conversion from stigma-free design (solving) to critical design (exposing), i.e., the 'critical twist' – was to make the students look at stigma from a novel perspective. By first finding solutions to stigma-sensitive problems in a conventional manner and second illuminating the chosen design challenge in a speculative manner, they had to let go of their initial solutions and consider them differently. In short, what we wanted the students to learn in these workshops was that critical design can work as a healthy challenger to conventional design thinking – not as a replacement, but an add-on.

The results and experiences from WS3 match those from WS4. This indicates that the learning environment, whether being face-to-face or hybrid, is of less importance if the content is relevant and engaging and both students and tutors are eager to do their utmost to make it work.

4 CONCLUSION AND FURTHER CONSIDERATIONS

As mentioned above, the primary aim of WS3-WS4 was to challenge the next generation of designers concerning their way of thinking about product-related stigmas and for them to take an evolving role in shaping our future with respect to the emerging societal challenges, such as health, demographic change and wellbeing [13]. However, the pandemic radically changed the ways we live, learn and teach and forced us to take WS4 into a hybrid environment – which in retrospect was a good thing, seeing that hybrid teaching and learning might change teaching methods across the globe [14]. We hope that

someday we get the opportunity to take the critical design workshop to an even larger group of students, beyond classrooms, universities and countries.
We strongly believe that designing with a critical lens has the potential to innovate the way we teach and learn design, regardless of platforms or learning environments. Moreover, 'SFD + CD' gives us the power to express unity in diversity in a world that is increasingly complex. In addition to the methodical take-aways from WS3 and WS4 – the design methods the students were armed with to tackle the challenges of stereotypes, prejudice and discrimination – they also gained valuable experience of interdisciplinary group work, which will better prepare them for the 'real' world following university.
Despite the different platform, the hybrid version of WS4 managed to maintain both the pedagogical content and the spirit of the earlier workshops. In addition, the students reported that the 'upside-down' methodology was liberating, engaging and effective. The CD twist led the students to experience the fundamental difference between affirmative and critical design, and the feedback from the participants was almost unanimous throughout the years: despite educational background and current methods of working. Like one student said that 'you learn to look at things from another perspective or attitude', which helps in 'realizing the different needs of people to help and understand them' [7].
To this we can add a comment made by Scotland-based educator Ewan McIntosh in a TED talk some ten years ago, which we think is still highly relevant in this context: 'education systems are crazy about problem-based learning, but they're obsessed with the wrong bit of it. While everyone looks at how we could help young people become better problem-solvers, we are not thinking how we could create a generation of problem finders' [15]. We could not ask for a better outcome.

REFERENCES

[1] Dunne A. *Hertzian tales: electronic products, aesthetic experience, and critical design*. London, England: Royal College of Art, 1999.
[2] Dunne A. and Raby F. *Speculative Everything: Design, Fiction and Social Dreaming*. The MIT Press, 2013.
[3] Cross N. Designerly ways of knowing. *Des Stud* 1982; 3: 221–227.
[4] Malpass M. *Critical Design in Context: History, Theory, and Practice*. London, England: Bloomsbury Visual Arts, 2017.
[5] Torkildsby A. B. *Existential design - revisiting the 'dark side' of design thinking*. University of Borås, Swedish School of Textiles, 2014.
[6] Torkildsby A. B. Critical Design in Universal Design Settings – Pedagogy Turned Upside Down. *Des Technol Educ an Int J* 2018; 23: 6–23.
[7] Torkildsby A. B. Empathy enabled by critical design – A new tool in the universal design toolbox. *Stud Health Technol Inform* 2018; 256: 760–770.
[8] Torkildsby A. B. and Vaes K. Addressing the issue of stigma-free design through critical design workshops. In: *Conference on E&PDE*. 2019. Epub ahead of print 2019. DOI: 10.35199/epde2019.11.
[9] Vaes K. *Product Stigmaticity: Understanding, measuring and managing product-related stigma*. Delft Academic Press, 2014.
[10] Vaes K. *Design for Empowerment, the Stigma-Free Design Toolkit*. Springer International Publishing. Epub ahead of print 2019. DOI: 10.1007/978-3-319-96071-5.
[11] Karlsen L., Maria M. and Nilstad I. Speculative and Critical Design — features, methods and practices. In: *ICED 2019*. Delft, The Netherlands, 2019, pp. 1623–1631.
[12] Dunne A. and Raby F. Dunne & Raby, http://dunneandraby.co.uk/content/bydandr/13/0 (2022, accessed 14 January 2022).
[13] European Commission. Societal Challenges, ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges (accessed 12 February 2022).
[14] Ali W. Online and Remote Learning in Higher Education Institutes: A Necessity in light of COVID-19 Pandemic. *High Educ Stud* 2020; 10: 16.
[15] McIntosh E. TED Talk London, https://www.youtube.com/watch?v=JUnhyyw8_kY (2011, accessed 5 January 2022).
[16] Dunne A. and Raby F. *Design noir: the secret life of electronic objects*. London, England: August Media Ltd, 2001.
[17] Malpass M. *Contextualising critical design: towards a taxonomy of critical practice in product design*. Nottingham Trent University, 2012.

HOW TO GET STUDENTS – FROM DIFFERENT BACKGROUNDS AND WITH NO EXPERIENCE IN DESIGN – GOING

Arthur EGER
Freelance Consultant, Writer and Lecturer, The Netherlands

ABSTRACT
Students that participate in the Honours Master-course High-Tech Systems and Materials (HTSM) of the University of Groningen have different educational backgrounds, they meet for the first time, they have never cooperated with High-Tech companies and they have no experience in product development or product design. For these reasons, the students have difficulty starting their projects. To solve this problem the Workshop Evolutionary Product Design was developed. This paper explains how we work in this workshop to get the students going. Before the workshop takes place, we give the students a preparatory assignment they have to work on in groups. They have to analyse the history of both the product design, the used (production) techniques and the working principles of their assignment for the course, e.g., by using the Internet. They are supposed to prepare a short presentation of about five minutes (maximum ten minutes) about this product history. The workshop starts with a lecture introducing Evolutionary Product Development. After the lecture, the students get an additional assignment to adapt the presentation that they have made, and to add what they have just learned. The students have half an hour to work on their assignment. After this, one by one the groups present their results to the teaching staff and their fellow students. The fellow students are challenged to give their colleagues feedback. Then the staff members give their feedback. With this, the students have made a start with their assignment, which was the goal of the workshop.

Keywords: Collaboration in teams, evolutionary product development, product life cycle, product history, product phases

1 THE COURSE: HONOURS MASTER HIGH-TECH SYSTEMS AND MATERIALS
The Honours Master is an elective, extra course for students at the University of Groningen. The students that participate in this Honours Master excel at the frontiers of knowledge and are looking for an extra challenge during their master’s degree. The Honours programme offers intensive, small group teaching with a group of like-minded, motivated students. The track offers a unique opportunity to collaborate with students from different disciplines on challenging, real-life product development assignments by the industry. Students who complete the HTSM Master’s Honours Programme receive a mention on their diploma and a letter of recommendation from the Rector Magnificus of the University of Groningen. This will give them an advantage when applying for positions in academia, the business world or the public sector.

2 THE PROBLEM
Students that participate in this course have different educational backgrounds: Arts, Behavioural and Social Sciences, Economics and Business, Health and Life Sciences, Law, Philosophy, Science and Engineering, Spatial Sciences (Geography, Environmental Planning, etc.), and Theology and Religious Studies. They have never cooperated with High-Tech companies and most of them have no experience in product development or product design. In the first year the course was delivered, the staff members had problems to get the students going. In this paper a workshop is presented that was created to solve this problem.

3 THE WORKSHOP: PREPARATORY ASSIGNMENT

In the Honours Master Course, the students work in small groups. Before the workshop takes place, they get a preparatory assignment they have to work on in the same groups. They have to analyse the history of both the product design, the used (production) techniques and the working principles of their assignment for the course, e.g., by using the Internet. They are supposed to prepare a short presentation of about five minutes (maximum ten minutes) about this product history. They get the instruction to bring at least one laptop per group (without knowing why).

4 LECTURE: INTRODUCTION TO EVOLUTIONARY PRODUCT DEVELOPMENT

The workshop starts with a lecture introducing Evolutionary Product Development. Until the late 1980s product development was generally considered to be a 'linear' process. The common idea is that the development of products is entirely controlled by inventors and engineers. However, products are not simply invented from scratch. Although everybody will agree that each individual product is intentionally developed, it can be shown that, once we consider the evolution of products over the course of many decades, it is clear that they do not follow a predetermined long-term plan. Therefore, the emergence of new types of products can be regarded as an evolutionary process [1].

4.1 History Matters

Most of the products that are developed and brought to the market are nothing more than slight adaptations or improvements of earlier versions of the same product. Even when, once in a while, a completely new type of product appears, it adds some novelty but always builds on existing knowledge. The wheel is not reinvented but refined and used for new purposes. Besides that, the freedom to design newer versions is narrowed down by earlier technologies, standards or products. The development path travelled so far cannot be completely redone. This significantly limits the amount of freedom to design newer versions. In short: HISTORY MATTERS.

The method of Evolutionary Product Development consists of three parts: the Product Family Tree, the Ecosystem and the Product Phases.

4.2 Product Family Tree

The Product Family Tree is a tree-like diagram, similar to the family tree based on the Linnaean taxonomy known from biology. The Product Family Tree maps the main relations between products through time, connecting a new type of product with later ones as lines of descent. The evolution of products is based on progressing know-how and know-what. This accumulation is not restricted to a particular product lineage. Rather, it is a common pool of knowledge from which many product lineages draw. Dominant designs constitute successful incarnations in a lineage of products. New types of products that give rise to new product families are rooted in prior accumulated knowledge. Consequently, Product Family Trees cannot unambiguously be combined into a single continuous branching tree, starting at the earliest products through to present-day products. Instead, a Product Family Tree is intended to be an analytical instrument to map how products evolve from a new type of product into a product family. It is therefore a simplified representation, limited in scope to a single product family and intended to explain the process of establishment of new types of products and their further evolution into a family of products. Various Product Family Trees connect to other earlier products or technologies via their roots.

4.3 Ecosystem

The Ecosystem describes how new types of products emerge and what influences their subsequent development. In the case of biological species, it is widely known that the ecosystem in which they live and reproduce plays a crucial role in their evolution. Changes in climate may, for example, lead to the extinction of one species (such as the mammoth) while causing another species to thrive. In the case of products, it has been demonstrated that, despite it being made up of man-made elements, their ecosystem is part and parcel of their evolution [1].

New types of products are not just invented from scratch but are developed on top of what has been invented before. Their evolution is fed by technologies developed for other purposes and is, to a large extent, determined by the way people deal with these products. The origin of these products can be explained by a process of descent with modification, but then, of course, in a way that is different to what we are familiar with in nature. Although it is not yet commonplace for designers to think about evolutionary next versions when designing products, tools – such as PEST [2] – are now being provided for this purpose.

4.4 Product Phases

The most important conclusion of the model of Product Phases is that the focus of the product development activities is influenced by the place the product has in its life cycle. In this model the well-known six phases of the economic product life cycle (development, introduction, growth, maturity, saturation, and decline (or ossification)), are combined with a qualitative model of six product phases called performance, optimization, itemization, segmentation, individualization and awareness. A practical implication is that designers need to take explicit account of this relationship when choosing specific product development activities. Besides that, the chance the product development process will deliver a successful product can be enhanced when consideration is given to the life cycle.

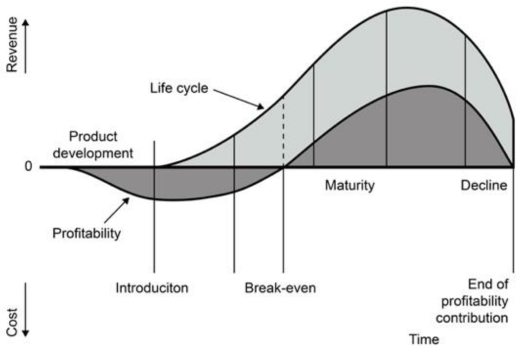


Figure 1. The six phases of the Economic Life Cycle

In the early phases of a new type of products' existence, the attention of the designer will focus mainly on functional aspects: first on technical functioning and later on the improvement of quality, ergonomics and safety. Next, the designing activities focus on price, styling, extra features and offering a line of products. However, in the later phases of a product's existence, there is a shift in emphasis. The development of extra features and accessories is an ending process: at a certain moment, the performance delivered exceeds what is needed. As a product progresses into later life phases, the importance of the experience provided by the product increases and so-called 'emotional benefits' are added to the product.

4.4.1 Product Phase 1: Performance

New types of products – that is, products that provide a new basic function – normally suffer from teething troubles for some time when they first appear on the market. By implication, improving the basic function (i.e., the primary purpose of the product) is the most important aspect of product development in this phase. New products often start as status symbols, and usually perform worse than the existing alternatives. The product characteristics of the product phase 'performance' can be summarized as follows. Technically speaking, the product is new and often results from a 'technology push.' The performance of the product is often poor (i.e., the performance of the basic function is still poor). Product development is primarily aimed at improving performance. Design in the limited sense of 'overall form giving' is unimportant and product aesthetics are, therefore, of minor concern. The product is often launched into the market by a monopolist or a small number of heterogeneous oligopolists, so competition is low. As a consequence, the price per unit can be relatively high. The product is frequently produced by standard equipment, it often has more parts than the minimum amount technically feasible, and assembly is mostly done by hand. In terms of adoption of innovations [3], the product is bought only by the innovators, a type of user willing to take risks with new types of products, and to adopt technologies that might ultimately fail.

4.4.2 Product Phase 2: Optimization

In the second phase, product development is broadened to include ergonomic aspects and issues of reliability in use and safety. The 'optimization' product phase is characterized as follows. Although the product is technically speaking still new, consumer awareness of the product is starting to develop. The performance of the product is reasonable, but product development is still aimed at improving performance. Other aspects, like increased reliability, improving ergonomics, and safety aspects, are becoming serious considerations. The price per unit is still relatively high, but increasing competition creates a tendency toward lower prices. In this and the following phase, it can be advantageous to involve clients in the product development process to improve the performance and ergonomics.

4.4.3 Product Phase 3: Itemization

When producers have improved their product to the point that they satisfy generally accepted standards of functionality and reliability, the edge of competition shifts to convenience. Buyers will prefer those products that are the most convenient to use and – especially in the business-to-business market – sellers that are convenient to deal with. Often in this phase there is a dominant design. Sometimes there are more dominant designs, e.g., in the case of shavers: wet shavers and electric shavers, based on either rotating or vibrating knives. Mass-produced products make personal selling impossible. The market grows less, and the number of competitors increases. As the product range grows, prices fall, and promotion costs increase. Endeavours are made to develop extra features and accessories, including special editions of the product that are developed for different trade channels and target groups. Design becomes more important, and product aesthetics become a major concern. The number of product parts of the basic (cheapest) products decreases, but accessories or extra features can cause an opposite effect, namely an increase in the number of parts. Mechanic and/or automatic assembly also becomes more important. If needed, well-organized service organizations are set up to support the product.

4.4.4 Product Phase 4: Segmentation

In the first three product phases (i.e., performance, optimization, and itemization), the focus was on improved functionality, reliability, ergonomics, and safety. An attempt to add extra features and accessories in order to differentiate the product from its competitors takes place somewhere in the third stage. However, this kind of development comes to an end. Indeed, there comes a time when the performance offered is actually greater than the performance required. For relatively uncomplicated products, such as furniture and trinkets, the possibilities for adding features or accessories are limited. Moreover, products become less attractive to innovators and early adopters during the latter product phases. The market share is such that the product is considered 'accepted.' Owning the product is no longer distinctive, as it does not offer any form of status. Adding emotional benefits to a product is now possible. Research [4] has shown that involving customers in the design of emotional benefits (experience design) does not improve the success of the product.

Characteristics of the product phase 'segmentation' are that the product is part of the daily life of almost all members of the target group. As the product, technically speaking, has entered the domain of some 'dominant design' (or a limited number of 'dominant designs'), product development is aimed at adding extra features and accessories, including special editions of the product for different trade channels and target groups. Design has reached a stage of complete integration of the various parts of the product into a completely unified and recognizable form and the design focus shifts from form giving proper to expressive features, aimed at increasing emotional benefits. The market approaches perfect competition.

4.4.5 Product Phase 5: Individualization

Extrapolation of segmentation (continuous fine-tuning of products on ever-smaller target groups) ultimately leads to a product that is properly attuned to one individual. The developments in information and production technology make this kind of individualization even more possible. These developments imply the following changes in characteristics in the 'individualization' product phase. Product development is geared to mass customization and cocreation, allowing the customer to influence the final result. Although prices approach average technical production costs of the dominant design, cocreation and mass customization offer possibilities to realize higher prices. Interactive media are used to customize the product to the needs of the individual customer.

4.4.6 Product Phase 6: Awareness

Marketing-related research on the importance of ethics in influencing consumers' purchase decisions shows contradictions [5]. If consumers are asked if they are willing to pay a higher price for ethical behaviour, the results are positive. According to this kind of motivation research, this group is growing

[6]. But when the purchase decisions are observed, it shows that these consumers still buy products from unethical firms if the price is lower [7,8,9]. These researches show what is called the ‘citizen-consumer paradox:’ as a citizen, one finds sustainability important, but as a consumer, one does not always take sustainability into account in purchases [6]. The purchase motivations of consumers who buy sustainable products also show that the personal motivations of consumers are more important than ethics: the trigger for consumers to purchase sustainable goods is rather their own interest than the public interest. For consumers who find sustainability important in their purchase decisions, this is especially the case when they benefit from it personally. This becomes apparent from how the number of consumers who find sustainability important differs per product type. For products where sustainability leads to cost savings such as white goods, cars, energy, and electric products, this is 60%. For food, this is 50%, with motives such as health, taste, or animal welfare. In contrast with products that have a high impact on the planet but fewer personal benefits, products such as household and personal care products, mobile phones, clothes, and flights, only 30% to 40% of consumers find sustainability important [6].

From this research, it can be concluded that a substantial proportion of the consumers is willing to contribute to a better environment and to help solving societal problems by changing their consumption patterns, but only if this can be done without much effort, and only if it does not lead to decrease in consumer satisfaction and a too big increase in the financial burden. Most people expect companies to play an active role in solving common societal problems. A company can successfully tempt a small group of consumers by offering them the possibility of showing their ethical involvement by acquiring products that in some way claim to be more environmentally or socially beneficial than their competitors.

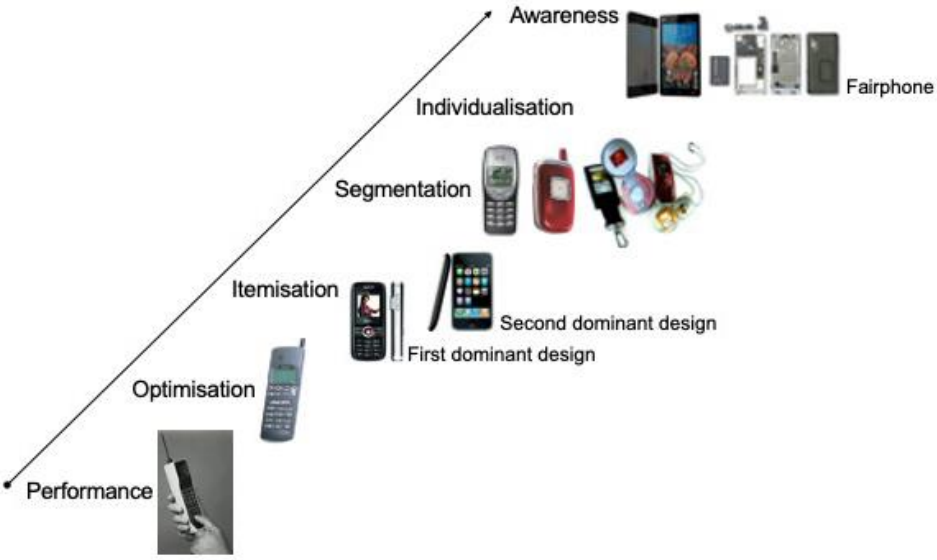


Figure 2. The Product Phases as they appear in the development of the smartphone

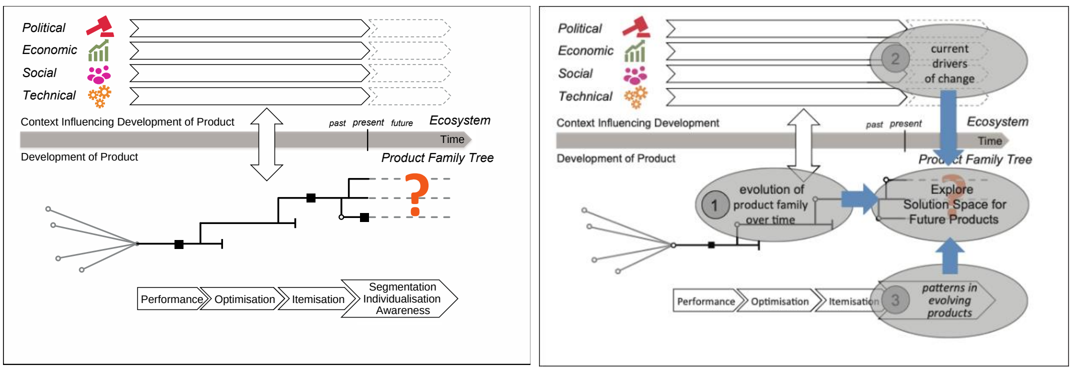


Figure 3. How the parts of Evolutionary Product Development determine the Solution Space for Future Products

5 ASSIGNMENT AT THE END OF THE WORKSHOP

After and during the lecture the students have the possibility to ask questions about the theory of Evolutionary Product Development. Then they get an additional assignment to adapt the presentation that they have made before the workshop, and to add what they have just learned.
They have to:

- analyse the history of the product of their assignment based on the theory of Evolutionary Product Development,
- give the product phase that they think the product of their assignment is in and substantiate their choice,
- give possible strategies for new product development for the product of their assignment (and again substantiate),
- make a presentation of between five and ten minutes of their results.

The students have half an hour to work on their assignment. After this one by one the groups present their results to the teaching staff and their fellow students. The fellow students are challenged to give their colleagues feedback. Then the staff members give their feedback. If all went well, the students have now made a start with their assignment.

6 CONCLUSION AND DISCUSSION

The Honours Master-course HTSM has been given since 2014. In practice it has been shown that the workshop had the intended result. In the first few years the workshop was given halfway through the course. However, since 2018, it has been brought forward to the second day of the course, immediately after the introduction and the students' acquaintance with the companies involved. Although the course has so far only been taught to students who had no, or very little experience with product development and design, we expect that it will also work for product design and engineering students.

REFERENCES

[1] Eger A. O. and Ehlhardt H. *On the Origin of Products. The Evolution of Product Innovation and Design*, 2018 (Cambridge University Press).

[2] Chapman R. J. *Simple Tools and Techniques for Enterprise Risk Management,* 2006 (John Wiley & Sons).

[3] Rogers E. M. *Diffusion of Innovations,* 1995. (4th edition. New York: The Free Press. Originally published 1962).

[4] Candi M., Gemser G. and van den Ende J. *Effectiviteit van Design*, 2010. (RSM, Erasmus University).

[5] Schäffer L. S. *The awareness phase in theory and practice: a study of the position of awareness products in the theory of evolutionary product development*, 2014. (Master thesis, University of Twente).

[6] Witte E., van den Berg V., Meijering J. and Bruggenwirth B. *Consument steeds kritischer over duurzame communicatie: Vijf lessen uit vijf jaar Dossier Duurzaam,* 2013. (Dossier Duurzaam).

[7] Marylyn Carrigan A. A. The myth of the ethical consumer – do ethics matter in purchase behaviour? *Journal of Consumer Marketing,* Vol. 18, no 7, 2001, pp. 560–578.

[8] Sandhu S., Ozanne L. K., Smallman C. and Cullen R. Consumer driven corporate environmentalism: fact or fiction? *Business Strategy and the Environment,* Vol. 19, no 6, 2010, pp. 356–366.

[9] Thøgersen J., Jørgensen A. K. and Sandager S. Consumer decision making regarding a ‘green’ everyday product. *Psychology & Marketing,* Vol. 29, no 4, 2012 pp. 187–197.

EMBEDDING IMMERSIVE TECHNOLOGIES INTO PRODUCT DESIGN EDUCATION: STUDENTS' AWARENESS OF VIRTUAL REALITY AS A TOOL TO SUPPORT THE DEVELOPMENT OF DESIGN SOLUTIONS

Laila AL JAHWARI, Vanja GARAJ and David HARRISON
Brunel University, London, United Kingdom

ABSTRACT

Using new and emerging technologies in education can increase student engagement and support teaching methods. However, using any technological tool requires prior knowledge and understanding, especially in education. An online survey was used to gather data on product design students' knowledge of Virtual Reality (VR) technology. As a case study, this survey will examine how the use of Virtual Reality technology can impact the product design development process and design thinking. A questionnaire was distributed to product design students as part of a mixed method approach. Students' views on common design solution development practices and Virtual Reality technology were quantified and analysed through open-ended and closed-ended questions. The survey revealed students' preferred modelling and rendering software, sketching methods, level of detail in sketches, prototyping materials and tools, assessment modes and aspects. The questionnaire also assessed students' knowledge of VR and their perceptions of its utility in product design. In product/industrial design education, high student awareness of technology indicates a bright future.

Keywords: Virtual reality, product design, higher education, design thinking, product development

1 INTRODUCTION

The use of Virtual Reality (VR) in product design education is revolutionary. Several impediments make implementation difficult. Obstacles can be related to the technology, the end users (educators and students), or their interaction with the technology. To overcome these hurdles, researchers must identify real-world problems that VR can solve, and demonstrate its educational value. A better approach is to investigate the current process, identify the challenges and barriers that prevent end-users from achieving good outcomes, and finally test potential solutions without forcing the latest technological trends. This study used mixed methods to gather data from various product design students. The survey assessed students' knowledge of VR technology and their perceptions of its use in product design. The study is part of a larger PhD research project investigating best practices for using VR to enhance product design education.

2 RATIONALES FOR THE STUDY

Prior studies established the great potential that VR and related technologies have in industrial/product design education [1], [2], [3], [4], [5]. An experimental study that examined three case studies including undergraduates, postgraduates, and design research concluded that VR had progressed beyond being a tool for visualisation and decision-making and might be ready to play a critical role in all phases of the design process [6]. In the field of industrial design education, several studies examined the effectiveness of using VR to aid design learning [7], [1], another study focused on the usefulness and ease of use of VR [2]. In contrast, Hamurcu et al. (2020), analysed the efforts of using VR in industrial design in professional and educational contexts by focusing on VR as a tool to represent and communicate design ideas [4]. Roberts et al. (2020) investigated using VR to aid in the design process across various stages from early conception through usability testing [6]. Jimeno et al. (2016) narrowed the focus to using VR sketch drawing software in the design process [3]. Camba, Soler and Contero (2017) , broadened the scope to using VR to facilitate multidisciplinary design education in industrial design, architecture, and interior architecture [1]. There is little evidence in the literature of studies that have investigated the current design process followed in product/industrial design education without proposing the "technology solution" from the beginning. The objectives of the work presented here are to investigate current approaches to developing design solutions among product design students, explore product design students' awareness and perceptions towards the integration of VR in developing design solutions, and reflect on the future of VR technology in product design education.

3 RESEARCH METHODS

This study utilised a mixed methods approach that included qualitative and quantitative aspects via the distribution of a questionnaire to product design students in various levels, BSc Product Design, MSc Integrated Product Design and PhD Design in Brunel University, London. A questionnaire was identified as the most efficient means of gathering information from a large number of students [8]. The type of sampling used was random sampling, with e-mails sent to the participants that contained the SurveyMonkey URL of the survey. There was no hypothesis testing in this study since the objective was to uncover the usual practices of product design students in terms of solution creation and to elicit participants' perspectives on incorporating VR into the product design process. The survey consisted of 28 questions divided into three main sections, A-Background of Respondent, B-Design Solution Development, and C-Experiencing Virtual Reality Technology. The survey questions were mainly multiple choice with one open-ended question. The open-ended question aimed to understand the participants thoughts about the usefulness of VR technology in developing design solutions. It was thought that the open-ended question would allow for the opportunity to gather rich and probably deeper data for the participants' perspectives on virtual reality and its implementation in product design education [9], [8].A three-phase pilot study was initially undertaken to test the questions, the variability of the answers, and the method of analysis.

4 RESULTS AND DISCUSSION

By the end of the survey period, data had been collected from 61 students.

4.1 Research objective one: Investigate the current approaches to developing a design solution among product design students

This research objective was established to give insights into product design students' existing practices when working on their design projects specifically when designing a solution. The findings add to information about duration, techniques, tools, and preferred software/hardware. The sequence and the flow of the questions were structured carefully according to the process of developing a solution in product design education starting from drafting concepts to prototyping the final design solution. For each phase, specific questions about duration, techniques, tools and software/hardware were asked. When constructing the survey, the *item-order effect* was applied to ensure that respondents would interpret later questions properly. According to Price et al. (2017), "One item can change how participants interpret a later item or change the information that they retrieve to respond to later items" [10]. Therefore, Section B [Design Solution Development] was initiated with a question which aimed to produce a cognitive attachment for the respondents on how to retrieve the later questions. The question was: "What is the overall expected time you need to re-create the following 3D CAD models?" Three different images of simple construction items, (a cup, a chair and a goblet) were provided. In this way the respondents would keep the provided images in mind when answering later questions. The results of this survey will be discussed in line with the findings of Noor Aldoy & Mark Evans's (2011) survey study, which investigated design graduates' insights into the use of conventional and digital design modelling tools in UK higher education. The findings on current approaches to developing a design solution among product design students are discussed below according to a) Time spent in each phase of solution development b) Sketching techniques used c) Level of details in sketches d) Prototyping materials and tools e) Assessment modes and f) Modelling and rendering the final concept.

a) Time spent in each phase of design solution development process:

According to the responses, the duration product design students spent in each phase increased subsequently as they progressed in the design process (Figure 1). This could be because students gradually employed digital methods in the process as they progressed in developing the design solution. The percentage of time spent on digital approaches grew dramatically as the design process continued [11].

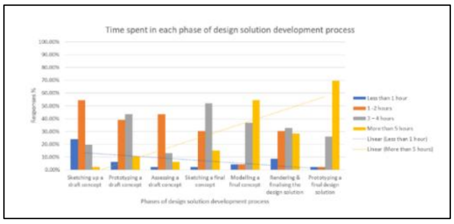


Figure 1. Time spent in each phase of design solution development process

b) Producing sketches throughout the design process

According to Pipes 2007 (as cited in [11]) , the majority of designers begin by creating drawings (such as 2D side view sketches, 3D perspective sketches, investigative/exploratory sketches, and explanation sketches).Throughout the concept-generation phase, sketching is widely employed to externalise, alter, and assess concepts. From comparing the responses of the students to their sketching modes, while generating concepts and while finalizing them (Figure 2), most of the participants prefer the conventional method of pen and paper for drafting concepts. According to Henry (2012), at the outset of the design process, sketches should be spontaneous and have little detail [12]. Remarkably, the same traditional method is still in a high percentage, 39%, in drafting final concepts. Sketching using drawing tablet is ten percent higher in the later phase. These results agree with those of Noor Aldoy & Mark Evans (2011), which showed that over 90% of respondents said that they always/frequently utilised freehand paper sketching. This was also confirmed by another recent study of the same authors in 2020, which showed that students believed that traditional drawing using pen and paper was a more efficient and effective approach to communicating early thoughts, particularly during the concept creation phase when they were expected to generate a significant number of ideas [13]. Reasonably, sketching using graphics software with a mouse increased from 6% to 15% in the concept finalizing phase as digital methods are more effective to support visual representation in the later phases. Participants who selected the choice "Other" provided a variant of answers which are similar to the provided choices. For example, in drafting concepts, students provided like "digital sketching, Sketch using graphic software with iPad and Autodesk Fusion 360". And one student said they preferred to use "Procreate" which is a raster graphics editor application for digital painting. Very similar answers were given when finalizing concepts.

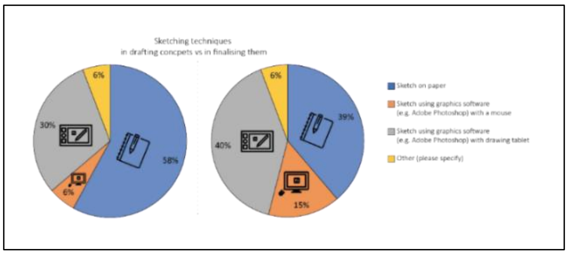


Figure 2. Sketching techniques throughout the design process

c) Level of details in sketches throughout the design process:

When comparing the degree of details in the proposed design from concept generation to final concept, it is obvious that students explore more details in the concepts such as materials and textures as they progress in the design process. As Figure 3 shows, the orange segment which represents *how thorough is the sketch of the final concept*, increases gradually from minimum details, with pencil or markers, to as many details as possible. In contrast, in the early phases of the design process students provide minor details in their concepts. These findings match those observed by Noor Aldoy & Mark Evans (2011), and they reasoned this was because product/industrial design students significantly employ more digital methods in the later stages which support increasing the level of details [11].

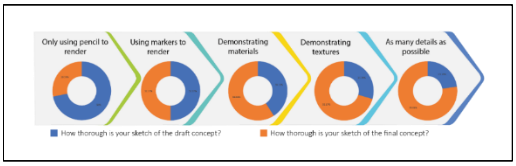


Figure 3. Level of details in sketches throughout the design process

d) Prototyping materials and tools throughout the design process:
The survey results suggested that workshop-based sketch models were more often utilised than digital sketch models during the early phases of design solution development. More than 80% of product design students used materials such as paper, cardboard, foam, wood, plasticine clay and a combination of multiple materials. During the late phases, students moved to employ tools such as CAD software and 3D printing as a full-size working design representation and used them to simulate some of or all the features for a proposed product. Interestingly, some product design students provided answers such as using Unity software and VR technology.
e) Assessment modes and aspects throughout the design process:
Communicating design concepts is a vital component of the design process, and design ideas must be expressed and communicated at each stage of the product design process , from concept design to detailed design – and must be assessed throughout the process [4]. However, assessment modes and aspects differentiate between the beginning of the process and the end. During the early phases, product design students are involved in activities such as self-assessment and peer-assessment. Being involved in these activities helps students to learn to recognise constructive collaborative behaviours by reflecting first on themselves, then on others, and lastly on a comparison of the two [14]. More than 84% of students elected self-assessment and peer-assents as their main modes of concept testing and evaluation in the early phases. Additional, as previously described, product/industrial design education is like a simulation of a professional design studio where teachers are the customers and students act as the designers, so assessment with the supervisor is crucial from the beginning of the process. More than half of the students selected "assess with supervisor" when drafting concepts, and this percentage increased when assessing the final concepts to be 76%. Moreover, when finalizing the design concepts, other modes of assessment appear such as user testing. Aspects of assessment started with assessing form and structure in the early phase. About 70% of students ranked those two aspects higher when answering "*What aspect of the draft concept do you usually assess?*". On the other hand, assessing features such as, usability, functionally, manufacturability, service attributes and Environmental Impact Analysis are ranked as more important when finalizing concepts.
f) Modelling and rendering the final concept:
Most designers begin the design process using pen and paper and then move to CAD software to model the final concept. The preferred software to model the final concept for product design students, classified from most favourite to least favourite, are Solid works, Fusion 360, Rhino, 3Ds Max, Maya, and CATIA. Renderings are sometimes referred to as 'presentation drawings' and 'persuasive sketches' ,for example, two-dimensional side view renderings and three-dimensional perspective renderings[11]. According to Noor Aldoy & Mark Evans (2011), computer-generated renderings created using software such as Adobe Photoshop were substantially more often employed than hand-drawn paper-based renderings [11]. This was demonstrated by the questionnaire replies, which revealed that product design students prefer to use software such as Adobe Photoshop, Adobe Illustrator, Individual rendering software and Procreate in iPad, to render the final concepts.

4.2 Research objective two: Explore product design students' awareness and perceptions towards the integration of VR in developing design solutions

a) Experiencing Virtual Reality Technology:
Section C of the questionnaire aimed to provide insights on product design students awareness about VR technology without linking it with design or design education initially. The first question is "Have you ever tried Virtual Reality technology before? And the choices provided are: "Yes, No, Not sure, I don't know what Virtual Reality technology is". The percentage of "Yes" and "No" answers is almost equal, with 45% of students answering "Yes" and 47% answering "No". When comparing our results to those of Noor Aldoy & Mark Evans (2011), it must be pointed out that there is an increase in the level of awareness about VR technology among product/industrial design students in the UK. Their study reported that eighty-eight percent of students had not tried Virtual Reality in 2011. As expected, most students, about 71%, have used VR "mainly for gaming", when asked about the purpose for using the technology. In second place came "gaming", and finally "education". VR technology is popular among university students for entertainment purposes, and this explains why Sony PlayStation VR is the most frequently used VR headset by participants. After that, other popular VR headsets come such as, HTC Vive, Oculus Rift, Oculus Quest and Samsung Gear VR. Due to its affordability, Google Cardboard is also popular among students.

b) The usefulness of VR in developing design solutions:
The Participants were asked an optional question asking: "*How useful you think Virtual Reality would be in developing design solutions?",* aiming to investigate their insights about the usefulness of using VR in the design process. All the respondents who provided an answer for this question, have used VR before for different purposes and using different VR headsets. The most interesting findings from this question are the following:

- Unexpectedly, there is no relation between the age of the respondents and their insight into the usefulness of VR. It was expected that younger students would be more enthusiastic about the technology whereas graduates and post-graduates would be more cautious. Interestingly, the respondent insights varied and there is no link between the age of the participants and their insights about VR.
- Unlike the age variable, the industrial expertise of the students influences their insights about VR. It has been noticed that opinions of students who are in their placement year range between "Extremely useful" and "Somewhat useful". Placement year students think that VR could be "Extremely useful" in mocking up designs, 3D modelling, testing solutions. Additionally, they think that VR features of full-scale and immersion will support the design process. Placement year helps product/industrial design students learn about the latest technologies in the product/industrial design profession and they could have the chance to test them. One of the emerging technologies which is more advanced in industry than education context is VR and its related technologies.
- Sixty percent of the participants think that VR would be "somewhat useful in developing design solutions. They think that deciding to use VR depends on the purpose of using it. According to the participants, VR could be somewhat useful for user testing of architectural designs, service design and interior design. Additionally, VR could provide a new way to interact with the product and can help in enhancing the rendering phase. On the other hand, they think that VR has limited potential in the design process and is "sometimes unnecessary". One of the respondents said that VR is not very useful for small individual products. Other participants highlighted that Augment Reality AR technology could be more useful than VR in product design scenarios because with AR we can assess certain aspects of the product, such as form and size in shorter time without the need for rapid prototyping. One of the participants said: *"I think VR would be useful to a certain extent. We must ask ourselves what type of projects would benefit most from the technology, and not just using it for the sake of using it".*
- A percentage of 33% of respondents think that VR would be "Extremely useful" in developing design solutions. One of the participants thinks that VR allows for a faster and more adaptable way of developing and testing design solutions within a 1:1 scale contextual environment. Another participant said: *"With the development of technology, Virtual Reality technology will gradually replace the traditional computer technology, such as hand drawing, CAD, etc. VR will become an indispensable tool for designers in the future, like computers now"*.

4.3 Research objective three: Reflect on the future of VR technology in product design education

- Studying the current design process that product design students are following and the common practices among them is extremely important in measuring the readiness of product design education and product design studio to fully employ VR technology as one of the digital design methods. Experimenting with the technology in short time and through narrow-scope sessions without investigating the end users' needs will not help in progressing toward a full employment of the technology.
- Analysing the strengths and the weakness of the current design methods and tools will determine the right time and proper context to effectively integrate VR technology. For example, according to the findings of this study, product/industrial design students spend a considerable amount of time in the later phases of design solution development. Thus, scenarios where VR could accelerate the design process in the later phases of product design studio could be proposed.
- The majority of experimental-based previous studies compared VR or any related technology with one or more of the conventional or well-established design methods. This study suggests comparing an emerging technology with another in the product/industrial design education context. For example, a study could compare the potentials of VR with the potentials of AR in product design education, or with Mixed Reality MR.

5 CONCLUSION AND FUTURE WORK

The first part of this study focused on common design development practices among product design students without using VR technology. The findings revealed significant details about students' preferred modelling and rendering software, sketching methods, level of detail in each phase's sketches, prototyping materials and tools, assessment modes and aspects. The questionnaire also assessed students' knowledge of VR and their perceptions of its utility in designing products. The high level of student awareness of technology indicates a promising future for product/industrial design education. Moreover, their generally positive views on the use of VR in design solutions show a high tendency to use and accept the technology. This study may change how educators and researchers view VR in the classroom – not just as a supplementary feature, but as a valuable component that should be planned from the start. A recognised limitation of this research is the study's inability to generate generalisations owing to the limited number of participants and the fact that the data were gathered at a single design school.

REFERENCES

[1] Camba J., Soler J. and Contero M. Immersive Visualization Technologies to Facilitate Multidisciplinary Design Education. *Lecture Notes in Computer Science*. 2017;:3-11.

[2] Hamurcu A. User Insights about Using Immersive Virtual Reality in Industrial Design Studio Courses. 2018 *2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT).* 2018;:1-8.

[3] Jimeno-Morenilla A., Sánchez-Romero J., Mora-Mora H. and Coll-Miralles R. Using virtual reality for industrial design learning: a methodological proposal. *Behaviour & Information Technology*. 2016;35(11):897-906.

[4] Hamurcu A., Timur Ş. and Rızvanoğlu K. An overview of virtual reality within industrial design education. *Journal of Engineering, Design and Technology.* 2020;18(6):1889-1905.

[5] Yu-Che H. and Yi-Ru C. The Study of Virtual Reality Product Design in Education Learning. *Proceedings of the 2019 The 3rd International Conference on Digital Technology in Education.* 2019;:9-11.

[6] Roberts S., Page R. and Richardson M. Designing in virtual environments: The integration of virtual reality tools into industrial design research and education. *DRS2020: Synergy*. 2020;.

[7] Lee A., Liang Y. and Liu S. A Study on Design-oriented Demands of VR via ZMET-QFD Model for Industrial Design Education and Students' Learning. *EURASIA Journal of Mathematics, Science and Technology Education*. 2016;12(5).

[8] Kiernan L. and Ledwith A. Is Design Education Preparing Product Designers for the Real World? A Study of Product Design Graduates in Ireland. *The Design Journal*. 2014;17(2):218-237.

[9] Baxter G. and Hainey T. Student perceptions of virtual reality use in higher education. *Journal of Applied Research in Higher Education*. 2019;12(3):413-424.

[10] Price P., Jhangiani R., Chiang I., Leighton D. and Cuttler C. RM in P 3rd ed. p. 133. *Research Methods in Psychology*. 3rd ed. 2017. 133 p.

[11] Aldoy N. and Evans M. A Review of Digital Industrial and Product Design Methods in UK Higher Education. *The Design Journal*. 2011;14(3):343-368.

[12] Henry K. *Drawing for Product Designers*. Laurence King Publishing; 2012. 9 p.

[13] Aldoy N. and Evans M. An Investigation into a Digital Strategy for Industrial Design Education. *International Journal of Art & Design Education.* 2020;40(1):283-302.

[14] Mattioli F, Ferraris S. Self-Evaluation and Peer Evaluation Tool for Design and Engineering Teams: Experiment Conducted in A Design Studio. *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019)*, University of Strathclyde, Glasgow 12th -13th September 2019. 2019;.

TOOL-BASED ETHICS EDUCATION FOR ENGINEERS; WONDERBERRIES AND WISDOM TILES

Wouter EGGINK[1], Karin van der HEIJDEN[2], Steven DORRESTIJN[2] and Ilse OUWENS[3]
[1]University of Twente, The Netherlands
[2]Saxion University of Applied Sciences, The Netherlands
[3]Cibap Vocational College for Design, The Netherlands

ABSTRACT
The Dutch research project "Wijs met techniek" (Tech-Wise) explores ethics education from a tool-based, practical perspective. Especially if and how practical tools for ethical deliberation on the impact of technology can be helpful in ethics education for engineering students. The approach is first intended as a variation on theories in ethics and technology. Secondly, the approach uses a focus on the impact of technology as a way toward ethical deliberation. Both characteristics are intended to better appeal to engineering students. In the project we cover three levels of higher education: a University, a University of Applied Sciences and a School for Vocational Training.
Together we are developing and testing a suite of activating working methods that can be tailored to various engineering programmes. A first result of this is the simple workshop format "ethics for engineers", consisting of five steps with four effective ingredients. In this paper we present the general format of this workshop and dive in particular into a specific instance of the workshop called "Wonderberries". The experiences from the workshop show that with a carefully chosen combination of engaging orientation, a specific 'technology' and a concrete design exercise the ethical questions and subsequent deliberation and reflection can be very rich.

Keywords: Ethics of technology, reflective skills, impact of technology, ethical deliberation

1 INTRODUCTION
We are faced with the challenge of fully exploiting the possibilities of new technology while at the same time being open to the questions and concerns that these entail. (Future) engineers are expected to think about the effects of new technologies on people, society and the environment, as they will be contributing to the shaping of these technologies [1]. The accompanying responsibility [2] makes that educational institutions, governmental organisations and companies should offer their students and employees the opportunities for learning to reflect on the impact of technology in an accessible and practical way.

2 ETHICS IN ENGINEERING EDUCATION
The Dutch research project "Wijs met techniek" (which can be translated with Tech-Wise and in the local culture also means "happy with technology") explores ethics education from a tool-based, practical perspective. It addresses how practical tools for ethical deliberation on the impact of technology can be helpful in ethics education for engineering students. The practical approach is first intended to be a variation on teaching from theories in ethics and technology and an addition to existing approaches that start from professional development [3] and personal development [4, 5]. Secondly, the approach uses a focus on the impact of technology as a way toward ethical deliberation. First experiences learn that these characteristics are both appealing to engineering students [6]. In the project we work together in three levels of higher education: a University, a University of Applied Sciences and a School for Vocational Training.
In the first phase of the research project, experiences of consulted students and teachers indicated that practical tools for ethical deliberation are most valuable, provided that they are linked to explicit learning goals [6]. In the second phase, efforts are being made to (further) develop and test a suite of activating working methods to achieve these learning goals. The aim is to develop a package of teaching materials, together with the various engineering programmes, consisting of concrete ethical exercises and

assignments that can be used as a continuous learning line during the entire curriculum [7]. In the project we have identified four important ingredients for such exercises and assignments; 1) an ambivalent (or controversial) technology; 2) an application close-by (or appealing to the interests of the participants); 3) a concrete (design) activity and 4) the 'right' questions to ask. These ingredients should allow for effective learning experiences, especially with lecturers of engineering subjects that are themselves not trained as ethicists.

3 ACTIVATING WORKING METHODS

One example of such an activating working methods is a simple workshop format. The general format of this "ethics for engineering students" workshop consists of five activities: orientation, research, select, design, and discuss. Each activity can then be tailored to the specific engineering discipline, and the knowledge, skills, and level of expertise of the students.

Until now we have explored different techniques for an engaging orientation phase and different formats for the design. Following our four ingredients we chose different technologies for which we thought that the application is either very well known to the participants or in which the purpose of the technology is not so clear or controversial. To cater to the different engineering and design disciplines, our interpretation of what a technology is, is very broad. In Table 1 an overview is provided of the different instances of the workshop we have experienced with so far. The first four columns give a brief description of the different workshops. The 5th column indicates with which engineering disciplines the instances were tested. The last column lists some engineering disciplines for which the exercise would be particularly suitable.

Table 1. "ethics for engineers" workshop instances

name	technology	orientation	exercise	tested with	suitable for
Wisdom tiles	Online meeting applications	Ironic movie clip "a conference call in real life"[1]	Write an aphorism on a Delft blue tile; a behaviour manifest in one phrase.	Engineering educators	Interaction designers, UX designers
Gender Neutral Toilets	Interior design	Ironic movie clip "gender neutral toilets"[2]	Design a lay-out for gender neutral toilets with matching logo's/signing	Interior design students, Industrial design students	Interior designers, Industrial designers, Architects
Wonder Berries	Taste influencing pills from Miracle Berry	Tasting session with several food items	Design and prototype an 'appropriate' packaging	Design educators, Industrial design students	Packaging designers, UX designers, Food engineers

A general description of the five steps:

- Orientation: experience the technology in a direct or indirect manner.
- Research: question the experience you had in the orientation phase together with your groupmates.
- Select: choose a direction for your design solution.
- Design: draft a solution, preferably with a concrete and communicable end result.
- Discuss: Look at what the other participants have come up with and start with the question how this relates to your own 'solution'.

The orientation phase can be done indirect by showing a provocative, ironic or speculative design, image, newspaper article or movie clip. When the orientation phase is done indirectly, it is however important that the participants can relate the footage to their own experiences. In the examples we chose for general experiences like online meetings and toilet arrangements as these are experienced by everyone. However, when teaching in a specific discipline one can tailor these also to specific engineering topics like for example autonomous driving for automotive engineers or health tracking systems for interaction designers. Figure 1. shows an indicative result of the "wisdom tiles" workshop

[1] (see https://www.youtube.com/watch?v=ElIUVDECGdA)
[2] (see https://www.npostart.nl/genderneutrale-toiletten/08-03-2020/POMS_NTR_16012936)

instance. In the remainder of this paper, we will discuss the set-up, execution, results, and the ideas behind the "wonderberries" workshop instance.

Figure 1. Result example of the wisdom tiles workshop with engineering educators [7]

4 WONDERBERRIES WORKSHOP

In this workshop the central 'technology' is shifting taste. Little pills, based on a natural ingredient from miracle berries, make that sour will taste sweet which is supposed to make you eat healthier (Figure 1, left) [8]. The orientation phase is done by actually eating the pills and tasting several types of food 'before' and 'after' (Figure 2, right). In the design phase the participants are then asked to create a packaging for the product. To make the discussion more open, the participants are not told what the intention of the technology is, and the existing packages are also not shown. The participants received the pills only in separate cut-out blisters. From there, one can easily imagine that it makes a difference if one packages and presents these pills in a medicine box, a sachet for sweets, a bowl of fruits or as a party drug. The idea is that, based on the presented packaging designs, the ethical implications of the technology can explicitly be discussed. The designs themselves serve as a so called boundary object [9] which makes multidisciplinary and multi-background communication easier. It is also easier to talk about something concrete than to present abstract thoughts. A principle that is adopted from other workshop formats like Lego Serious Play [10].

Figure 2. Miracle Berry tablets packaging (left) and an impression of the 'test material' of the workshop

To stimulate the discussion even more, the participants were asked to write down their initial thoughts on the product during the digesting (suck, not chew!) of the pills, answering the simple question "what am I doing?". From there the participants could start experiencing the effect with the aid of several more or less sour food products (Figure 2, right). To speed up the design process after the tasting session, the participants were then asked to make a word-spin (or mind-map) about the meaning of the pills, starting from the question "what is this pill about?".

The first time we ran the workshop with design educators, in which the participants had to fabricate their packaging designs to a presentable outcome within half an hour (Figure 3). A second run of the workshop with industrial design students was spread out over several days so there was more time to develop the packaging designs (Figure 4).

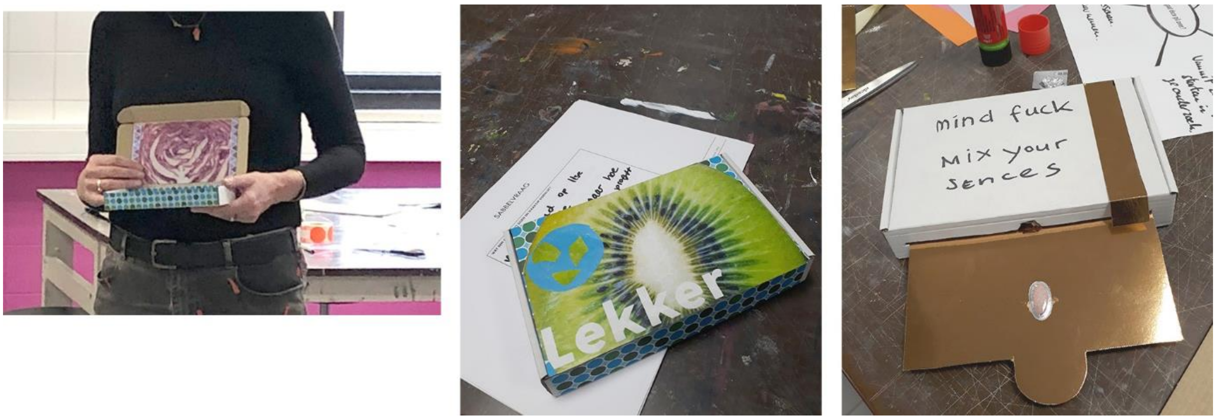


Figure 3. A participant pitching the prototyped packaging "lekker" [tasteful] which was supposed to help relieving starvation in underdeveloped countries. The "Mind Fuck" packaging presented a single pill as something special for an evenly special experience

Interestingly, the packaging proposals in figure three are very different in their approach and communication of the technology. Although the goals of the two proposals seem legitimate for the first packaging (relieving starvation) and rather gratuitous for the second one (have a fun experience), the related ethical reflection learns quite the opposite. Helping people in need that have little access to good food with sending them a means to eat bad food is rather doubtful. While providing people with a voluntary fun experience is not, and even better when the packaging is inhibiting overuse and addiction by providing only one pill.

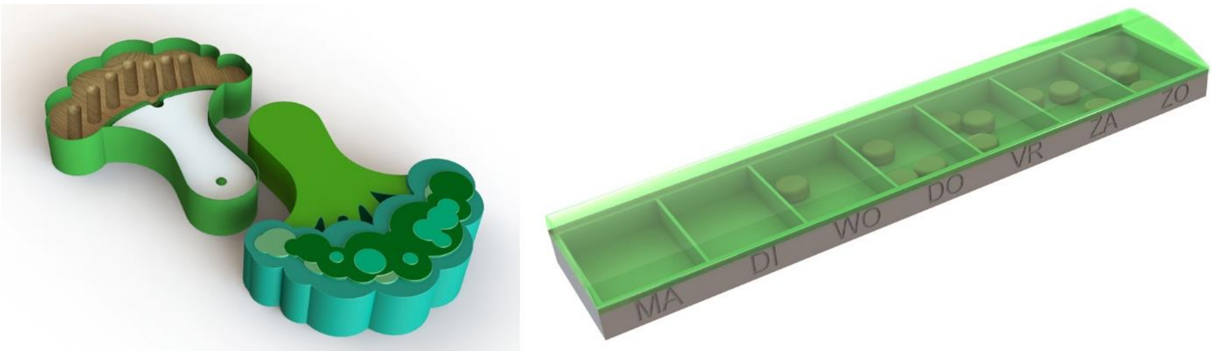


Figure 4. Two packaging designs from a three-day workshop. The broccoli shaped container is meant to aid children in eating healthy food. The other design was meant to help patients regain their taste after chemotherapy and was styled in a typical day-by-day medicine dispenser [by Jesper Cassiman, Ennis Jacobs, Yosse Claesen & David Florea]

The two packaging designs in Figure 4 are also ethically different. Not many people are inclined to disapprove with restoring a bodily function after being ill. The 'serious' medicine like packaging underlines this legitimacy of the goal. Otherwise, for a lot of people tricking children into eating something they do not want can be doubtful. Even when the end goal (healthier children) is definitely not. This unease can even be emphasised by the playful toy-like packaging design which is of course part of the trick.

All-in-all the miracle berries in the Wonderberry workshop were an excellent vehicle to demonstrate the all-encompassing ambiguity of technology. Insights from philosophy of technology deepened the reflection further. The miracle berries can for instance be linked to the ancient Greek concept of the Pharmakon, which can both mean "healing medicine" *and* "poison" [11]. Technologies do not simply have a well-defined function. What is actually the purpose of this strange thing, that makes sour taste sweet? All it does is convert, which reminds of a characterization of the technological by Bruno Latour [12] as that which bends, transforms, reverses an element in how all things connect to all other things in the world. That description differs from "functionality", as it does not refer to functionality for a well-defined purpose, but alludes to a change of direction, regardless of purpose, in any direction. Which again addresses the responsibility of the designer-engineer to consciously choose the *better* direction.

5 ETHICAL DELIBERATIONS

As said, the last important ingredient is to ask the right questions. This does not mean that there are also wrong questions, rather that there are specific questions that make explicit how the exercises from the workshop are linked to ethical deliberation. To show this we take a step back -or zoom out if you wish- to discuss the theoretical concepts that are underpinning our approach. We will limit ourselves to highlighting a few aspects, following up on the question how the approach on ethics and technology that we are specializing in does connect to engineering education. Our approach is about ethical reflection on the impact of technology. This means an intricate relation between ethical questioning and technology from the onset, in response to insight in the meaning and the effects of technology [13]. This approach is very clear in the Product Impact Tool[3] which offers an overview of concepts and examples for understanding the impact of technology on different levels, or in other words how technology is affecting us humans from all sides [14]. This tool is intended to be useful for analysing the effects of technologies, and to help to design for desired impact on society. We have used and tested this tool in industrial design education extensively, especially in the context of responsible design [15-17]. Within the Tech-Wise project we found that it also stimulates ethical deliberation about technologies [18, 19].

In order to offer a more accessible tool in which the connection between the impact and the ethics of technology is more upfront we have also developed a concise tool in the form of a short list of deliberation questions about means and ends. We called this the Ethical Readiness Check[4] to explicitly mention the term ethics, unlike the Product Impact Tool. The term ethical readiness further refers to Technological Readiness Levels, a concept that is widely used in engineering [20]. In this list of questions, means and ends form a scheme, clearly related to technology and to ethics, which is very simple and familiar in the basis. However, ultimately the relationships between means and ends, and between ethics and technology are very complex. Inspiration for this approach of using the familiar but rich scheme of means and ends stems from Bruno Latour [21] and Dietmar Hübner [22].

The Ethical Readiness Check consists essentially of two basic questions in terms of means and ends of a technical innovation: 1) Is the technology a means for a good end?; and 2) Is it the good means for the end? These two questions can then be unfolded and developed. For example: What is the goal? Are there conflicting goals and values? May there be an alternate goal, or something like a double agenda? Is the technical means effective and fitting for the goal? What are the actual effects of the technology? Are there also side effects, regardless the intentions? Maybe even counteracting to the initial goal? Or harming other goals that are also important? The last questions about the effects of technology can then be supported with the analysis of impacts through the beforementioned Product Impact Tool [14]. The Ethical Readiness Check in its turn makes the connection between impact and ethics more explicit.

6 DISCUSSIONS

For now, we have only tested the workshop format with a few technologies and a few engineering disciplines, however also with different levels of knowledge and experience. The results are interesting and inspiring although we need to expand the experience base to be conclusive about the effectivity. Especially evaluating whether the ingredients of the workshop are also sufficient for lecturers without a background in ethics. Several important insights already came to the fore though; firstly, actually writing down of thoughts in templates is important to govern the progress in reflecting and deliberation. Secondly, starting the discussion actively as facilitator of the workshop is still necessary, otherwise an attitude of ‘solving the problem’ that is so ingrained in the character of engineers can easily prevail.

7 CONCLUSIONS

The experiences from the workshop show that with this carefully chosen combination of engaging orientation on a specific ‘technology’ and concrete design exercise the ethical questions and subsequent deliberation and reflection can be very rich. Depending on the knowledge and interest of your students, these reflections can then be explicated with applicable tools and ethical theories.

ACKNOWLEDGEMENTS

The authors like to thank all the participants of the workshops for their creative contributions and the University of Antwerp and Cibap Vocational College for Design for the generous hosting of the events.

[3] (see www.productimpacttool.org)
[4] (see www.stevendorrestijn.nl/downloads/Ethical_Readiness_Check_concept.pdf)

REFERENCES

[1] Verbeek P.-P., Design for Society: Understanding and Evaluating the relations between Humans and Technologies. In: *Proceedings of the International Conference on Engineering and Product Design Education; Human Technology Relations*. 2014. Enschede: The Design Society.

[2] Eggink W. et al. Setting the stage for Responsible Design. In: *Proceedings of the biannual Design Research Society conference (DRS) Synergy*. 2020. Brisbane (Australia): Design Research Society. pp. 713-730.

[3] Ledsome C. Learning to be a Professional Designer. In: *Proceedings of the 21th International Conference on Engineering and Product Design Education*. 2019. University of Strathclyde, Glasgow: The Design Society. pp. 1-6.

[4] Hiort af Ornäs V. and Keitsch M. Ethics in Design Curricula - Teaching Approaches. In: *Proceedings of the 18th International Conference on Engineering and Product Design Education*. 2016. Aalborg (Denmark): The Design Society.

[5] Sonneveld M. Positive Ethics in Design Education. In: *Proceedings of the International Conference on Engineering and Product Design Education; Human Technology Relations*. 2014. Enschede: The Design Society. pp. 87-92.

[6] Heijden K.v.d. et al. *Wijs met techniek; ethisch (leren) reflecteren op de impact van techniek*. 2021. Available from: https://www.techyourfuture.nl/impactinterview-wijs-met-techniek.

[7] Heijden K.v.d. et al. Teaching Track For Ethics of Technology in Engineering Education. In: *Proceedings of the Blended Learning in Engineering Education conference*, 2021. Technische Universität Berlin: European Society for Engineering Education (SEFI). pp. 1561-1570.

[8] Merwin H. Homaro Cantu on Miracle Berries, Chewing Tin Foil, and the Best Peanut-Butter Cookies Ever., in *Grub Street;* 23 January 2013, Vox Media: New York.

[9] Akrich M. The de-scription of technological objects, In: *Shaping technology/building society*, W.E. Bijker and J. Law (Eds.). 1992, MIT Press: Cambridge, Massachusetts. pp. 205-224.

[10] James A. R. Lego Serious Play: a three-dimensional approach to learning development. *Journal of Learning Development in Higher Education*, 2013(6).

[11] Stiegler B. *What Makes Life Worth Living: on Pharmacology.* 2013, Cambridge: Polity Press.

[12] Latour B. *An inquiry into modes of existence.* 2013: Harvard University Press.

[13] Eggink W. et al. Ethics, Design, and Creativity: a Fruitful combination. In: *Proceedings of the biannual Design Research Society conference (DRS)*. 2022.Bilbao (Spain).

[14] Dorrestijn S. and Eggink W. Product Impact Tool Workshop; mastering affect and effect in human-product relations. In: *Proceedings of the International Conference on Design & Emotion; Colours of Care*. 2014. Bogotá: Ediciones Uniandes. pp. 467-469.

[15] Belle J.v., Giesberts B. and Eggink W. The Use of Philosophical Theories in Design: A Research-Through-Design Case of Treatment Compliance. In: *Proceedings of the biannual Design Research Society conference (DRS) Catalyst*. 2018. Limerick (Ireland). pp. 218-228.

[16] Raub T., Dorrestijn S. and Eggink W. Using the Product Impact Tool for Prospective Thinking. In: *Proceedings of the biannual Design Research Society conference (DRS) Catalyst*. 2018. Limerick (Ireland): Design Research Society. pp. 253-268.

[17] Eggink W. Cultivating Responsible Design with the Product Impact Tool. In: *Proceedings of the 22th International Conference on Engineering and Product Design Education*. 2020. VIA University College, Herning (DK): The Design Society. pp. 1-6.

[18] Eggink W. Ethics in Design Education, but different; practicing the Practical Turn. In: *Proceedings of the 23th International Conference on Engineering and Product Design Education*. 2021. VIA University College, Herning (DK): The Design Society. pp. 1-6.

[19] Dorrestijn S. A Tool for the Impact and Ethics of Technology: The Case of Interactive Screens in Public Spaces, In: *Relating to Things: Design, Technology and the Artificial*, H. Wiltse (Ed.). 2020, Bloomsbury: London & New York. pp. 151-172.

[20] Olechowski A., Eppinger S.D. and Joglekar N. Technology readiness levels at 40. In: *Proceedings of the Portland International Conference on Management of Engineering and Technology (PICMET)*. 2015. Portland (USA): IEEE. pp. 2084-2094.

[21] Latour B. and Venn C. Morality and Technology. *Theory, Culture & Society*, 2002. 19(5-6): pp. 247-260.

[22] Hübner D. Ethik und Moral In: *Forschungsethik. Eine Einführung*, M. Fuchs, et al. (Eds.). 2010, Weimar: Stuttgart. pp. 1-3.

'ART EXPERIENCES' AS DISRUPTIVE IMPULSE, AND MENTORING FOR NEW DESIGN ENGINEERING EDUCATION STRATEGIES

Marina-Elena WACHS
Hochschule Niederrhein – University of Applied Sciences, Faculty of Textile and Clothing Technology, Germany

ABSTRACT
This research study questions the significance of *understanding* what it means to create the change by design in context of today's knowledge and self-management, and also to advanced design engineering education. Needless to say, holistic, sustainable and humanity-centred education begins as early on at preschool. In the future, a central interest of 'good design' is to ensure that the planet 'profits,' by utilising a variety of 'art of languages' in an interlinked way: The synergy of an art pedagogical + design didactical approach in schools and at universities, not only manifests collaborative designing across the generations; it is also giving rise to a revaluation of fine arts and the multi-level benefit of art and design, e.g., core factor in supporting self-belief as training element of mentoring culture, which supports Initial Teacher Education (ITE) systems of design teachers, which calls for you to trust your intuition to develop an excellent 'personal intelligence.' To train the trainer with embodiment, will focus on three key factors: - teaching various design methods, - developing the fundamental self and knowledge management of individual and digital systems, - including (cross)cultural education. The 'trainer' and her/his concept of leadership count. Design didactic knowledge and 'motivation to act-instruments,' these experiences, are part of the best students' education for next design engineering mentor.

Keywords: Design didactic & art pedagogical education, mentoring as part of design engineering education, innovation by disruption with art experiences, Initial Teacher Education + intuition, motivation to act – instruments

1 INTRODUCTION
Since 2019 we discussed a 'revaluing the manual sketching experiences' [1] of children, such as drawing in the sand, as well for designing good within a mixed or Augmented Reality (AR). Respectively, this research paper focusses on two significant directions for action:
First, harvesting the synergistic benefit of an art pedagogical + design didactical approach in schools and at universities (see chap. 2 + 4). Here, new collaborative partnerships in the field of 'Kids and Designing' should be developed (see chap. 3). Second, incorporating new profile elements to curricula to help develop a 'mentoring' culture in design engineering programmes (see chap. 3.2 and 4) and set a new standard for the future. This will get good design back on track.
Also, during the covid 19 crisis, the question arose again regarding the value of 'fine art' and its benefit to society and individuals, as well as the method of learning (see chap. 3.2). This question seeks to reveal the significance of *understanding* what it means 'to gestalt, to know, and to be capable;', when philosopher Hannes Böhringer focussed his research on asking: where would the sciences be 'without the art of language, without the rhetoric of pictures and the art of persuasion'? [2], what are the sciences without the power of poetry, of artefacts, and the variety of senses (e.g., expressed by music, literature, art or design ideas)? This is a fundamental question for our knowledge management today.
We must rebuild learning landscapes to create playful learning spaces for young children, as they are essential to the 'gestalt' process, in the sense that creating, designing, and promoting sustainability begins with children's ability for self-expression, using the power of their bodies, hands and minds. This is an essential element of 'embodiment' (see chap. 4): creating learning spaces that promote capabilities and a 'yes you can' atmosphere (and mentality); However, from an art pedagogical point of view, the most important thing for the creation process is the joy and curiosity regarding the environment and the courage to take action and do something [3], which can be transferred to doing design. This is important,

as we consider that 'from the neurological point of view, these connecting areas in early primary basic education set the ability to interpret in complex patterns and give the ability of abstract thinking' [4].
According to Helga Nowotny, a social scientist, the capacity of curiosity and preference is an important factor in creating the new or seeing things as new [5]. The unexpected influences the beauty and expression of time – just as in modernity and modern cities [6], Nowotny explores the idea that innovation has to be associated with our ability of knowing things from the past, through the unexpected intertwining of times and the standards of science, technology and societies [7]. This dilemma, to find a balance between science and technology, in relation to the emotion of the human beings involved in life as it is – this is our cultural resource (see chapter 4). Only by recognizing the differences between the times, gives the opportunity to *ideate* the new, which is then accepted and esteemed as being better.
The case studies that examine and compare the social value of graffiti's artistic merit and the social benefit of sgraffito ornaments on buildings, allow us to get a deeper understanding of the research thesis: the art of languages in different creative disciplines are shaping humans' everyday experiences, while also contributing to all sciences and applied sciences – including but not exclusively in design and architectural scientific issues. From the art pedagogical, design didactic and holistic – primarily anthropological - point of view, how many 'art and design languages' are needed to 'design' our future? How much knowledge of art is needed for a well-educated person (pupil) to be able to design and be prepared for the Post-Digital Era; and how much knowledge of design/ing is needed for studying the fine arts, thus being beneficial to our cultures and societies – including the perspectives of STEM disciplines? Knowledge management relates to the method of 'mapping' [8], which enables the next experts of good design to develop key competencies, such as reflection and being able to formulate questions relevant to the system. This requires an education with a design teacher, who serves as a mentor, thus enabling designing across generations. The next chapters will discuss whether we need a 'mentoring culture integrated into self-management' programmes, in context to coaching-courses and ITE, and answers to the questioned significance of a revalue of artistic experimenting and experience spaces - for designing our future.

2 GRAFFITI AND S'GRAFFITO: AN ALLIANCE OF ART AND DESIGN

2.1 Graffiti a synaesthesia of fine art and design and the design pedagogical approach

In order to answer the research question focussing on the benefit of fine art, design, and engineering as a whole, let us break down the borders of disciplines:
When we look at graffiti designs in the year 2022, two main questions arise: What is new, or *different* in graffiti, as a form of abstract and artistic self-expression in the city, as compared to previous years? How can the phenomena of graffiti in cities evolve in 2022 – what kind of a statement and symbolic representation of culture in time will they portray - as part of architecture and expression of identity? And what about the benefit and the different meanings, when children create graffiti in the safe environment of their pre-school, or as teens at a hidden place in the cities wall-paintings scenario?
On the one hand, graffiti is a 'reference letter' [9] from history and a testimony of our culture in art, as it was for Banksy in particular moments in time, which still speaks to us today. Graffiti as art could be seen as a development in the decoration of cities. This can be compared to 'sgraffito' used in the past – as well as today – as graphical patterns and decoration on architectural facades [10]. Yet, on the other hand, graffiti in art and design are also artistic expressions of revolutionary cries; it represents the youth's rebellion. Very often it is done on secret paths and by young people at night – this entails spraying on facades (see fig. 2), walls, and surfaces of railways and trains – to revolt against societies conventions, law and order. From the art pedagogical point of view, the 'act' in relation to joy [11] experienced during the process of spraying on the wall, for example, is an important element of development – the process of humans' self-discovery. (see: fig. 1 and 2),
Doing design by ideating with your *hand* enables different experiences, in contrast to *talking* about design codes. When we look at the phenomena of emotional appropriation it is important to use a new 'design pedagogical' [12] point of view, by regarding the parameter of 'design codes' and 'product language' as symbolically meaningful representatives (see fig. 3), of a society. Dagmar Steffen puts the understanding of symbolic meaning in relation to the psychological effect of representatives. 'Representatives' in this psychological and sociological context refers to the ideas, images and thoughts in association to the object, that declare the relationship between human beings and this object, while also 'paving the way' [13] for the emotional appropriation of this object.

2.2 S'grafitto and the design didactical approach

Today, at the beginning of the Post-Digital Era, patterns and ornaments are crying for attention. In the past, the meaning of ornaments was interpreted differently, and was viewed in different artistic, societal and design historical contexts: '*styles and methods of ornaments were based on a progressive accumulation of tradition, religious influences, technical advances as well as the availability of materials, the exigencies of climate, the wealth and stability of societies, and the whims and ambitions of individual men, whether tyrants or artists.'* [14].

Comparing architectural facades, fashion designs and art in urban environment with graffities as artistical patterns and codes in cities' (see fig. 3) designs – they come alive with patterns and ornaments, symbolic meanings of time. We have to read into these ornamental codes within the cultural (historical) context of the Modern and Post-Modern Era compared to those of the Post-Digital Era.


1


2

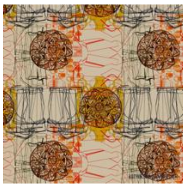
3

4

Figure 1. Graffiti by Max at the age of 10, Figure 2. Graffiti by 15-year-old (teen) – Max, Figure 3. modified street sign, Florence, 2001; Figure 4 'street-art inspired design' - K. Grobheiser

As well in comparing this with design didactical and art pedagogical significance. This view and the artistic expressions allow us – citizens, artists, designers, as well as children – to learn from each other. At the same time, the significance of fine art in graffiti – which involves designing, sketching and spraying, that span cultures and generations (fig. 1: 6-year-old child fig. 2: graffiti by 15-year-old teenager), is providing a design theoretical and socially resilient view of sgraffiti design that is good. It is good for integration because it is uniting and embracing cultural codes and 'embracing the unknown' [15] as 'differences' like the 'otherness' in society (see fig.4 by designer K. Grobheiser, inspired by the street-art and style at New York).

In the end, graffiti as cultural rebellion and remembrance is triggering the art pedagogical and design didactical effect on society – in particular, the experiences of the future generations. We have to 'embrace,' or rather withstand this dilemma – like Nowotny means when talking about the unexpected intertwining of times and the standards of science, technology and societies – to create the new and different as something good.

3 MAPPING THE WORLD + SUSTAINABLE DESIGN EDUCATIONAL STAGES

3.1 Artistic experiences + self-management as (social and economic) trigger points

Graffiti and S'grafitto present the world in a different way, which elicits the core question: how we create our 'picture' of the world? Georg Peez argues that creating pictures (including graffiti) is elementary to developing a personal belief system, self-confidence and developing the ability to express and reflect the internal pictures by the individual from an art pedagogical perspective [16]. Julia Wendemuth underlines, that visual impressions have such diverse impacts on each individual, as seen from a scientific art didactical point of view: On an initial level, artistic images have content-related, historical and symbolic and semantic meaning. Second, as a viewer we question what and why an artists created, and what it means to them. Third, when interpreting images, didactical elements help you to reflect upon, perceive, question and classify this picture [17].

If the concepts of the inner self understanding of the artist, the creator is related to self-consciousness confidence and belief systems, the elements of this 'system' – or the concept of making yourself an image of the world – are crucial for developing a personal value-system; - which is the key to making a sustainable life and creative studies possible on our planet. Art can express so many values, self-beliefs and relation to other persons and to the planet, like graffiti + sgraffito articulate with narrative character to all people. – express identity of each time in a related pattern, to coloured (figurative) arrangement.

To underline the thesis above – of the benefit of future synthesis of art pedagogical + design didactical outcomes -, we could learn from each other. The paradigm shift towards sustainability and digitalisation calls for new leading educators. '*Although education alone cannot achieve sustainability, it is obviously one of society's keys. Educational objectives require a fundamental shift – from learning how to* *memorize and understand, to learning how to think in new, systematic way.*' [18]. It is beneficial when learning is taught within credit systems at schools and universities, by using 'formative assessment and feedback training and experience' instead of summative assessments (this includes preparatory pre-design educational experiences at preschool). Collaborative learning and learning how manage self-learning programs show positive effects, when used in combination with interactive peer-tutorial programs and webinars, using digital, interactive learning spaces. Sustainable future education should be value-based, due to the demand for changes relating to climate change, inclusion and diversity. [19] 'We need earlier design education (strategies) at primary schools, which may coincide with a change in the terms 'design' and 'industry' [20], as well as fine arts, because the right to experience cultural education and gender equilibrium is one of essential goals of the SDGs, which relates to UNESCO's 'Education of Sustainable Development' (ESD) program.

3.2 'Change' by ESD in 'design languages' to come with Mentoring and ITD

In the Digital Era, learning and working conditions have been undergoing a change and enabled new skills, such as 'train the trainer' and 'inner conflict coaching' – in addition to the array of self-learning programs for all education levels. Short in-house webinars have also been used in companies to support value-driven corporate social responsibility (CSR). Within this area the question arise, would a 'mentoring culture' as education tool be beneficial, by adding it to the curriculum – being prepared?

The pre-requisites for the inner conflict coaching mentioned earlier are: first, self-awareness, self-reflection and self-motivation [21]; and second, personal, face-to-face coaching, which has gained value and addresses the effect of psychological involvement and embodiment. The role in mentoring as a design teacher [22] is quite a different, as it takes on an outside perspective to skill transfer in a traditional way [23]. Different 'languages' reflect the different perspectives of the trainer, coach or mentor and results in the outcomes. Personal trainings focus on pre-framing a situation within the enterprise later on and need to be integrated into the conventional curriculum as part voluntary courses in-house University. Coaching is more cerebral and is influenced by the coaches psychological and philosophical background [24], mostly from external and specialised business fields.

Mentoring as an additionally honoured credit, is currently not part of curricula, however, such content is becoming increasingly relevant in the design engineering shift that is in progress. In these times of 'uncertainty,' emotional intelligence is fundamental for self-confidence and mental stability. The current Digital Era, is causing us to discuss the value and benefit of 'Artificial Intelligence' for society, along with 'Emotional Intelligence' [25], which are both needed in addition to 'Personal Intelligence'. The latter two will be essential key competencies for mentors involved in the Initial Teacher Education (ITE) and learning methods, in the coming years.

Mentoring in design engineering improves the creative process and results because it:

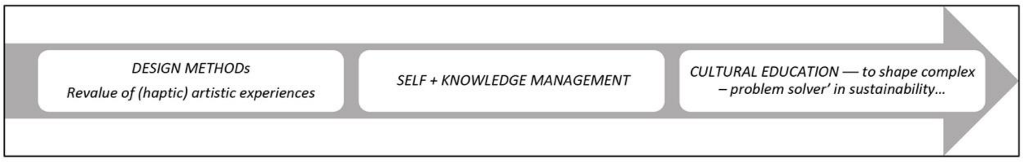
- provides the mentee a positive, stress-free environment that is non-hierarchical - in a 'flow'
- reflects an open-minded and integrative mindset, designing atmosphere that allows failure,
- allows playful designing,
- provides challenging tasks and experiences, helps you develop by exploring your limits,
- promotes emotional appropriation through intrinsic motivation and positive associations,
- develops personal intelligence carefully as well as a balance of mind and emotion.

The designer James Skone uses the term 'educare' [26] as the essence of deep design mentoring.

4 TRAIN THE TRAINER WITH *DISRUPTIV* DESIGN METHODS AND 'MOTIVATION TO ACT – INSTRUMENTS'

As we have shown, from the art pedagogical, design didactic and scientific perspective, the future educational systems for design engineering need to include a revalue of artistic experimenting spaces, a designing atmosphere to support self-belief by different (and multi-sensual) designing methods and: three key factors, mentioned above (see: table 1). Once implemented, ITE can benefit from interactive learning through cross-generational models: older experts – who serve as mentors and experts for the students – and students who mentor the children, can all design together. Cross-generational designing should be part of future university curricula, in answer to the need for good design = sustainable design. In the future, a mentoring culture could be worthful by courses like 'sustainable living.' 'Needless to say, holistic education begins early on.' [27]

Table 1. Key factors for future design engineering education, the author, 2021

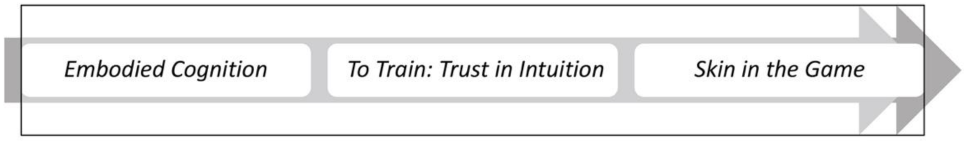


Although all three key factors – teaching various design methods, developing the fundamental knowledge management of individual and digital systems, and including cultural education – will have a positive influence on the 'trainer' and her/his concept of leadership is important. Leadership, according to Hans Hinterhuber, goes hand in hand with management. However, it is essential that they are able to combine their skills in terms of 'character,' 'knowledge' and 'action,' in order to open people's minds to resilient visions, and convince and motivate them. To complete a change process in education strategies, we have to distinguish between a trainer and a coach first:

Coaching means providing problem-based mental and emotional analyses and personal psychological consulting. This leads clients to change their perspective from the problem to a distinct solution [28]. According to neuroscientist and coach, C. Sander's, coaching also evokes the motivation to 'do' and 'act,' which is quite relevant for the changing process, as well from the philosophical point a view, by Corine Pelluchon, and art pedagogical point of view, by Georg Peez, both underlined in 2018 [29].

This leads us to training the trainer: as 'training' is original focussing on physical performance, the key skills for being a leader in sustainable education with a holistic view. As such, in the next years, 'embodiment' will play an important role in various instances: self-learning and coaching, design engineering education, change management, and personal intelligence. For the preschool teacher, embodiment means the combining mindful and corporal development and understanding bringing hand and mind together [30]. Learning in terms of embodied cognition is connected to a person's values and their self-motivation, leading to change. Self-perception and how you perceive the world and as described for 'imaging' in chapter 3.1., relates to artistic and design concepts, as well as to the design (or creative) method, for example the method of 'mapping'.

Table 2. 'Motivation to act - Instruments' in Design Engineering Education, M.Wachs, 2022



Intuition is seemed to be one core element in design education, as James Skone stated, it is a big challenge for the design educator to become a mentor. As design teachers, we have to fulfil both roles: to mediate knowledge and train each student to develop their ability to reflect, while mentoring future design engineering experts. Ergo, it would be best to educate our future mentors of good design in a sustainable and holistic manner, now. As a mentor you have to be at your students' side and support a 'motivation to act' skill, by the instruments of: – embodied cognition training, - trust in intuition – skin in the game character (see table 2). As a design engineer, we have learned to collect information and to transfer (mapping methods). In this process, our intuition is our best guide to achieving a mood, creating and expose images that relate to our personal belief system – as graffiti as mentioned at the beginning of this text. The beneficial experience of design didactical learning systems forms part of the foundation for art didactics and art pedagogical knowledge, as compared to Peez, Wehmeier, Piaget and other cultural and education scientists.

When it comes to self-management in using design didactics learning formats and in addition of mentoring culture, it comes to 'designing good,' in a sustainable manner: In this sense the 'art of languages' integrates holistic view and relate directly to human-centric material codes. So, we return to the initial question that seeks to reveal the significance of *understanding* what it means 'to gestalt, to know, and to be capable.' As we move forward, we will be using disruptive artistic experiences and 'motivation to act - instruments' to create the sustainable future as design engineer mentor.

REFERENCES

[1] Wachs M.-E. and Hall A. European Driving Range - innovative landscapes for a tangible, non-hierarchical learning space within a material and immaterial togetherness, EPDE 2019, Scotland.

[2] Böhringer H. in: Wachs M.-E. and Weinlich D. Writing a PhD in Design – a cakewalk?, 2011, p. 15. and p. 16., German: […] auf die Suche zu gehen, herauszufinden, was das ist: gestalten, wissen, können, translated by Wachs, M.-E., (Blumhardt).
[3] Peez G. Einführung in die Kunstpädagogik, 2018. (Kohlhammer),
[4] Wachs M.-E. Self-confidence & self-expression through Sketching - the significance of drawing in 'primary education' & the next generation of Engineering, EPDE Conference 2021, DK
[5] Nowotny H. Unersättliche Neugier – Innovation in einer fragilen Zukunft, 2005, p 9 ff., (Kadmos).
[6] Lampugnani V. M. Die Modernität des Dauerhaften, 1995, (Wagenbach).
[7] Nowotny S. Insatiable Curiosity – Innovation in a fragile Future, 2008, (Springer).
[8] Wachs M.-E. Materialising Immateriality-workshop: at RCA, London, invited by A. Hall, School of Design, 2019; see: Winther, R. G., 2020, When Maps become the world, (University of Chicago Press).
[9] Wachs M.-E. Material Mind – Neue Materialien in Design, Kunst und Architektur, 2008, (Kovaç).
[10] Weyer A. Sgraffito in Change, Materials, Techniques, Topics and Preservation, 2019, (M. Imhof).
[11] Peez G. Einführung in die Kunstpädagogik, 2018, p. 117, (Kohlhammer).
[12] Wachs M.-E. Zeichnen als Weltentwurf: analog und digital – Die Bedeutung des Zeichnens in der Primarausbildung mit Blick auf Design Engineering in Europe, 2021, EEE Konferenz Dresden.
[13] Steffen D. Design als Produktsprache, Der Offenbacher Ansatz, 2000, p.85. (form).
[14] Tan J. 2011, in: Racinet, A. & Dupont-Auberville, A., The World of Ornament, 2015, p. 9, (Taschen).
[15] Nowotny H. The Cunning of Uncertainty, 2015, (Wiley).
[16] Peez G. Einführung in die Kunstpädagogik, 2018, p. 117, (Kohlhammer).
[17] Wendemuth J. Bildwissenschaftliche Kunstdidaktik – Perspektiven einer Orientierung der Kunstvermittlung an Bildfragen und Bildgebrauch, 2019, p. 209, (kopaed).
[18] Weizsäcker E. U. and von Wijkman A. Come on! Capitalism, Short-termism, Population and the Destruction of the Planet – A Report to the Club of Rome, 2018, p. 196, (Springer).
[19] Weizsäcker E. U. et al 2018, p. 198 f; ibid.: Wachs, M.E. EPDE, 2021, ibid.: Schwab, K. *The fourth industrial revolution*, 2016, (Penguin); ibid: Wachs, M.-E., Hall, A., see: [1]
[20] Wachs M.-E. Design Engineering – sustainable and holistic, 2022, (Avedition).
[21] Martens J. U und Kuhl J. Die Kunst der Selbstmotivierung – Neue Erkenntnisse der Motivationsforschung praktisch nutzen, 2005, (Kohlhammer).
[22] Skone J. 2016, in: Park, J.H. (Ed.), *Didaktik des Designs - Design & Bildung – Schriftenreihe zur Designpädagogik*, Bd. 1, 2016, p 102f, (kopaed).
[23] Scott H. 2014, in: Philpott, C., et al, *Initial Teacher Education in Schools*, 2014, p 58 f, (SAGE).
[24] Sander C. *Change! Bewegung im Kopf. Ihr Gehirn wird so, wie Sie es benutzen*, 2017, (BV).
[25] Wachs M.-E. Design Engineering – sustainable and holistic, 2022, (Avedition).
[26] Skone J. 2016, in: Park, J.H. (Ed.), *Didaktik des Designs - Design & Bildung – Schriftenreihe zur Designpädagogik*, Bd. 1, kopaed, 2016, p 102f.
[27] Wachs M.-E. 2022, see: [20].
[28] Sander C. 2017, p. 245, see: [24].
[29] Pelluchon C. *Ethik der Wertschätzung – Tugenden für eine ungewisse Welt*, wbg Academic, 2019 p 58 (Ethics of Consideration, 2021); ibid: Peetz, G., *Einführung in die Kunstpädagogik*, 2018, chap. 3.1. + 4.2.
[30] Wachs M.-E. 2022; ibid: Martens, J. U., 2005, ibid: Peez, G, 2018, p. 123.

Figures:

[1 + 2] Max as 6- and 15-years old boy sprayed, 'FLY, pic.: Wachs M.-E. 2003 and 2012.
[3] Street sign – modified by unknown person, Florence, 2001, pic.: Wachs M.-E. 2013.
[4] 'Street art inspired design', pic. and design by Grobheiser K.

Tables:

[1] 'Key factors for next education in design engineering', 2021. table.: by Wachs M.-E.
[2] 'Motivation to act - instruments', 2022, table.: by Wachs M.-E.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

A PAN-EUROPEAN TRANSFORMATION TO BRIDGE THE GAP BETWEEN TANGIBLE EXPERIENCE AND VIRTUAL IDEATING SPACES

Marina-Elena WACHS[1], Theresa SCHOLL[2] and Giulia D'ALEO[3]
[1]Hochschule Niederrhein – University of Applied Sciences, Germany
[2]Textile Engineer, Germany
[3]Master Student from Politecnico di Milano, Italy

ABSTRACT

Pan-European design innovation needs new spaces for ideation and ongoing transformation. The key to this transformation is a symbiosis between 'interactive learning and ideating landscapes', and respecting mixed-stakeholder interests. It is important not to separate the academic and industrial spaces from one another, we have to bridge the gap between these – 'osmotic ideating spaces' can be the future.
When building innovative cross-border experiences, the design research approach is more useful than ever, with its greatest influence being on interdisciplinary fields. Attention can be drawn to digital interaction design, as a practice that balances behavioural and computer sciences that are used to direct the development of technology towards human desires, emotions and needs.
One way of (co-)designing draws a new focus to the field of design education. Because the interactions with humans are not as predictable as those with a technological component; we need social sciences, such as 'ethnography' in the field of hardware design education.
Finding a balance between the needs and interests of different stakeholders, and between the perspectives of UX and product design, it becomes irrelevant whether they are a student or an entrepreneur, they are ideating together in a sustainable social interaction. From an economic *and* didactical point of view, this benefits all parties. A great parameter for transformation is to *regenerate* designing experiences in relation to our 'values' as humans; this is when the 'design engineer artist' becomes the innovator and is responsible for the success of the transformation and reaching the SDGs.

Keywords: *Pan-European osmotic designing spaces, sustainable societal innovations, disruptive management as wishful thinking, design engineer artist as innovator, balancing knowledges for SDGs*

1 INTRODUCTION

Europe needs different stakeholders to come together into osmotic ideation spaces, in which it will be possible to envision and design solutions capable to manage the complexity of the challenges framed by the Sustainable Development Goals agenda. We have to create pluralism in the (design) industry through 'osmotic ideating spaces' [1] as a future model – a useful instrument for achieving more SDGs (Sustainable Development Goals) [2]. Within these generating fields, *disruption* can be a worthwhile didactic element in evaluating process management.
The next chapters will examine whether we need a new form of designing across disciplines and cultures to find answers to this thesis. Creative thinking and practices have been increasingly praised for their ability to cut across disciplinary borders, thus becoming a new engine for innovation [3]. Nowadays several research laboratories and tech companies are driven by mixed teams, where artists and designers work together with scientists, developers, entrepreneurs and activists to shed light on current developments in our digital society.
Designers are used to gathering qualitative and quantitative data that enables them to have a broad understanding of the problem. Their unconventional way of tackling and representing complexity is what can help smooth the frictions among different disciplines [4]. While focusing on user experience [5], creating a perfectly shaped product is no longer the main focus of industrial design. When a digital service is added to a product, it enables feedback to be obtained from the customer and the product to be updated during its lifecycle. In consequence, chapter two focusses, on the one side, on new forms of

interaction design in education and businesses strategies, and, on the other side, the value of new forms of storytelling – because narration and cross-cultural understanding create the pluralistic process, that we need for different learning and ideating levels within the post-digital era.
Our European collaboration – from different countries and different areas of work – demonstrates, from the perspective of both the industry and academic institutions, how to combine the respective skills and invest in self-management. Challenges in bridging the gap between disruptive design areas and the design experiences, which must be created for a sustainable future, are described in chapter three (3) with the help of case studies that focus on the following research topics:

- 'Osmotic' creative spaces – to build new 'bridges' for creating mixed media spaces
- Disruption as wishful thinking – involving new subjects in the process demands mindful flexibility, which never takes place without friction, a kind of 'inharmonious management'
- Narrative tools like 'new storytelling' serve as a bridge between material and immaterial design engineering spaces – to mediate between tangible experiences AND virtual ideating spaces.

All these research topics are summed up and evaluated – in relation to the SDGs, the didactic value and economic application – see chapter four (4).
The benefit of the interlinked, cross-cultural and cross-disciplinary collaboration was and is the successful European transformation towards balancing the 'un-tangible' laboratory, thus, ideating the best sustainable solution in Europe's design engineering post-digital era.

2 CREATIVE THINKING NEEDS MORE INTERACTION – RELATED TO SDG NO. 3 + 12

2.1 New forms of design will shape behaviour in a digitally-based world

Currently, scientific research is driven by a surge in technological and engineering sciences as a result of enormous budgets that are supporting the digital transformation in the EU. [6] Creative disciplines, social sciences and humanities in this phase of technological development must find ways to bridge the gap between the sciences, society and the environment. Design can be seen as a useful discipline that can be integrated into R&D processes, thanks to the 'indeterminate' nature of its subject matter [7] and its ability to understand hidden relationships in 'wicked problems' through meaningful visualizations [8].
Interaction designers are a good example of how design penetrated the field of human-machine interaction. Their education includes knowledge from both IT and the behavioural sciences, which help them design products and systems with a fine equilibrium between the functions and behaviours. This is carefully achieved by defining 'the who, what and how of interaction' process. [9] Interaction designers could be seen as shapers of behaviour. This crucial ability proves its value when facing social and cultural problems that are difficult to solve. For instance, one of the greater challenges that the 2030 Agenda for Sustainable Development places at the centre of a new developmental vision is good health and well-being (SDG No. 3). This can be achieved if people are able to access quality assistive products when and where they need them. [10] QBreathe, a project developed at the Polytechnic University of Milan, by students enrolled in the MSc in Digital Interaction Design programme, is an example of how an IoT product associated with an application can help people with problems related to stress and help them develop healthier habits – see Figure 1. This map represents the experience of using an augmented fidget gadget, which take advantage of humans' tendency to release their stress by pressing buttons to detect their stress level. If it is too elevated, the product suggests that the user perform a breathing exercise, providing a quick fix to their anxiety crisis. On the other hand, the app keeps track of the sessions and, through subtle hints, reminds the users to practice their breathing. In such a manner, the product helps people engage in a behavioural change cycle that helps them acquire resilience over time. Finally, a pulse sensor embedded in the object allows the heart rate to be detected and can check the user's blood pressure. This shows how user-centred methods applied to the development of man-machine interactions within the 21st century can play a central role in the democratic availability of technologies, making them truly capable of empowering humans in their daily lives.

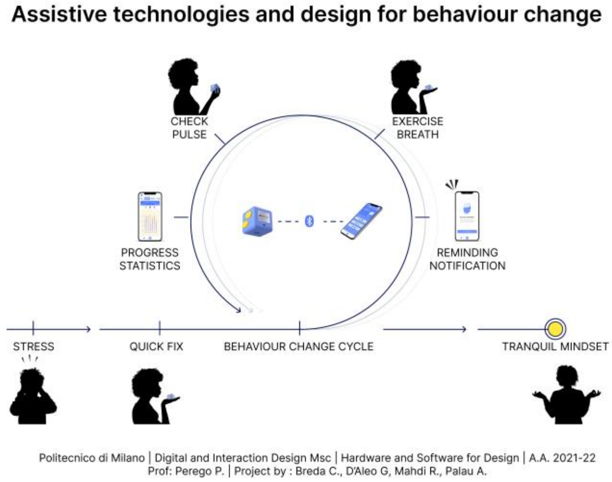


Figure 1. Map showing the experience of behaviour change triggered by QBreathe, IOT+app assistive technology system

2.2 Transformation in product design regarding sustainable product-user-interaction

With the increasing focus on user experience, creating a perfectly shaped product is no longer the main focus of industrial design. [11] This shift is leading to a change in the way product designers define themselves. It is crucial to be more than just a craftsman with an excellent sense of shapes and materials. More than ever, designers have to be aware of the potential interaction between a product and its user, and how digital services create a connected system related to an object. Theories like Design Thinking or Interaction Design are currently at the centre of attention. [12]

However, in today's industry, product designers – and especially their clients – often tend to focus on the product itself, production methods and sales strategies instead of the users' needs and desires. [13] Since the interaction with humans is not as easy to predict as the functions of technologic components, a new focus on social sciences, like ethnography, is needed in the field of industrial design education. [14] This change brings a huge potential for the relationship between the designer of a product and its users. If a digital service is added to a product design, it is also possible to receive feedback from the customers and update the product during its lifetime. [15] This new way of (co-)designing is resulting in more sustainable products because they actually match the users' needs and can adapt to new circumstances.

Adding a new medium to a product design – in this case, digital services – also leads to a new way of storytelling. A simple, non-digital product, like the fashionable IT bag of the season, tells the story of being desired, a style icon. However, if the interaction with the product is brought more into focus than the product itself, the story also has to change. The product should tell its user how it would like to be handled to perform best, and what kind of different interactions are possible between the product and its user. [16]

For this new way of storytelling, the so-called 'Offenbacher definition of product language' by Dagmar Steffen – and consideration of Jochen Gros's preconditioned framework – serve as a good knowledge base. [17] In order to create a story of usage around a product, it is important to understand the product's language first. Storytelling has to transfer this language in a unique way to create a credible narration, which can influence the relationship between the product and its user. [18] A good starting point for creating such a story is the choice of material. According to Gernot Böhme, materials have a very amorphous character and are part of the product's atmosphere, because materials 'create' products. In our unconscious mind, materials are linked to synaesthetic perception, cultural codes and interpersonal experiences. In the relationship between the product and its user, the material can influence what the user feels while looking, touching and using the product. [19]

Considering the SDGs, in particular goal number twelve (SDG No.12), it would be interesting to understand how the story of a product, especially as told through the selected material, could create a more sustainable use of the product by its user. An example that emphasises this consideration is the comparison of the Italian design factory Alessi and the Scandinavian-based brand Stelton; both produce housewares and kitchen items but have a different focus. Alessi is well-known for very poetic and brand shaping designs and is not as focused on material choices and functionality as Stelton, which focuses more on products with high usability and material-appropriate processing. [20] So, from the perspective of product-user-interaction, what would now be the more sustainable product – the emotional one or the functional one?

3 BALANCING DESIGN AREAS – PLURALISM IS KEY

3.1 Interconnected European designing – Osmotic creative spaces

Finding a balance between the different design perspectives of UX and product design 'generating' programmes, regardless of if you are a student or an entrepreneur, you are ideating together.
The challenges faced when bridging the gap between the co-ideating spaces are as follows:
The transformation is a question of two essential elements: Firstly, the challenge lies in motivating the members of enterprises/institutions, and designers/design students, of course, to collaborate and develop their skills, and convincing them to invest in self-management – this is not a question of 'continuing education' [21] and 'coaching courses' [22] within industry or universities. Secondly, this 'motivation to act' correlates to osmotic learning and designing spaces [23]. Utilising this interdisciplinary design field involves technical virtual connected areas, on the one hand, while it is characterized by osmotic learning levels on the other: Different learning taxonomy levels of different participating partners are beneficial for the process and the result. That means teenagers, students, managers, experts, and teachers all come together in stress-free creative learning spaces, non-hierarchical creative landscapes around Europe [24]. The didactic benefit of this form of co-designing is that the young generation of students and teenagers who participate can learn from the experiences of experts and managers, and vice versa. This allows the managers to gain insights into the naïve view of teenagers and students. These different perspectives illustrate the pluralistic points of view as wishful thinking in designing – not only in Design Thinking.
In addition to building new 'bridges' by creating mixed media rooms, this approach is supported by the worthy pedagogical aspect of tangible experiences, which can be combined in virtual learning landscapes through materialized storytelling [25]. Pan European workshops in Germany and Great Britain gave reason by 'materializing immateriality workshop method' in the year 2019 [26] for recovering the cognition-based experiences within the designing process for diverse partners.

3.2 Building bridges – making experiences in design spaces possible – free the artistic experiment to accept the disruption of a 'new design engineer artist'

When it comes to 'designing experiences' or offering experiences in the design process as a design didactic approach, we have to regard different types of experiences, which is taken from the industrial practitioner's point of view, according to Rossmann and Duerden. Their aim was to define a framework of experience types and '*[...] to introduce (you) to approaches and tools that will allow you to practice experience design more effectively and systematically*.'[27] But is this the main focus of the design process with tangible experiences? Could this *preformed* frame for experiences guarantee a frictionless, smooth design process for ideating sustainable solutions? Based on the European design didactic teachings, we may consider 'failure' [28] and 'voids' (R. Sennett) and disruption to be beneficial and a playful frame for greater and more expansive variations of design pathways in the future. Richard Sennett describes the negative impact of only using CAD systems for designing, focusing on an 'overdetermined planning' [29]. Introducing disruption to the process can offer a kind of inharmonious management, leading to a reflection upon and rethinking of the design. This element is beneficial to both the mind and hand coordination, as well as thinking through drawing. The experience of drawing and explaining your sketch to other people leads you to re-value and evaluate your design; you sketch again, and this is worthwhile as a repetitive evaluation process of the result.
In the Digital Era, learning and working conditions will benefit artistic experimentation, giving voids, failure and disruption a chance, in the stress-free environment of using artistic media: This could represent a re-evaluation of the 'designer engineer artist' [30] of former times.

4 EUROPEAN TRANSFORMATION IN BRIDGING THE 'UN-TANGIBLE' LABORATORY TO PRESENT DESIGN PRACTICES

4.1 How to push stakeholders to engage more in *socially* relevant SDGs

Experience matters – again! As we have seen, the 'motivation to act' and change your habits, or to develop your skills – through self-management in each stage of your education or career – transitions through different steps of education and experiences in the digital post era. But what is a great experience today and in the near future – in 2030? How does it relate to the need for changes in habits that facilitate a better relationship to the SDGs? From the pedagogical perspective and design didactical point of view, with a focus on hands-on design *and* digital designing experiences, it is part of a new 'educare' [31] space, in which the young talents are mentored and offered spaces for designing in a flow. No fear of 'white paper'. Let us encourage young people and teenagers to work together seamlessly with experts and designers, for a sustainable mixed media environment: analogue, tangible and digital – all connected in Europe, more than ever before – with the value of narrative tools, like a new form of storytelling (see above).
Designing experiences and creating spaces for experiments – UX design, co-designing, and the customers' perspectives are related to the motivation to act. And the instruments that Wachs describes as 'inharmonious management' [32], or disruption as wishful thinking, can be used to involve new subjects in the process. This demands mindful flexibility, and never occurs without friction.

4.2 Sustainable change in creating open spaces for sustainable behaviour

As the augmentations in chapters 2.1 and 2.2 demonstrate, it is possible to learn more about the users' needs and desires through design disciplines, like digital interaction design. Keeping this in mind should be the focus of today's product designers. With regard to sustainability, it doesn't matter if we create more emotional products or ones with high functionality: The most sustainable products are those that help the users in their daily life, offer the joy of use and are adaptable to new circumstances. Sustainable change can't be designed on a piece of paper, designers have to study humans' experiences and create tools and spaces that can change habits in daily – sustainable – product-user-interactions. It is impossible to solve serious environmental issues with one design, but we can design products that lead to sustainable activities and behaviour.

4.3 Creating a balance between engineering and social sciences – how designers can take part in the European transformation

Europe needs a new generation of designers, who are able to reshape behaviours as well as empower and help people walk their way towards a more sustainable lifestyle. To do that, they have to be able to penetrate other intellectually robust fields, like tech, medicine, policy, or law, thereby bridging the gap between the sciences, society and the environment. Designers will need more knowledge to be able to communicate with researchers and developers with different backgrounds and, therefore, they have to develop some key qualities. Firstly, they need to be educated on interaction, experience and service design. Secondly, they need to develop methodologies to validate and assess their assumptions and design proposals. The tools for these products are interlinked ideating spaces, experimental research and disruptive management processes. Thirdly, though not finally, they must develop appropriate methods for sharing their process in a suitable and scientific way.
If all these steps are realized in a corporative European interactive and ideating space – as well as impulse exchanges with different stakeholders – didactic, economic and socially sustainable gains are obvious. Mind the gap between Design Doing and Digital Interaction Design.

REFERENCES

[1] Wachs M.-E. *Design Engineering – sustainable and holistic,* 2022, p. 82 (avedition, Stuttgart).
[2] United Nations, *The 17 Goals*. Available: https://sdgs.un.org/goals [Accessed on 2022, 20 February], (2020).
[3] Catricalà V. *The Artist As Inventor: Investigating Media Technology Through Art*, 2021, pp. 9-13 (Rowman & Littlefield, Lanham).
[4] Kolko J. *Thoughts on design* , 2011, p. 40 (Morgan Kaufmann, Burlington).
[5] Kalbach J. *Mapping Experiences: A Complete Guide to Creating Value Through Journeys, Blueprints, and Diagrams,* 2016 (O'Reilly Media, Inc., Newton).
[6] Negreiro M. and Madiega T. *Digital transformation*, 2019, Members Research Service PE 633-171 June 2019, p. 5-6.
[7] Buchanan R. Wicked Problems in Design Thinking, in *Design Issues*, 1992, 8(2), p. 16 (Mit Press, Cambridge).

[8] Kolko J. *Thoughts on design* , 2011, pp. 96-100 (Morgan Kaufmann, Burlington).
[9] Hassenzahl M. Experience Design: Technology for All the Right Reasons, in *Synthesis Lectures on Human-Centred Informatics* , 2010, pp. 11-13, (Morgan & Claypool, San Rafael).
[10] Tebbutt E., Brodmann R., Borg J., MacLachlan M., Khasnabis C. and Horvath R. *Assistive products and the Sustainable Development Goals (SDGs)*, 2016, https://globalizationandhealth.biomedcentral.com/articles/10.1186/s12992-016-0220-6.
[11] Stevens G. *Soziale Praktiken als Gegenstand der Gestaltung*, In *Das Design Digitaler Perspektiven*, Denzinger, J. (Ed.), 2018, p. 98, (Birkhäuser, Basel).
[12] Norman D. A. *Die Zukunft des Design: Die Entscheidung für einen Weg? Nimm beide*. In *Das Design Digitaler Perspektiven*, Denzinger, J. (Ed.), 2018, pp. 16-23, (Birkhäuser, Basel); see: Norman, D. A. *The future of design: When you come to a fork in the road, take it.* In *Design X.*, Gianni Sinni (Ed.), 2016, pp. 193-306 (Macerata).
[13] Spellmeyer G. *Materialimpulse.* In *Die Sprachen des Materials*, Wolfzien, F./Scholz, M. (Ed.), 2016, p. 38, (Reimer, Berlin).
[14] Oswald D. *Digitale Produktsprache - Produktdesign und Designstudiengänge in Zeiten der Digitalisierung*, In *Das Design Digitaler Perspektiven*, Denzinger J. (Ed.), 2018, pp. 60-70, (Birkhäuser, Basel); see: Oswald, D. *Towards a Redefinition of Product Design and Product Design Education.* In *12. International Conference on EPDE*, 2010 (Glasgow).
[15] Stevens G. *Soziale Praktiken als Gegenstand der Gestaltung*, In *Das Design Digitaler Perspektiven*, Denziger, J. (Ed.), 2018, p. 98, (Birkhäuser, Basel).
[16] Ruf O. *Storytelling für Designer*, 2019, p. 95f (avedition, Stuttgart).
[17] Steffen D. *Design als Produktsprache – Der „Offenbacher Ansatz" in Theorie und Praxis,* 2000, (Verlag form).
[18] Ruf O. *Storytelling für Designer*, 2019, p. 95 (avedition, Stuttgart).
[19] Böhme G. Atmosphäre, Essays zur neuen Ästhetik, 2019, Vol. 4 (Suhrkamp, Berlin), see: Böhme G. *The Aesthetics of Atmospheres (Ambiances, Atmospheres and Sensory Experiences of Spaces*, Thibaud, J-P. (Ed.), 2016 (Routledge).
[20] Spellmeyer G. *Materialimpulse.* In *Die Sprachen des Materials*, Wolfzien F. and Scholz M. (Ed.), 2016, p. 40, (Reimer, Berlin).
[21] Meggison D. et al. *Continuing Professional Development*, 2003, (cipid, London).
[22] Scott H. in: Philpott C. and Scott H. *Initial Teacher Education in Schools – A Guide for Practitioners*, 2014, p. 58 (Sage, London).
[23] Wachs M.E-. *Design Engineering – sustainable and holistic*, 2022, p. 82 at all (Avedition, Stuttgart).
[24] Wachs M.-E. and Hall A. *European Driving Range –Innovative Landscapes for A Tangible, Non-Hierarchical Learning Space Within A Material And Immaterial Togetherness* 2019, International Conference on EPDE, Glasgow, September 2019.
[25] Hall A. 2018, *Introducing Tangible Aesthetics: Contrasting the Introduction of Aesthetic Analysis Tools for Product Designers and Interdisciplinary Design Researchers,* International Conference on EPDE, London, 2018, pp. 482-487.
[26] Wachs M.-E. *Design Engineering – sustainable and holistic,* 2022, pp. 139 - 154 (avedition, Stuttgart).
[27] Rossmann R. and Duerden M. D. *Designing Experiences*, p. 177, (Columbia University, N.Y.); ibid: see p. fig. 3.1 and 3.2 pp. 40-41.
[28] Hall A., Bahk Y., Gordon L. and Wright J. *The Elastic Octopus: A Catalogue of Failures for Disrupting Design Education*, 2016, (EPDE Conference, Aalborg).
[29] Sennett R. Handwerk, 2008, p. 63 ff (Berlin); see Sennett, R., *The Craftsman*, (Yale University Press, New Haven).
[30] Wachs M.-E. *Design Engineering – sustainable and holistic*, 2022, p. 6 and chapter 7 (avedition, Stuttgart).
[31] Skone J. in: Park J. H. *Didaktik des Designs*, 2016, p. 101 f, (kopaed, München).
[32] Wachs M.-E. *Design Engineering – sustainable and holistic*, 2022, p. 255 (avedition, Stuttgart).

INVENTING AND PATENTING USING HALF-CAUSATION: NEW PHILOSOPHICAL TOOLS FOR ENGINEERING DESIGN EDUCATION

Mo ABOLKHEIR and Michael WISNOM
Department of Aerospace Engineering, University of Bristol, United Kingdom

ABSTRACT
This paper has two objectives. The first is to briefly introduce a readership in Engineering Design education to Half-Causation, which is a philosophical model for inventing and patenting. Following a brief introduction, Half-Causation will be illustrated using the well-known case of the centrifugal vacuum cleaner, which was invented by the British inventor Sir James Dyson in the late 1970s. The second objective is to present the outcome of a 3-hour workshop which took place at the University of Bristol in 2021, in which doctoral engineering students were introduced to Half-Causation, before being given an engineering design problem to solve using it. The problem was 'how to reduce the probability of a cyclist unseating (flying over the handlebar) when braking at high speed.' Instead of addressing the problem in the traditional terms of morphology or functionality, the participants were encouraged to focus on *causal properties*. The participants were divided into four teams, and they clearly got a reasonable grip on *Half-Causation Branching* and followed its instructions faithfully. The four teams developed 44 inventive concepts, albeit some of the same or similar inventive concepts were developed by multiple teams. The workshop ended with discussing the optimisation of the scope of sought patent protection, using *Half-Causation Encapsulation*. The paper concludes by recommending adding the Half-Causation tools to engineering curricula, both in terms of generating ideas and intellectual property, specifically patents.

Keywords: Inventions, patents, half-causation, engineering design education

1 INTRODUCTION
Abolkheir 2019 presented 'Half-Causation', which is a philosophical model for the systemisation of the process of *inventing*. [1] Abolkheir 2021 addressed how to optimise the process of *patenting* [2]. This paper has two objectives. First, to briefly introduce a readership in Engineering Design education to Half-Causation. The second is to present the outcome of a 3-hour workshop which took place in 2021, in which doctoral engineering students were introduced to Half-Causation, before being given an engineering design problem to solve using it. The workshop was the first at doctoral level, and progressively followed on from earlier undergraduate workshops, and patent-developing collaborations with students and academics. It is worth briefly highlighting where Half-Causation is positioned within the different intellectual attitudes towards creativity. We have those in the early 20th Century who argued that creativity is mysterious and resistant to structuring e.g., Popper [3]. Then we have the different approaches to systematic design which gradually emerged decades later including functional analysis, morphological charts, TRIZ and C-K; see for example [4] & [5]. Half-Causation sits within the systemisation efforts, while benefiting from solid philosophical grounding and from strategically targeting patentability.

2 HALF-CAUSATION
Half-Causation consists of five phases of reasoning, each terminating with taking a 'logical branch.' In the first instance, Half-Causation is a descriptive generalisation of how technological inventions have been developed in the past i.e., engineers and scientists (and inventors generally) could be seen to have developed their technological inventions using something like Half-Causation, albeit partly consciously and partly not, and partly efficiently and partly not. The abstract tools of philosophy were used to isolate and articulate the inventive reasoning involved, before presenting it as a *prescription* which can be

followed in future invention projects to systematically develop inventions. Half-Causation as a method is named after its first phase which consists of a methodological idealisation of the causal process, by pinpointing *half* of a possible causal relation while ignoring everything else. Following this, Half-Causation prescribes how the reasoning should proceed, which ultimately constructs a complete and novel causal process. In non-technical terms, Half-Causation captures the reasoning from a technological problem towards multiple possible solutions, or from a technological solution towards multiple problems which can possibly be solved by it. [1] [2]

2.1 The Half Causation Phase

This phase consists of the pinpointing of *half* of a possible causal relation, which can either be:

- A **Distinctive Causal Input ['DC Input']** which is available, but for which some desired Distinctive Causal Output ['DC Output'] is sought i.e., there is *a technological opportunity*.

Or

- A **Distinctive Causal Output [DC Output]** which is desired, but for which some available Distinctive Causal Input [DC Input] is sought i.e., there is *a technological problem*.

2.2 The Domaining Phase

At this phase, the half-causation (be it a DC Input or a DC Output) is domained in a specific technological area/arena, within which a matching half-causation might be found (at the next phase). The Domaining is done by figuring out what would happen in the middle of some causal process or another. The history of technology has shown that many great inventions were developed following novel domaining which occurred at this phase.

2.3 The Matching Phase

At this phase, the half-causation gets matched with some other half, both of which belong to the same technological domain. So, if the half-causation was an available DC Input, then it gets matched with a desired DC Output. But if the half-causation was a desired DC Output, then it gets matched with an available DC Input. It is at this phase that the inventive concept is clinched i.e., some in-principle understanding of the causal process: what DC Input would be present at the beginning; what would happen in the middle; then what DC Output would emerge at the end.

2.4 The Essentialisation Phase

At this phase, the essential details of the causal process are identified and synthesised. The term 'essentialisation' reflects the fact that it is the synthesis of the DC Input, the DC Output and the *essential* physical conditions that constitutes the invention and confirms that the match actually works. The essentialisation can be physical or analytical. It is important to note that until this phase is terminated there is no invention yet. If patent protection is sought, then the information that is generated at this phase would be helpful in preparing a patent application.

2.5 Accessorisation Phase

At this phase, the essentialised match between the DC Input and the DC Output finally gets accessorised by adding *accessory* physical conditions. These features are deemed 'accessory' because they are not 'essential' for the invention. This phase terminates with the generation of the first industrial product design which incorporates the essentialised DC Input-DC Output match. The termination of this phase constitutes the end of a given invention project. All subsequent activities e.g., the generation of other product designs, or achieving business and financial successes fall outside the scope of Half-Causation.

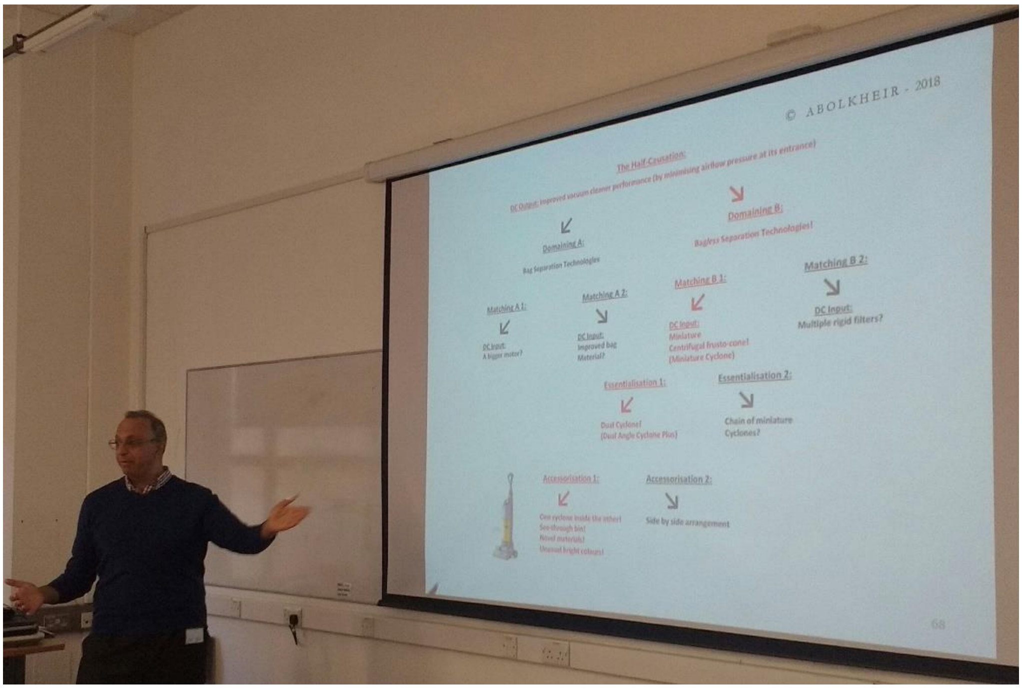


Figure 1. Mo Abolkheir presenting the Dyson case at a face-to-face Half-Causation workshop in 2019

3 THE CENTRIFUGAL VACUUM CLEANER CASE STUDY

This invention was triggered by a technological problem. James Dyson (now Sir James Dyson) recognised that the vacuum cleaner bag gets clogged soon after first use, causing a loss in pulling-in power. A vacuum cleaner works by creating airflow pressure that is lower than atmospheric pressure, and as such pulls in dirt-laden air. So, the desired DC Output was improved vacuum cleaner performance, by having airflow with minimal pressure at the entrance of the vacuum cleaner. [1] [2] [6] [7]

- So, at the end of the Half-Causation phase, the DC Output was identified as improved vacuum cleaner performance, by having airflow with minimal pressure at the entrance of the vacuum cleaner, and that finding some DC Input that causes it was deemed in principle technologically possible.
- At the Domaining phase, the DC Output was domained in ‘bagless’ separation technologies i.e., the domain of causal matches in which airflow pressure causally engages, in the middle of the causal process, with bagless separation entities. This was crucially different from the traditional technological domain of bag separation technologies, in which airflow pressure causally engages, in the middle of the causal process, with a bag. Indeed, it was precisely this domaining that set Dyson apart from the rest of the world.
- At the Matching phase, the DC Output was matched with the DC Input of a miniature cyclone unit (i.e., a centrifugal separator which separates dirt out of the airflow, instead of using the cloth of a bag to do the separation).
- At the Essentialisation phase, an arrangement of essential physical conditions was stipulated, and included a motor driven fan etc. plus the all-important ‘dual-cyclone’ (i.e., two cyclone units in a series, the upstream is parallel-walled for separating large debris, and the downstream is frusto-conic for separating fine dust). It was this essentialisation that confirmed that the DC Input – DC Output match actually works.
- At the Accessorisation phase, the numerous added accessory physical conditions included industrial design features such as positioning the frusto-conic cyclone inside the parallel-walled cyclone, and the innovative use of materials and colours, which were included in the first product: the ‘Cyclone.’

4 THE WORKSHOP

The workshop took place online in April 2021. It was attended by nine engineering doctoral researchers and lasted for three hours. The objectives were to provide a basic command over two tools:

- **Half-Causation Branching:** How to logically map a given inventing space, systematically pinpointing multiple inventive concepts.
- **Half-Causation Encapsulation:** How to optimise the scope of sought patent protection.

The workshop started with a lecture introducing Half-Causation, including questions & answers. The participants' questions indicated that they were engaging with the philosophical content, specifically asking about the nature of *Half-Causation as a method*; the distinction between a *Distinctive Causal Input* ['DC Input'] and a *Distinctive Causal Output* ['DC Output']; and the distinction between *Essential Physical Conditions* and *Accessory Physical Conditions*. Following that, the exercise part started. The participants were given a design problem that relates to increasing the safety of bicycles. They were asked to logically map the inventing space using Half-Causation Branching, searching for solutions. Here is the problem:

How to decrease the probability of a cyclist unseating (flying over the handlebar) when braking at high speed?

Due to the limitation of time during the workshop and to assist the participants get going, they were given a part-completed Half-Causation Branching template (which is not shared in this paper). The completed part can be summarised as follows. The first task was to conclude the Half-Causation phase, by making a clear statement of the Half-Causation logical branch. So, in the proper Half-Causation terminology (and more importantly its 'conceptual framework') the problem which was originally stated as a *question* needed to be converted into a statement of the *desired **DC Output***. This statement reads: **Decreas*ed* probability of a cyclist unseating (flying over the handlebar) when braking at high speed**. Such a clear statement defines the 'boundaries of relevance' of *this* problem/project. So, the participants were instructed to avoid ideas such as 'cycling slowly in the first place,' or 'taking the bus instead of cycling altogether'. Such ideas, as valuable as they may very well be, are irrelevant to the stated problem (which specifies the use of a bicycle, and cycling at speed), and as such the reasoning should exclusively focus on relevant information.

Following that, it was presented to them that instead of paying attention to 'morphological' and 'functional' considerations, Half-Causation focuses on *causal properties* (of the DC Output, or the DC Input, whichever the first phase consists of), each of which defines a given domain. So, three causal properties of the bicycle DC Output were pre-identified, and as such the participants were presented with *three domains*, namely: **speed**; **cyclist's body** and **handlebar pivot**. The participants' task was then to search within each domain for multiple DC Inputs, each of which can be matched with the desired DC Output to form an inventive concept. The three pre-identified domains were not intended as being exhaustive. Indeed, participants in other workshops occasionally identified other domains, and so did some of the participants in this workshop. However, the purpose of the exercise is not to exhaustively map the inventing space and actually develop an invention, but to train the participants in systematic reasoning using Half-Causation Branching. Due to limitation of space, this will not be addressed further here.

4.1 Exercise Outcomes

Circa 15 minutes were spent presenting the problem to the participants. Following that, the participants were divided into 4 teams each in a Microsoft Teams breakout room and given one hour to see how far they can progress their reasoning. Each pinpointed DC Input would be matched with the desired DC Output to constitute an 'inventive concept.'

Team 1 consisted of three participants. They managed to pinpoint 11 DC Inputs.

Team 2 consisted of two participants. Their grasp of the problem situation and the use of Half-Causation Branching was impressive. In the branching template they were given, they managed to pinpoint 13 DC Inputs. As they ran out of space, they created their own Word document and listed 5 more DC Inputs i.e., 18 DC Inputs in total.

Team 3 consisted of two participants. They managed to pinpoint 7 DC Inputs.

Team 4 consisted of two participants. They managed to pinpoint 8 DC Inputs.

The following is a summary of the matched DC Inputs which were generated, quite a few of them were pinpointed by more than one team, albeit occasionally with a different terminology.

- Within the domain of speed, the matches included: ABS technology, wind shield, parachute, folding flaps, smart helmet, alarm system, and augmented reality (google glasses).

- Within the domain of cyclist's body, the matches included: strap up (seat belt), drag flap (on the body), airbag, bent frame as to make the CG more towards the back wheel, reverse brake in seat post (to automatically lower the CG), and magnetic clothing & seat.
- Within the domain of handlebar pivot, the matches included: (permanently) raised handlebar, automatically raised handlebar when braking, suspension damping (axial springs/pneumatic/hydraulic).

4.2 Half-Causation Encapsulation

The workshop then moved on to how to optimise the sought patent protection, using Half-Causation Encapsulation. Only 30 minutes were available. First, the participants were provided with basic information about patents, largely based on Abolkheir 2021 [2]. So, a patent protects the way an invention works, as opposed to a registered design which protects how a product looks. A patent is a monopoly which prohibits others from practicing the invention, in a given country during the validity of the patent. A patent application consists of several parts: Abstract, Description and Claims, which may be supplemented by Drawings. The Claims are the most important part, as they state the legal boundaries of the invention. Whilst mathematics can be used in the Description, and whilst the Drawings can be referred to in the Claims, neither can be included in the Claims. What does this mean? It means that ultimately a patent's enforceable legal boundaries boil down to the use of *language*. Indeed, it is language , language, language! A crucially important lesson for engineers and designers to learn if they desire to obtain patents. Of course, patent agents write the patent application, and they work with the inventor(s) to clarify the nature of the invention. However, it is not their role to contribute to the inventing process as to become co-inventors. That is why inventors would benefit from learning how to formulate and state their inventions in a *clear, optimised language*. This is where the tools of Half-Causation Branching, and Half-Causation Encapsulation come in. The basic idea is to first identify, then plug, any gaps in the sought patent protection, through which infringers can circumvent the patent. So, first Half-Causation Branching assists with pinpointing *multiple* inventive concepts, then Half-Causation Encapsulation assists with encapsulating them within a *Single* Inventive Concept. This satisfies the legal requirement of having 'unity of invention', and protects a broad class of technological possibilities, including some which may be developed in the 20-year life span of the patent.

The participants were then presented with a pre-prepared pedagogic example from previous workshops, which related to the same bicycle design problem, and resulted in three inventive concepts, within the domain of cyclist's body, namely: *bucket seat*, *angled seat*, and *spring-loaded seat*. So, if you invented one, a competitor could invent one of the others and circumvent your patent. Now, can they all (and more) be encapsulated in *one* patent application? Here are the four Half-Causation questions, which inventors (and their patent agents) need to answer:

1. What is the invention's Distinctive Causal Output? I.e., what the invention purports to achieve.
2. What is the invention's Distinctive Causal Input? I.e., what is unique about the invention.
3. What are the invention's Essential Physical Conditions? I.e., the absolute minimum features without which it cannot work, which should be included in Claim 1 (and any other independent claims).
4. What are the invention's Accessory Physical Conditions? I.e., variations which should be introduced alternately and in combinations in dependent claims.

- The answer to the first question is simple: *decreased probability of a cyclist unseating (flying over the handlebar) when braking at high speed*.
- The answer to the second question requires 'higher order terminology' which encapsulates all three inventive concepts (and more). Here is a basic example. If a term like 'slotted head screw' is used in a claim, a competitor can use a 'Phillips head screw' to circumvent the claim. However, the term 'screw' is higher order, and the term 'mechanical fixing means' is even higher, and thus better. So, an encapsulating higher order term for the DC Input in the bicycle is: '*unseating-resistant means*.
- The answer to the third question is: *attachment means* (to attach the system to the bicycle frame), and *cyclist supporting surface*. These are the absolute minimum features.
- The answer to the fourth question consists of a long list of variant features, which are stated using lower order terminologies that are introduced in subsequent dependent claims.

Ironically, the three inventions we started with become downgraded to being mere variations (Accessory Physical Conditions)! So, the bucket seat, the angled seat, the spring-loaded seat, and others are introduced as variations of the DC Input of *unseating-resistant means*. The Description (preferably accompanied by Drawings) should include sufficient technical details which enable a person skilled in the art to practice the invention and support the Claims.

5 CONCLUSIONS

Half-Causation has been successfully presented and implemented in a workshop with doctoral engineering students. From methodologically qualitative observations at the workshop (and other workshops), the teaching of the Half-Causation tools needs to be given appropriate time to allow each student to get a firm grip on it and master its use. Unlike a brainstorming session, there is little value in rushing the process. Notwithstanding scheduling pressures, it would be beneficial for the students that the delivery is for longer than three hours, split over two days. For example, an undergraduate engineering student used Half-Causation to co-invent a system, which has since been granted a GB Patent [8]. After attending a 3-hour Half-Causation workshop, he attended three weekly 2-hour one-to-one mentoring sessions with Mo Abolkheir. So, besides the *nine* hours of contact, the student benefited from three weeks of in-between time to think and research. In any event, the systematic ordering of Half-Causation was put into practice almost immediately during the workshop. Whilst idea generation techniques and taught design processes exist for solving technological problems, Half-Causation is distinguished by the 'Domaining' which is interposed between the problem and multiple potential solutions. Furthermore, Half-Causation is unique in that it uses the same philosophical framework for solving technological problems and for exploiting technological opportunities; this is an area of Engineering Design pedagogy that is worth further exploring. Strategically, Half-Causation benefits from targeting patentability. It is therefore recommended to add the Half-Causation tools to engineering curricula, both in terms of idea generation, and intellectual property protection, specifically patents.

REFERENCES

[1] Abolkheir M. If You Wish to Invent Then Follow the Half-Causation Method. *Techné: Research in Philosophy and Technology, 2019, Volume 23, Issue 1, pp 26-50.*
[2] Abolkheir M. How Half-Causation can enlighten the drafting of patent claims. *Queen Mary Journal of Intellectual Property, 2021, Vol 11, No 4, pp 469-483.*
[3] Popper K. *The Logic of Scientific Discovery*. 1959 (Routledge), pp 31-32.
[4] Pahl G., Beitz W., Feldhasen J. and Grote K. *Engineering Design: A Systematic Approach*. 2007. (Springer), pp 85-86.
[5] Dieter G. E. and Schmidt L. C. *Engineering design*. 2012 (McGraw-Hill), pp 214-241.
[6] Dyson J. *Against The Odds: An Autobiography*. 2001 (Texere), pp 98-129.
[7] Patent No. EP 18197. [Accessed from www.epo.org 3 March 2022].
[8] Patent No. GB 2588495. [Accessed from www.epo.org 3 March 2022].

REFLECTIONS ON ADDRESSING TABOO, SHAME AND SOCIAL STIGMA IN DESIGN PROJECTS

Casper BOKS and June Kyong TRONDSEN
Department of Design, NTNU Norwegian University of Science and Technology

ABSTRACT
Social phenomena which are taboo-prone and in which self-conscious emotions such as shame play a role, appear to be increasingly of interest for students, and it is believed that design can play an important role in developing interventions which can contribute to more social, healthy and sustainable behaviour. Based on recent experiences with supervising master's projects where connotations of shame play an important role, this article summarizes key insights related to choosing topics, choosing and triangulating methods, conducting supervision meetings, as well as general reflections on the role of the (student) designer in such projects.

Keywords: Design, design education, shame

1 INTRODUCTION

The scope of design is continuously evolving. Throughout the past decades focus on producing artifacts for the industry has moved into embracing the non-physical sphere of services, digital interfaces, experiences, as well as public services and systems. The issues designers engage with are growing in complexity and impact; these days phenomena such as lifestyles, politics, norms and values have made it into the design agenda [1, 2]. Along with the expanding scope of design, there is an emerging demand for design education to keep up with this development and better prepare students for the tasks ahead. It is increasingly common that design students take on topics where socio-cultural aspects play a dominant role in the challenges at hand, often beyond what is common in more traditional industrial design projects, and therefore often beyond what both students and their supervisors are accustomed to. Such projects include topics which require students to get a grasp of how social phenomena are intertwined with taboo and shame, and how negatively-valanced self-conscious emotions such as shame play a role in what people think, do, see, hear and feel (but also what they do not (want to) think, do, see, hear and feel) – and it is precisely this second aspect of understanding users which we would like to address in this paper. Examples of such contexts include:

- In a health context: Disability stigma, loneliness, mental illnesses such as anxiety, depression and eating disorders, sexual shame, body and health image, addiction of all kinds, violence, etc.
- In a social context: Gender roles, fake news, social pressure, online shaming, call-out-culture, racism, political preferences, subcultures, unconventional lifestyles, crime, poverty and wealth, etc.
- In an environmental context: Food waste, flight shame, plastic pollution, overconsumption, blame for climate crisis, hedonic shopping and compulsive buying, meat shame, etc.

Such topics not only share a high level of complexity which is strongly affected by norms, culture and politics, but they also challenge students in their ability to deal with the more sensitive sides of society. Whilst design education has equipped students with the tools that enable them to raise good questions, design with empathy, access tacit knowledge, this toolbox becomes less straightforward when dealing with awkwardness, embarrassing questions and dark spots. The issue of equipping students (and supervisors) with appropriate tools for research and reflection has become even more timely since our department has been actively recruiting master's students to write their final master's thesis on shame related topics, in connection to an ongoing PhD project focusing on the role of shame and taboo in design [3]. Thus, this paper is based on our experiences with supervision of these students, and aims to address how design students, together with their supervisors, can be prepared to design for social contexts influenced by stigma, taboo, and moral (or self-conscious) emotions such as shame, embarrassment and guilt.

The paper is structured as follows: section 2 provides a brief overview of the sparsely relevant literature. Next, chapter 3 provides a description of the student projects which form the basis for mapping our experiences and continues with key insights for both students and supervisors derived from them. Chapter 4 concludes the paper.

2 LITERATURE REVIEW

Although not in abundance, literature provides some examples of design projects which have explicitly addressed taboo and shame. One recurrent topic is that of female intimate care; various papers present design-led approaches to engage participants in addressing menstrual taboos or female pelvic fitness [4-7]. Other taboos concerning embarrassment and bodily fluids have also been investigated. Wilde [8] presents a case study in which autoethnographic inquiry (including documenting food and excrements over a longer periods of time) was used to engage participants in workshops dealing with serious gut disease, as well as their family members. The aim was to spur a genuine interest in otherwise taboo-ridden social discourse on 'shit' and the food system, develop new imaginaries, and thereby new practices or positions. This estrangement process provided a more nuanced sense of the participants' willingness to transgress taboo (phrased as 'hang their taboo on the wall for a while'), address vulnerability, and eventually develop alternative relationships with their gut microbiome. Helms [9] also explores bodily excretion and its relevance to our everyday function and well-being, focusing on how interaction design can support to leverage intimate and somatic data to manage urination. Papers like these do reflect on design-led tools and approaches to address taboo-prone topics in transformative and empathic ways. They do however rarely so from a design education perspective, and thereby do not focus on the implications for students and their supervisors when choosing and conducting projects with address such issues. It is in particular this perspective which this paper aims to address.

3 EXPERIMENTING IN MASTER'S LEVEL STUDENT PROJECTS

Both in 2020 and 2021, we were fortunate to be able to recruit in total eight master's students in design who were interested in exploring taboo-related topics where feelings of shame and failure in meeting social expectations would 'obviously' play an important role. Below, a short description of the six projects (some students worked in pairs) is provided as it sets the scene for the rest of this paper.

- Design for sexual wellbeing [10]. After a general mapping of various topics related to sexual wellbeing for different age groups and sexual orientations, this project focused on embarrassment related to expressing the desire for and the usage of personal lubricants, in a romantic setting.
- Safe personal sexual exploration for young male adults [11]. This project explores attitudes concerning male sexuality, questioning the lack of openness and sex-positivity, and highlighting the semantic differences in how openly we talk about and how we talk about male versus female sexuality, attempting to reduce sexual taboos and communicate sex positivity amongst young males.
- "Sending nudes" culture in secondary and high schools [12]. As a response to the increase in victims of nude image sharing online, this project investigates how an educational board game can create a safe arena for teenagers to learn about, discuss and reflect such a sensitive issue.
- Rethinking gender roles in design education [13]. As a critique to the binary gender system and conventional gender roles, and the physical surroundings that explicitly (and implicitly) support this worldview, this project focused on developing workshops and guidelines to make designers aware of explicit (and implicit) gender biases and support designers to design for a more gender fluid society. The results of this project have partly been documented in a conference paper [14].
- Design in the context of economic shame. This project has a focus on anticipated shame and awkwardness connected to several common situations like applying for unemployment benefits and taking up additional loans.
- Rethinking (voluntary) childlessness and the nuclear family. This project explores perceptions on awkwardness related to the need to justify such life choices (in- and outside relationships), in relation to societal perceptions on the female social role and the nuclear family.
- Design for male mental and physical health and wellbeing. As it is not uncommon for men to be reluctant and feel embarrassed to discuss mental and physical health issues with family, friends and even doctors, this project investigates the shame connected to this social phenomenon, with special emphasis on young men.

3.1 Method

Our empirical data for extracting the key insights presented in the next subsection is about 150 hours of supervising the above projects: on average three hours per month (2-3 meetings), for five months (in four of the seven projects for nine months as the projects included both a pre-master's thesis (22,5 ECTS) and master's thesis (30 ECTS). In the majority of supervision meetings, both authors were present, notes were taken and frequently discussed, both between the supervisors and with the students. The relevant literature which is partly presented in section 2 has provided us with some reference material to compare our own experiences with, but the main reference material is comparison with 20 years of experience with supervising a wide range of 'regular' design master's projects. Additionally, the first full draft version of this paper was shared with all involved students, with an invitation to comment and add to it, which provided input which helped to further nuance the paper.

3.2 Key insights

Based on the content of the projects described above, and our experiences with supervising them, we distinguish between the following project phases to present our insights. When guiding students in choosing their topic, during supervision meetings once the project is in progress, related to the choice of methods during the project, and after the project is concluded.

3.2.1 When guiding students in choosing their topic

Although the student projects were spurred on by a project proposal focusing on the intersection between design and shame, few of the students started off their projects with a single clear direction. Instead, the first stage of the project would concentrate on discussing multiple, and sometimes very different directions for the project, in terms of type of shame or type of design intervention. Some students were more eager to design solutions to improve a current situation, some were more interested in a norm critical approach, while others again wanted to focus on improving the designer's own toolkit. Independent of these differences in topic, user groups and medium, what distinguishes these "shame projects" from more "traditional" design projects - which are often initiated by a given problem and/or defined by a company or organization - is that they were personally motivated, with challenges identified by the students themselves. This could be thoughts about (or frustration with) unfairness or injustice related to observations of everyday phenomena they found hard to make sense of topics they found intriguing (or irritating), social areas they did not have the chance to engage with due to taboo, and gaps in their own toolkit to handle topics of a sensitive nature and/or form a norm-critical perspective.

3.2.2 During supervision meetings once the project is in progress

Supervision meetings tend to include discussions on the topic in a very broad sense. As opposed to more conventional industrial design projects such as appliance design, themes addressed in the aforementioned projects are complex and not well-articulated in scientific or popular media. Finding the relationship between shame and the topic at hand requires broad exploration of historical contingency, social and cultural context. We found that such an initial broad divergence in the topic at the outset of the project was both inspiring and mind opening, but also overwhelming for some students. As supervisors it is important to balance a holistic and broad understanding on one side, and keep projects mentally manageable for students, as well as feasible to complete in one semester. This is not easy, as a practical consequence of this tendency (or need) to diverge is that it motivates students and supervisors to brainstorm about various relevant perspectives and, experiences, almost without a filter; each new thought may be novel, valuable, and worth articulating. Similar to an abductive approach, it is not upfront clear which directions in a conversation may be worthwhile to pursue or lead to interesting conclusions; each digression is potentially interesting. Examples of such conversational digressions are questions like 'are there boundaries to how much shame one can have,' 'would it be scientifically and ethically correct to interview people who had a few drinks to make it easier to talk', 'is removal of shame inherently the same as steering away from it'. We found that it is essential to distinguish between discussing taboo-prone topics, where taboo and shame is inherently connected to the topic (like sexuality or racial discrimination), and topics where taboo and shame play important roles, but without it being taboo or shameful to discuss the topic itself (like addictions or mental health). In the first case, there is a much greater need to establish a sense of trust, to find a common language and level of openness that feels comfortable for both student and supervisor. Only then is it possible to address shame as a design factor in the same way as we are used to talk about 'experience,' 'quality' or 'user-friendliness,' to name a few topics that are part of most student design projects. We also observed that our students tend to mature into their own project specific technical language and become able to articulate sensitive parts of their topic in a clear and direct manner, with a choice of wording that sets judgement aside and comes across as neutral and non-offensive to bystanders.

3.2.3 Related to the choice of methods during the project

As indicated above, uncovering and articulating the complexity of social phenomena in the aforementioned projects takes more time than when choosing a conventional topic. Not only during supervision meetings but also in the factual design process, we see value of encouraging students to use more than average time in framing their research topic, rather than blindly starting with context mapping as they are perhaps used to. As expected, we found that in these 'shame projects,' traditional methods of inquiry such as surveys, interviews and focus groups were not necessarily suited for context mapping and for uncovering user needs, wants and perspectives – although these methods were used as well. In addition, we have experimented with, and adapted, a number of tools and methods that were thought to be especially suitable to gain user insights about these taboo-prone topics where shame, embarrassment, awkwardness, peer pressure, stigma and other nuances of shame obviously would play, and indeed played a role. This in an attempt to uncover hidden, personal feelings which would not be shared through traditional methods of inquiry. The methods we used included a graffiti wall, cultural probes including scenario booklets, context safari, bridging concepts, association games and empathy cards. In the second cohort we worked with, students also used early prototypes of tools which we had developed for the specific purpose of designing in shame and taboo-related contexts, including a 'shame-stretching' tool, a meme tool, and an inspiration card deck tool. They expressed that it was exciting and inspirational to use unfamiliar tools and to contribute to develop them.

All research projects, including student projects, need to follow ethical guidelines and data protection regulations. The Norwegian Centre for Research Data, where all student projects need to be reported to, and which verifies that guidelines and regulations are followed, has good procedures for this, and even provides recommendations for how to conduct research which reduces the risk of privacy issues. We find it essential to strictly follow these requirements and seek support from NSD, as well as relevant research ethics committees, given the cautious nature of topics in the projects reviewed.

3.2.4 Related to the use of methods during the project

We encouraged students to depend heavily on literature and experts from disciplines that address relevant social phenomena and shame in particular. But in addition, although using internet as a source of information is often seen as non-scientific and sometimes even discouraged as a source of reliable information for students, we chose to stimulate the use of internet and other popular media in addition to scientific and expert sources, to research how shame and related concepts manifest themselves in popular culture and public discourse. Sources like urbandictionary.com, imgur.com, reddit, blogs, discussion forums and social media posts have proven to be invaluable to capture such manifestations. In particular user generated content such as humorous memes have proven to be extremely useful to capture the essence and nuance of certain complicated social phenomena.

Interview situations

Even though the students were creative in using a variety of designerly methods of inquiry, all of them partly relied on interviews, focus groups and workshops which were dependent on direct contact with respondents. Based on the student's experience, we like to share the following insights:

- Selecting close friends or classmates as participants for interviews and focus groups is usually, for obvious reasons, not encouraged in design projects. However, we have encouraged recruiting this way for the purpose of obtaining general insight in phenomena such as gender, money, sexuality, family structure – which people can most relate to, but which may be easier to discuss in the presence of familiar participants. That said, some student groups also experienced that it is possible to create an atmosphere where even participants who did not know each other before, were comfortable enough to share very personal thoughts and experiences.
- Motivating participants (by humour, social interaction, creativity) to disclose information people might find embarrassing and uncomfortable to share – while still respecting their boundaries.
- Probing to uncover hidden knowledge that many people are unaware of/ things we take for granted – make something implicit and underarticulated more visible and explicit.
- Use language used by respondents themselves (for example 'horny' instead of 'sexually aroused').

- Account for a greater need for anonymity and a safe environment when disclosing information on a sensitive topic. It is important to refrain from sound and video recording when interviewing respondents (unless interviewing experts).
- Though partly obvious, we felt that it was necessary to point out to the students to make sure that their interview behaviour should be free from sharing personal experiences related to the topic, and to take a generally judgement free role as investigator by avoiding sharing opinions which interview subjects could consider as judging or opinionated.
- We became aware that respondents may be or become affected by questions asked during an interview, and that it was therefore important refrain from an inquisitive tone which may make the respondent uncomfortable or even shut down completely. This requires an attentive interviewer who is able to read the respondents' reactions and mediate in a way that limits discomfort.

Method triangulation

Based on experiences with the projects, we found that it is important to:

- triangulate with methods where respondents are guaranteed absolute anonymity, including from the researcher, by allowing for participation without anyone noticing (graffiti wall, or anonymous scenario booklets to be put in locked boxes).
- triangulate with methods which focus on gathering opinions about a theme, rather than digging into respondents' personal experience, and triangulate with methods which allow respondents to reflect on others' behaviour instead of only reflecting on their own.
- triangulate with methods which map culture around a phenomenon, opinions about the phenomenon, and own experiences with the phenomenon.
- avoid obsequious following of established design methodology.
- allow for contextual reinterpretation of terms like 'tacit knowledge,' by understanding that knowledge could be tacit because of shame related issues instead of just unprobed.

3.2.5 Reflection on the student designer's own role

It is important to continuously question one's own role when investigating the phenomenon at hand, questioning one's objectivity, even accepting one's subjectivity – and adapting methods of inquiry accordingly. For example, design students who are avid surfers or bikers would be well accepted as highly suitable for designing innovative concepts for surf boards or bicycle accessories. But students who choose 'shame projects' because of own experiences, should evaluate the suitability of the topic for them, for example by assessing how they may become emotionally affected by it. In none of the projects supervised autoethnography was explicitly used as a method, but students expressed that it cannot be excluded that personal experiences played a role – for better or for worse: it may have enabled a more tangible impression of the phenomenon, but personal experience with the topic or specific feeling may also have coloured collection and analysis of data. Other potentially challenging situations which may occur, and students should be (made) aware of include:

- handling views from respondents about shameful topics which contradict with the student's personal values or moral.
- handling opinions from family, friends and peers who question the suitability or appropriateness of the topic, either in general or for that specific student. Others, influenced by their own norms and values, may say that the chosen topic is not really worth investigating, or that other problems are more important to address. Similarly, handling views that it is not the designer's business to address the problem and that it instead should be taken care of by, for example, psychologists.
- Handling the uncertainty during the project whether the topic will actually lead to a result which is perceived to show the student's ability as designer, both by friends, peers, and, not unimportantly, external examinators of the project.

Such reflections about the suitability of the student-topic match should – in addition to close friends – obviously be done in dialogue with their envisaged supervisor(s), who should themselves evaluate whether they are suitable for supervising the topic, as it may involve emotional moments which may be uncomfortable to handle. We are currently not aware of tools which facilitate such reflections, neither for the student nor the supervisor, at least not in a design education context. When pursuing more of such student projects to inform our research, it will be necessary to learn from for example study programmes in psychology and art, where it is said that many students choose master's thesis topics related to personal experiences. Another valuable recurring discussion theme in supervision meetings was acceptance that the implicit designerly role of moralising actor as well as 'problem solver' may be inappropriate. It is important that students understand the difference, and differentiate between ethics and own personal moral, and acknowledge that while they might communicate certain moral values through their project, taking the observer and/or mediator role may be more appropriate in some cases.

4 CONCLUSIONS

As similar papers do not seem to exist, we found it valuable to share our experiences with working with master's students on shame and taboo-prone topics. This paper summarizes our learnings so far and lists insights related to selecting topics, choosing and triangulating methods, conducting supervision meetings, as well general reflections on the role of the (student) designer in such projects. The general feedback we have gotten from students is very positive, and they appreciate the encouragement and opportunity to take up these topics. Colleagues within and outside our department have expressed similar support, though sometimes combined with surprise, caution or even concerns about pitfalls such taboo-prone topics may impose. This helps us to continuously reflect upon these concerns and thereby better support our students to take on unconventional projects, explore unknown territories and discover untapped potentials – and thereby helping them to achieve their goals. Finally, we would like to acknowledge and thank the students from the NTNU's Department of Design who chose to do their master's projects on the topic of design and shame, and thereby contributed with input for this paper.

REFERENCES

[1] Malpass M. (2019). *Critical design in context: History, theory, and practice*. Bloomsbury Publ.

[2] Margolin V. (2015). Social design: From utopia to the good society. In: Resnick, E.: *The Social Design Reader*, Chapter 3. Bloomsbury Publishing.

[3] Trondsen J. and Boks C. (2022). Design and Shame. In Proceedings of the Design Society: DESIGN Conference , Volume 1 , May 2022, forthcoming.

[4] Almeida T., Comber R., Wood G., Saraf D. and Balaam M. (2016). On looking at the vagina through Labella. Proc. of the 2016 CHI Conf. on Human Factors in Computing Systems (pp. 1810-1821).

[5] Tran B. and Choi L. N. (2018). Menstrual maze: A toy exploring public engagement in menstrual health education. Proc. of the 2018 CHI Conf. on Human Factors in Computing Systems (pp. 1-6).

[6] Diehl J. C. and Salarić P. (2020). How to design for taboos? A design intervention to overcome the taboo of menstruation in India. In E. Duarte, & C. Rosa (Eds.), Proceedings book of UNIDCOM/IADE Conferences (pp. 213-222) http://senses2019.unidcom-iade.pt/

[7] Søndergaard M. L. J. and Hansen L. K. (2016). PeriodShare: A bloody design fiction. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (pp. 1-6).

[8] Wilde D. (2022). Shitty food-based world-making: Recasting human microbiome relationships beyond shame and taboo. *Futures*, *136*, 102853

[9] Helms K. (2019, June). Do you have to pee? A design space for intimate and somatic data. In Proceedings of the 2019 on Designing Interactive Systems Conference (pp. 1209-1222).

[10] Trondsen J. (2015). Hvordan designe for seksuell velvære. NTNU Master Thesis, http://hdl.handle.net/11250/2417114

[11] Carlsen R. N. (2021). Hvordan designe for å unngå seksuell tabu. NTNU Master Thesis https://hdl.handle.net/11250/2983243

[12] Janøy K. (2021). Kort om nudes - Utforskning av hvordan designintervensjoner kan hindre ufrivillig spredning av nakenbilder. NTNU Master Thesis, https://hdl.handle.net/11250/2834798

[13] Lillegård M. H. (2021). Rethinking Gender in Design. NTNU Master Thesis, https://hdl.handle.net/11250/2834797

[14] Lillegård M. H., Trondsen J. K. and Boks C. (2021). Encouraging Reflection on Gender Bias in Design Education. In *DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), Herning, Denmark. 9th-10th September 2021*.

DESIGN AS A TOOL TO REDUCE FOOD WASTE: PRESENTATION OF SALVAGE FOOD IN GROCERY STORES

Maja Wawrzyniak SOLENG
Oslo Metropolitan University, Norway

ABSTRACT
The global issue of food waste affects us all. Measures to reduce food waste have been introduced at various places, but there is still a need for development of new strategies. How grocery stores present their salvage food and the measures taken to sell the products vary. This master project in product design aims to draw connections between the customer experience in grocery stores in relation to salvage food and a reduction in food waste, an angle which is yet to be thoroughly investigated. The results of observations and interviews have been shared and discussed. The findings suggest several measures grocery stores could implement, which may lead to a reduction in food waste. Further studies on the topic in collaboration with grocery stores, customers and designers would be beneficial.

Keywords: Grocery store, food waste, customer experience, design education

1 INTRODUCTION: ISSUES OF FOOD WASTE
Food waste is a global issue. By removing produce from the food chain, resources used for production, such as water, land, energy, and more are wasted. The importance of a circular economy comes to light when seeing how food waste increases global emissions and world hunger [1]. In June 2017, Norwegian authorities and the food industry settled on an agreement to reduce half of the food waste in Norway by 2030 [2]. While grocery stores account for 15% of the Norwegian food waste, households are responsible for 55% [3]. Most of the food related household waste is bought in grocery stores. This gives grocery stores opportunity and power to influence the customers and their behavior pattern. By increasing awareness and building knowledge about the issue, grocery stores could possibly contribute to the reduction of food waste.

2 BACKGROUNDS: REDUCTION OF FOOD WASTE IN GROCERY STORES
In this study, *salvage food* is used to represent grocery store products that have passed their expiration date, are out of assortment, have damaged packaging or are otherwise unfit for sale. Is it possible to salvage these products from being wasted? While Norwegian authorities and the food industry are defining goals and working towards them, there is a lack of research related to how grocery stores can present salvage food to reduce food waste and create awareness. Related existing studies are based on how grocery stores can reduce packaging, plastics and similar waste. The focus area of this study will be how stores choose to display salvage food. By understanding how to influence consumer behavior, grocery stores can use design to reduce food waste. Current research shows that consumers who think food waste is immoral, waste less food [4] and the most common strategy used to reduce food waste in grocery stores is price reduction [5]. Some stores also donate their surplus to charity organizations. Products with reduced prices are displayed differently in various grocery store chains, but we do not know which approach is the most efficient to influence consumer food waste behavior. By combining this knowledge, grocery stores could aim to influence consumers to reach their goals of waste reduction, which leads to the research question; *How can grocery stores improve the salvage food customer journey?*

3 METHODOLOGIES: A QUALITATIVE APPROACH IN RESEARCH DESIGN

3.1 Literature review

The database Web of Science was used as the primary source for literature findings. Keywords such as ‘Food waste behavior’ and ‘Food waste grocery stores’ were used. The article written by Horos and Ruppenthal [5], follows a qualitative approach. The data is of importance to understand the perspective of German grocery store owners, providing valuable knowledge to the research. The article investigates and explores the stores’ strategies, challenges and practices to prevent and reduce food waste.
The article by Misiak, Kruger, Kruger and Sorokowsk [4], is based on both quantitative and qualitative data. It is a psychological study with 562 participants. The study contributes with input to the customer behavior in relation to morality and food waste. It indicates that people judging food waste as unethical due to environmental- and socio-ethical issues, waste less. The findings are interesting as it may imply that increased awareness and knowledge on food waste may lead to changed behavior.
Other studies and research show that values influence behavior, and more so if the value is of significance to the person. As environmental issues become more important, values are affected and thus persons’ behavior. Values can be the root cause of an individual’s goals. If these goals are of importance, attention on actions will increase, which has been explored through a master thesis by Bruchfeld and Lind [8]. The articles were selected due to their different focus area, which has been a contribution to each end of the chosen research question.
The book by Wakinson [6] has been used to broaden the understanding of expectations set by customers and how to use this knowledge to fulfil these expectations to improve the customer journey. Furthermore, the book by Leavy [7] has been used as the main source behind research methods and approaches used throughout this study.

3.2 Methods of study & ethical considerations

To investigate how grocery stores display salvage food, field visits with a naturalistic approach have been conducted. The mentioned approach is unstructured, focusing on observing unplanned behavior in a natural, unaffected environment. Observation is beneficial to understand the customer experience and may give input to how the presentation can improve. In Lillestrøm, a town part of the Oslo metropolitan area, grocery stores of different retail houses were visited in order to uncover variations. The stores were; Coop Obs, Kiwi, Rema1000, and Meny. The customer experience journey was mapped to create an overview of the experience. Interviews were conducted with a narrow pool of only two customers as a test case and experimentation for further study.
Results from the observations were shared with the customers in a qualitative method of an in-depth, open-ended interview, see table 1. Information from customers is essential to understand their thoughts and experiences which is valuable to the research. Questions regarding food waste, salvage food presentations, experiences and expectations in stores were asked. Examples on questions asked are, ‘What are your thoughts and expectations regarding salvage food from grocery stores?*’* and ‘What do you think about the salvage food section in your local grocery store?’. Ethical considerations are of importance when conducting an interview. The interviewees will therefore be anonymised and only relevant information to the research topic has been included [7] as well as generalized information regarding age, gender, income, and children. Medium income is based on the average salary in Norway.

Table 1. The interviewees

Person	Gender	Age	Income	Children
1	Male	20-30	Medium	No children
2	Female	60-70	High	No children under 18

4 FINDINGS

4.1 Understanding the customer

Research shows that customers are affected by the store environment [9]. Layout of quality design in a store is an important factor to consider when creating a pleasant shopping experience. This includes

cleanliness, lighting, and structure in terms of wide aisles, tangibility, well-marked directions and signs. Another element for satisfaction is the experienced value of the bought food, where pricing is the key factor and should in most cases reflect the value. Watkinson presents ten principles vital for positive customer experiences in his book [6]. The principles relevant to this study are experiences which are stress free, indulge the senses, consider emotions, and meet the expectations of the customers. I have mapped measures and goals to find an overview of important aspects of a customer journey through a store, based on the principles of creating a positive customer experience [6], see table 2.
The table shows three phases of the customer experience journey and factors and actions that could influence it. The first point being awareness, which captures how the customers are made aware of salvage food. Second, goals for the customer experience in terms of consideration and deciding to buy the products, and last, how to facilitate satisfaction and loyalty, making sure the customers want to keep buying salvage food. Examples of measures to increase awareness could be to have visible signs, easy access and making the section visually pleasing, for example by keeping it clean and structured. Furthermore, after being aware of the salvage food section, the customer is in the phase of consideration and decision making. It is natural to compare the products' value with the fresh food available. Pricing is an important tool to convince the customer. Other important factors are clear information and to target the identity of the customers. The last phase of the journey is related to loyalty and satisfaction. Considering these as goals, and fulfilling them, increases the probability of customers coming back. As shown in table 2, expectations are one key factor. What the customers expect of the food need to correspond with the actual experience. An example would be that the food should still be edible when buying it. Emotions should also be mentioned, as customers wanting to contribute to less food waste could achieve a sense of satisfaction after making the decision to purchase. Stores could also consider giving the customers the possibility to give feedback post purchase, both before leaving the store or at home for customer clubs registering the purchase digitally. The feedback should be thoroughly followed upon.

Table 2. Three phases of the customer experience journey by Maja W. Soleng

	Awareness	Consideration & decision	Loyalty & satisfaction
Measures & goals	• Ads • Visible signs • Accessibility • Visually pleasing • Indudge senses	• Comparison • Pricing • Planning • Information • Stress free • Identity	• Expectations • Customer service, social aspect • Emotions • Feedback & follow-up

4.2 Expectations and measures to raise awareness

When visiting the mentioned Norwegian grocery stores, their inventory and the construction of the stores were observed. The stores followed a similar pattern giving the customers resembling experiences when stepping inside. The section of vegetables presents itself first, while the cashier is at the end meeting the customers before they leave the store. The way customers interact in stores may not differ much, however, their experiences and planning before grocery shopping will vary. Stores have potential to nudge people to think about salvage food before shopping, through advertisement, coupons, and customer clubs. Using these methods to present salvage food and create awareness about food waste issues was not observed nor experienced throughout this research study in any of the store chains mentioned. When addressing food waste to explore the interviewees' awareness of the topic, both thought of food waste as bad, but for different reasons. Person 1 mentioned energy waste and world hunger while person 2 thought of other environmental issues, but added that she tries to act sustainably, when given the choice. While both had their opinions about food waste, they mainly bought salvage food due to price reduction to save money. While the price is important, several factors could be considered.
When discussing important factors to raise awareness and increase interest to buy salvage food in stores, different measures were mentioned. The interviewees expressed that the salvage section should be easy to find with clear signs. German grocery store owners have shared their thoughts on how to avoid food waste [5]. The store owners emphasized that salvage food placed so that customers know exactly where

to find it, has been successful. The interviewees assessed the same, mentioning that structure, organized food and cleanliness would feel more inviting. Person 1 expressed 'If a grocery store gives the impression of not caring about its salvage food, it increases scepticism towards salvage food', and continues by adding 'I have seen trolleys filled with different products, which makes me not want to look. It is not my job to organize the produce'. On the other hand, person 2 did not mind, but stated that it would be easier if the products were sorted.

4.3 Store's presentation of salvage food

Discussing the phase of consideration and decision making with the interviewees, being given the correct information as well as a high price reduction were mentioned as important. Person 2 pointed out, 'I accept that the food looks less fresh, but I expect the taste to still be good'. Reduction of price seems to be the only direct action influencing the consumers. The most common measures to reduce food waste in Norwegian grocery stores, discovered through observations and stores' online information channels, are reduction in price, food donations, apps as tools to notify expiration dates and similar [10]. An observation is that stores try to reduce food waste but have yet to give attention to how they present salvage food to customers. At Coop Obs, trolleys were used as troughs filled with products, placed around the store. There seems to be a lack of structure, other than similar products sharing the same trolley. Kiwi and Rema1000 had the same solutions, but with only one trolley in the store. This could be related to the size of the stores, as Coop Obs has more products being the largest store visited. Figure 1 is an illustration from Coop Obs. Meny had the section for out of assortment-food and food related to expiration separated. The former was on a shelf by the cashier with a clear sign, while the latter in a corner after vegetables, fruit and refrigerated food. No signs or information about the contents of the shelf were seen, other than a red sticker with the reduced price in percentage points, and the produce had not been organized. Figure 4 shows how Meny presented their food. The local stores used by the interviewees were visited and each had a section for salvage food. The stores used trolleys and a fridge trough. The first interviewee, person 1, had not bought salvage food in his local store and mentioned that he did not believe a section for it existed. He added that he would check the selections each time if he knew about it. Person 2 was aware of the section in her local store and informed that she used it quite often. This enhances the possible lack of a store's regard towards the awareness phase inside the store but could also vary based on where the customers' put their attention in grocery stores.
Discussing loyalty and satisfaction, the interviewees were both specific about their needs and expectations. Trust in regard to the food being edible was the most important aspect. Person 2 communicated this clearly, 'If I end up buying rotten food, I will not take that risk again. Trust is important'. This is an important aspect of the customer journey, where the main responsibility lies with the stores.

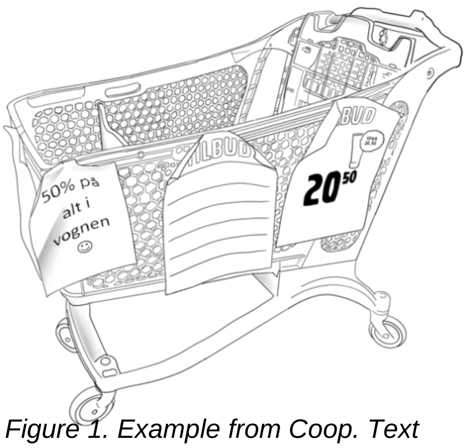


Figure 1. Example from Coop. Text translation: '50% on everything in the trolley'

Figure 2. Example from Meny. Text translation: 'Drink & enjoy

5 DISCUSSIONS: COLLABORATION WITH CUSTOMERS

The findings show the potential grocery stores have to reduce food waste. Society has become more aware of this issue, which affects how people judge food waste behavior. Knowing that such morals cause people to waste less [4], stores could put more focus in influencing persons' awareness. The stores giving customers the opportunity to help reduce food waste would speak to their values and identity, making it easier to use the salvage food section more often. The second interviewee substantiated this by saying that she tries to act sustainably if given the choice, as long as it is beneficial compared to new products. Creating awareness could be achieved through use of ads, visualizations with storytelling, clear information, and more. Additionally, as food waste is seen as a global issue, news, political measures and other external factors are also part of spreading information and raising awareness, which stores could benefit from. Having an inviting and visible section for salvage food could make it easier for the customers to consider and decide to buy. These actions and measures should be implemented thoroughly and preferably in collaboration with customers and designers. As Watkinson has made clear, customers should be in control without feeling pressured [6].

Through design education, designers have been taught to explore and represent the customer’s needs and desires, which would be helpful to the contribution of achieving the goals of reducing food waste. The needs cannot be found without customer input. In this way, designers could help spread valuable information and increase awareness on the topic. Such a collaboration could also be presented as a project in participation with students in design education.

Interviewees expect some benefits when buying salvage food, such as price reduction, which was the main reason mentioned to buy salvage food. Continuing on using price reduction as a tool is crucial as the food still needs to mirror its value and to keep the interest of a wider range of customers. However, there are opportunities to increase the attractiveness of salvage food, in which creative minds of designers could contribute. How stores raise awareness and present themselves in relation to the topic of sustainability to customers could be included both pre and post purchase. The presentation of salvage food in grocery stores should be designed to visually appeal and be easy to detect [9]. The visual aesthetics are of significance since it presents food which is to be bought and eaten and therefore should look appetizing. Making the section easy to detect was brought to attention by the German grocery store owners, as this was important to their customers who used this section regularly [5]. The findings from this qualitative research approach indicate that design could be an important tool to reduce food waste in grocery stores. The small number of interviewees may limit the information available for the research study leaving the findings less diverse and conclusive. However, their voices represent some existing opinions in the society being important for the research.

6 CONCLUSION & FURTHER WORK

To reach the goal of reducing food waste in Norway by half, grocery stores have to take their part of the responsibility. Through a master project in product design education, this study has investigated how grocery stores can improve the salvage food customer journey to ultimately reduce food waste. While measures already are in place, such as food donations and price reduction, the findings revealed areas in which they can improve and explore. Mapping the three phases of the customer journey was helpful to address measures and compare them to the findings from observations and interviews. The measures discovered could be improvement in structure, visibility, trust, and visualization tools to increase awareness, which aligned with the map of the three phases of the customer journey. Feedback options as well as providing clear information and building a stronger identity which speaks to the customers could further contribute. A reduction in food waste is a potential outcome and a contribution to a circular economy, ensuring a food system that ideally does not create waste. Further research on the topic should be conducted. While the representation of different customers is narrow, it may give indications to topics of further study. It would be beneficial to have a quantitative study on customers and their behavior in stores related to the presentation of salvage food. Said study would broaden the understanding of the topic, especially when looking at presentations in relation to increased sales. Comparing the behavior of customers of different age, gender, income and with or without children would also be important, as their expectations and needs may vary. Communication between stores and customers pre and post purchase could be explored with the help from designers. Informing about food waste issues and how customers can contribute directly through the store could increase interest and lead to a change in behaviour. Getting the point of view from grocery store owners in Norway, as well as information on how changes affect the store financially and its employees, would also give valuable input to the research.

REFERENCES

[1] Forbes H., Quested T. and O'Connor C. Food waste index report 2021. In *United Nations Environment Programme*, March 2021. Available: https://www.unep.org/resources/report/unep-food-waste-index-report-2021 [Accessed in 2021, September 26].

[2] Regjeringen. *Avtale om å redusere matsvinn.* Available: https://www.regjeringen.no/no/aktuelt/avtale-om-a-redusere-matsvinn/id2558931/ [Accessed in 2021, September 20] (2017) 26 July.

[3] Callewaert P., Presterud K. and Stensgård E. A. *Matsvinn i Norge - Rapportering av nøkkeltall 2015-2019.* Available: https://www.matvett.no/uploads/documents/OR.51.20-Matsvinn-i-Norge-2015-2019_2021-02-24-111320.pdf [Accessed in 2021, September 14] (2020).

[4] Misiak M., Kruger D., Kruger J. S. and Sorokowski P. Moral judgments of food wasting predict food wasting behavior. In *British Food Journal,* 2020, Vol. 122[11], p. 3547-3565. https://doi.org/10.1108/BFJ-07-2019-0576

[5] Horos K. I. and Ruppenthal T. Avoidance of Food Waste from a Grocery Retail Store Owner's Perspective. In *Sustainability*, January 2021, Vol. 13[2], 550. https://doi.org/10.3390/su13020550

[6] Watkinson M. The ten principles behind great customer experiences. *Pearson Education Limited*, 2013.

[7] Leavy P. Research design. *The Guilford Press*, 2017.

[8] Bruchfeld A. and Lind V. *Service Design to Reduce Household Waste.* Available: https://www.diva-portal.org/smash/get/diva2:1155756/FULLTEXT01.pdf [Accessed in 2021, September 27] (2017).

[9] Boshoff C. and Terblanch S. N. The in-store shopping experience: A comparative study of supermarket and clothing store customers. In *South African Journal of Business Management*, December 2004, Vol. 35[4], p. 1-10. 10.4102/sajbm.v35i4.663.

[10] Spar. Spar skal redusere matsvinn med 70 prosent. Available: https://spar.no/baerekraft/spar-skal-redusere-matsvinn-med-70-prosent [Accessed in 2021, October 11] (2021)

[11] Ilyuk V. Like throwing a piece of me away: How online and in-store grocery purchase channels affect consumers' food waste. In *Journal of Retailing and Consumer Services,* March 2018, Vol. 41, P. 20-30. https://doi.org/10.1016/j.jretconser.2017.11.003

INVERTED CLASSROOM TO ENHANCE ENGAGEMENT AND CRITICAL THINKING

Mithra ZAHEDI, Virginie TESSIER, Sarah TANNIR and Marie-Pier AUBRY-BOYER
School of Design, University of Montreal, Canada

ABSTRACT
The Flipped Classroom or Inverted Classroom Model (ICM) has been gaining increasing attention in recent years. This student-centred pedagogical approach has been practiced in various educational fields, but minimally in design pedagogy. The aim of ICM is to *disrupt* the passive approach of conventional learning. The model seeks to engage students actively in their learning experience and *transform* the classroom setting into a participative, creative and dynamic environment which, in return, can *regenerate* critical and innovative ways of thinking. The paper aims to explore the implementation of ICM within a graduate design course. More precisely, it seeks to understand the implications and influence of ICM on students' learning experience, engagement, and critical thinking. By analysing students' answer to a short online questionnaire, we discuss the challenges and benefits related to the organisational dynamics of an ICM course, some consequences on learning outcomes and teamwork, as well as specifics related to the teaching approach. These will eventually help in finding ways to improve ICM as an innovative pedagogical strategy for future graduate design courses. In the end, the study suggests that an ICM-inspired seminar can not only help foster critical thinking, and class engagement, but also help students to develop collaborative skills. The learning experience shared in this paper is an attempt to establish a framework for future design educational practices, coupling the teaching of theoretical notions with active learning experience - most typical to designers.

Keywords: Inverted classroom model, design pedagogy, engagement, learning experience

1 INTRODUCTION
The Inverted Classroom Model (ICM), also known as Flipped Classroom is a pedagogical innovation to learning and teaching that has been mostly utilised in various disciplines of higher education – mainly including fields such as Science, Technology, Engineering, and Mathematics [1]. While ICM has received praise by many, there seem to be limitations to its application as the new pedagogical standard for learning and teaching. It is also noted that research on learning experiences have been mostly focusing on high school or undergraduate contexts. In that respect, we noticed that ICM has not been widely implemented and studied in design education.

More specifically, in this paper, we propose to explore the implementation of ICM in design education and study its inherent role in instilling reflective thinking in design practice. Ultimately, we aim to contribute to training students in becoming thorough researchers, professionals, and practitioners concurrently. In that sense, this study seeks to answer the following questions: (1) What implications could ICM have for design graduate courses? (2) How does this pedagogical shift affect students learning experience? (3) How can we enhance this approach to better support student success?

The first section of the paper introduces the theoretical groundings of the inverted classroom approach. Then, a few paragraphs will describe how this approach was tentatively applied as part of a graduate-level design seminar. Before presenting the research findings, the data collection process organised around an online questionnaire, is explained. The findings are presented in the fourth section of the paper, along with a discussion that sheds light on ways to improve ICM as a pedagogical tool for design graduate courses. The study concludes with a reflection on the limits of ICM, together with the implication for future use and research.

2 INVERTED CLASSROOM MODEL

Chen et al. [2] present inverted classroom as a form of "blended learning" in which both online and traditional in-person methods are alternatingly used for teaching. According to Green et al., [3], this educational model was first introduced by Colorado high school teachers, Bergmann and Sams. After experimenting with pre-recorded lectures and noticing their underlying benefits on student success, these teachers decided to further implement ICM, and promote it as an educational practice [4]. Similar initiatives have also taken place by other instructors as a way, to ensure the optimisation of student learning *beyond* the classroom setting.

In general, the aim of ICM is to disrupt the conventional and passive learning experience of students that restricts them to the boundaries of the physical classroom setting and places them as mere recipients of information. It relies on their engagement prior to the classroom, as they individually delve into the subject matter at their own pace and liking [5]. Out-of-class learning activities may include readings, narrated presentations, video-recorded lectures [6]; all of which are coupled with learning "incentives" like written assignments, discussions, or pre-class quizzes [7]. This tailored learning is followed by classroom activities where students get to apply what they learn, explore, collaborate with peers, and deliberate with professors. Such an approach builds on active learning in a collaborative and dynamic setting.

Numerous studies have revealed the benefits of the inverted classroom model on students as it increases their motivation [8], attendance [9], performance [10], satisfaction [11], and personal growth [12]. Hence, the approach helps foster the overall learning experience and promises to increase student retention and, most importantly, their success. The next section will introduce in more detail how the ICM approach was put into practice as part of a graduate level applied design course.

2.1 Application of ICM at graduate level

A tentative application of ICM was integrated as part of a first-year graduate seminar. The seminar entitled "Innovative approaches for design" focused on design thinking and innovation. It was coordinated by the first author of this paper at the Faculty of Environmental Design at University of Montreal.

The seminar was composed of guided discussions amongst students, theoretical presentations by the professor, and a guest lecturer. The enrolled students came from different masters' programmes such as "Theories in design", "Design, creation, innovation", and "Urban planning". The class took place during the autumn semester of 2021, 3 hours every week for 10 weeks. The learning objectives of the seminar were: (1) to understand and acknowledge the recent developments related to design research, (2) to develop efficient collaborative mechanisms, (3) to be able to understand and co-construct a complex problem and identify innovative solution paths, (4) to learn about the various design processes and approaches and use them in appropriate contexts, and (5) to mobilise innovative approaches to deal with ill-defined problems.

For 7 weeks, classes followed the ICM structure and asked for some preparation from both students as well as the professor. As a first step, the inverted structure of the course required preparatory work from students before each class. Each week, two journal articles were suggested as readings to the students. The readings treated topics such as design thinking, innovation, ill-structured problems, and design process. Before the beginning of each class, a 200-word summary of each article as well as three questions related to the topic, had to be submitted online. These questions were compiled to acknowledge students' inquiries on the article's subject before some of these questions were randomly distributed among small teams of students. About 45 minutes were allocated for team discussions while the professor went from team to team to interact and stimulate these discussions. Teams were asked to schematise their ideas and present their conclusions to the class. Once this preparation was done in the first part of each seminar, the students were well-prepared and ready to receive a short, and more traditional lecture-style teaching. As students were aware of the content in advance, they were able to discuss, ask questions, or comment on the course material. The last 3 weeks of the seminar's weekly schedule encouraged students to get together to carry out various exercises to apply the knowledge acquired on processes and innovative strategies according to different complex situations.

3 DATA COLLECTION

The data collection organised as part of this research is based on a qualitative approach. A short questionnaire aiming to get a sense of students' learning experience of the studied ICM design graduate seminar was introduced. The questionnaire was sent out to students by email via Google Forms a few weeks after the end of the semester and was administered in French. It was composed of 5 open-ended questions pertaining to the students' level of engagement, the challenges they faced, and the development of their critical thinking (questions are translated and presented in the next section). In total, 9 students out of 19 answered the questionnaire anonymously.

4 DATA ANALYSIS

This section will present the distillation of the research results according to the five questions of the questionnaire. These serve as a synthesis of the student's appreciation of the seminar and point to both positive and negative aspects of their learning experience. Before sharing this synthesis, the following Figure 1 identifies the variety of terms used by the respondents in the questionnaires (in alphabetic order) to describe their experience of the seminar.

Learning experience	Engagement	Critical thinking	Challenges	Improvement
Autonomy	*Active participation*	*Appropriation*	*Collaboration difficulties*	*Defining concepts from the start*
Beneficial	*Dynamic*	*Autonomy*	*Divergent views*	*Develop a common vision*
Chaotic	*Emotional commitment*	*Brainstorm in groups*	*Diversity of concepts*	*Discussions*
Connected-Different	*Framing of discussions*	*Build your own argument*	*Diversity of members*	*Diversity*
Disorganized	*Improvisation*	*Confrontation*	*Evaluation criteria*	*Explanations of concepts*
Familiar	*Investment*	*Discovery*	*Fast communication*	*Evaluation criteria*
Freedom	*Routine*	*Diversity of opinions*	*Fast pace*	*Frequent and quick returns*
Good	*Speaking*	*Expression*	*Further explanations*	*Global feedback at the start of the course*
Initiative	*Stimulating*	*Flexibility*	*Insecurity*	*Learning objectives*
Interesting	*Time and energy*	*Influence of others*	*Integration*	*Links between theory and the real world*
Memorable	*Time-consuming*	*Judgment*	*Large group*	*Number of people per team*
Personal	*To ask questions*	*Knowledge transfer*	*Listening*	*Quantity of concepts*
Positive	*True interactions*	*Left to himself*	*Multidisciplinary*	*Time allocated to activities*
Proactive		*Put into practice*	*Opinions left out*	
Stimulating		*Redirects*	*The team at the heart of the project*	
		Strong critical thinking	*Time and schedule*	
		The emergence of points of view	*To be in the dark*	
		Theory enrichment	*Understanding of texts*	
			Work habits	

Figure 1. Overview of the vocabulary used by the respondents

Q1. How did you find this learning experience?
Six respondents out of 9 were in favour of this learning approach. In fact, their appreciation of this learning experience was expressed using words such as "autonomy", "liberty", "initiative", and "self-organisation". One participant highlighted how the approach helped in adopting a "proactive mindset instead of a reactive mindset". Yet, four respondents out of nine mentioned that they felt rushed in learning the class material and did not have enough time to participate actively to class discussions on theoretical notions.

Q2. Compared to a standard lecture teaching formula, did the seminar's approach contribute to create a different level of engagement on your part?
All respondents found that this learning approach promoted their engagement in class. The students mentioned that the seminar's approach encouraged them to get prepared and actively participate in class activities. It also contributed to create a "dynamic", "collaborative", "stimulating", and "engaging" learning environment. One student highlighted that "the improvised aspect [of the seminar] was extremely engaging on an emotional level, compared to a standard theoretical seminar."

Q3. Did you find that this learning experience favoured the development of critical thinking?
Seven respondents out of nine strongly expressed that the seminar supported the development of their critical thinking skills. Through their answers, we believe that the theoretical component of the seminar also played a role in developing these high-level skills. However, three respondents also noted that the theoretical concepts discussed in class could have been implemented more proactively as part of hands-on activities to better support their comprehension of the theory and its impact on design activities. The dichotomy between theory and practice will be discussed in more detail in the discussion of this article.

Q4. Did you encounter any challenges or difficulties over the weeks? Which ones? How could these challenges or difficulties be avoided?
Four of the respondents mentioned difficulties regarding their work in class. In fact, two of them found that the discussions within teams of five to six were difficult as they did not favour the convergence of

ideas and opinions. On the other hand, two other students mentioned that they experienced challenges regarding their comprehension of the proposed readings – especially when the papers presented complex theoretical notions that were new to them. Moreover, the time factor was a recurrent topic in the answers of the respondents. Students felt like they always needed "more time" to have additional discussions, explanations on theoretical notions or models, and practical tools or approaches.

Q5. If this learning approach was to be repeated in the future, do you have any suggestions for improving its design or your learning?

A suggestion common to all respondents was related to time allocation. They wanted to have more time for team discussions with the participation of the professor, allowing them to address questions and deeper understanding of the concepts presented in each article. One wrote "structure discussion periods with the supervision of the professor". The other time-related suggestion was to allow periods, each week, for applying the theoretical learnings into practice. We grouped other comments into two categories: one is related to course content and the other related to class organisation and dynamics. Figure 2, presented in the next section illustrates these findings. The synthesis of the questionnaire's answers leads us to note that the students appreciated globally their inverted classroom experience, but that specific improvements could enhance the impact on learning. The next section will discuss a few recommendations and their potential impact on the seminar's dynamics.

5 DISCUSSIONS

The seminar was implemented for the first time as part of a new curriculum for a master's programme. To improve the seminar for future implementations, as identified in the answers of the respondents, we will need to target both content and class organisation (Figure 2). Some of these recommendations are discussed in the present section, and target: the organisational dynamics of the seminar, difficulties relating to understanding key concepts, team management issues, and the division between theoretical concepts and practical applications.

Course content	Class organisation and dynamics
Clarify the evaluation criteria and learning objectives *Elaborate on the link between theory and practice* *Explain the concepts to the entirety of the class instead of to certain groups* *Limit the number of concepts/theoretical notions in the course*	**Student-teacher dynamic** *Allocate more time for frequent feedback* *Allow more time for the practical/concrete application of theoretical notions* *Allow more time for in-class activities (explanations and discussions on concepts with the teacher)* **Groups dynamic** *Diversify the members of the group* *Limit the number of people per group*

Figure 2. Two shortlists of recommendations (in relation to question 5 of the questionnaire)

(1) Organisational dynamics of the seminar. Working on the basis of action-research, the seminar was planned broadly at the start of the semester and was adjusted according to class feedback. The action-research process is defined by a four-step cycle: planning, acting, observing, and reflecting [13]. Stringer [14, pp. 8-9] describes action-research with a "basic routine" composed of three interrelated actions: look, think, and act – which "should be read as a continually recycling set of activities".

As such actions were being guided by the professor, some students felt that the course was *disorganised.* This was a reaction to the adaptation of course content which was adjusted throughout the semester in response to student reactions. In that sense, action-research asks for an ease with improvisation, managing unexpected events, and rapid responses to questions and time management issues. Students are often much more comfortable with detailed and structured activity instructions and evaluation grids, which offer clear guidelines to perform according to a course requirement. Still, the overall students' appreciation ranged from a positive perspective, defined by individual autonomy, to a negative perspective, characterised by an impression of a lack of organisation.

(2) Difficulties understanding key concepts. These difficulties could be explained by the fact that (a) most students were French educated, and English was their second language, and (b) the background education of students were professional studies with no or very little experience in reading scientific articles. The course content is aimed at demystifying and offering a theoretical understanding of notions discussed by design researchers (i.e., Cross, Dorst, Schön, Valkenburg, Hobday, et al., Lorenz, von Stamm, and Kvan). The following notions were elaborated on: "*design thinking*", "*design processes*",

"*innovation*", "*wicked problems*", "*interdisciplinary collaboration*", "*co-reflexive practice*", "*framing and reframing*", "*problem setting*", "*problem finding*" and "*critical thinking*". As these notions are complex, connected to each other, and can have many angles and interpretations, students had to, not only achieve a broad understanding of these notions but also understand the relationship between them and their implication in design practice. One student suggested to develop, with her team, a lexicon of definitions of important words. This request shows that students can be uncomfortable with less clear, unstable, and multifaceted definitions.
(3) Team management issues. Singh et al. [15] note that familiarity of teammates does contribute positively to facilitate team collaboration as teammates are more aware of each other's patterns, forces, and expertise. Within this case, team management issues seem to be related to the unfamiliarity of teammates as students came from different backgrounds, fields of study, and countries. These differences may have contributed to the need for more team support.
(4) Theoretical concepts and practical applications. A last general observation as a result of our analysis regards the division between the comprehension of theoretical notions and their application as part of class activities. In educational research, knowledge can be distributed across five types: scientific, applied, strategic, praxis, and practical knowledge [16]. The seminar played on varieties of these types. First, scientific lectures were used to guide discussions and class interactions. Second, applied and practical knowledge was solicited through class activities, which also asked for strategic thinking through critical thinking. Although both theoretical and practical applications asked students to be proactive, it might also be a cause of stress as students had to navigate between a plurality of knowledge types.

6 CONCLUSIONS

The overall student perceptions of the "Innovative approaches for design" seminar were mainly positive. This proves the benefits of the ICM approach, compared to other traditional learning methods. As this study revealed, this innovative approach not only helped in promoting student engagement and participation but also improved their critical thinking. Through student questionnaires, we were able to identify some of the gaps that could enhance this pedagogical approach for future graduate design seminars. These include giving more prominence to understanding complex notions, managing teamwork, applying theoretical notions, and clarifying seminar structure and organization; all of which could help in better supporting student success. Theoretical class discussions and practical group activities allowed for the development of students' collaborative skills through informal confrontations which encouraged to negotiate their way toward a common understanding and reaching consensus [17]. Future research may benefit from looking at how ICM could be used as a tool to promote cross-collaboration between graduate design students.
As an educator, the first author of the paper looked at this opportunity through the lenses of action-research, as explained earlier. She approached the planning and the implication of the course, on the one hand, based on her pedagogical knowledge and experience, and on the other hand, from her practice as educator and a designer. Elements of uncertainty and uniqueness, as explained by Schön [18] were present during the sessions and had to be dealt with. Uncertainty of the situation was about problems that could not be predicted (i.e., activities that took more time than planned, class questions that broaden the discussions). The situation of uniqueness (i.e., teams that were not functional) were presenting themselves and she needed to find ways to work with them as she couldn't apply any rules or procedures to manage them. We believe that by explaining and reflecting on these situations, with students, these complex and unique situations can be transformed into experiences that are useful and enriching. The ICM created the space for reflection on "knowing-in-action" [18] and the opportunity to learn for future situations.

ACKNOWLEDGEMENT

Many thanks to our students, without which this work would not have been possible. Direct citations from respondents in the text are free translations from French by the authors. The research project described here has been supported by the Social Sciences and Humanities Research Council of Canada under Grant number 430-2019-01110.

REFERENCES

[1] O'Flaherty J. and Phillips C. (2015). The use of flipped classrooms in higher education: A

scoping review. *The Internet and Higher Education*, *25*, 85-95. https://doi.org/10.1016/j.iheduc.2015.02.002
[2] Chen Y., Wang Y., Kinshuk & Chen N.-S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education*, *79*, 16-27. https://doi.org/10.1016/j.compedu.2014.07.004
[3] Santos Green L., Banas J. R., Perkins R. A. and Springer International Publishing. (2018). *The Flipped College Classroom Conceptualized and Re-Conceptualized.*
[4] Bergmann J. and Sams A. (2012). *Flip your classroom: Reach every student in every class every day*. International Society for Technology in Education.
[5] Goedhart N. S., Blignaut-van Westrhenen N., Moser C. and Zweekhorst M. B. M. (2019). The flipped classroom: Supporting a diverse group of students in their learning. *Learning Environments Research*, *22*(2), 297-310. https://doi.org/10.1007/s10984-019-09281-2
[6] Peterson D. (2015). The Flipped Classroom Improves Student Achievement and Course Satisfaction in a Statistics Course: A Quasi-Experimental Study. *Teaching of Psychology*, *43*. https://doi.org/10.1177/0098628315620063
[7] Mcnally B., Chipperfield J., Dorsett P., Del Fabbro L., Frommolt V., Goetz S., Lewohl J., Molineux M., Pearson A., Reddan G., Roiko A. and Rung A. (2017). Flipped classroom experiences: Student preferences and flip strategy in a higher education context. *Higher Education*, *73*. https://doi.org/10.1007/s10734-016-0014-z
[8] Altemueller L. and Lindquist C. (2017). Flipped classroom instruction for inclusive learning. *British Journal of Special Education*, *44*(3), 341-358. https://doi.org/10.1111/1467-8578.12177
[9] Castedo R., López L. M., Chiquito M., Navarro J., Cabrera J. D. and Ortega M. F. (2019). Flipped classroom-comparative case study in engineering higher education. *Computer Applications in Engineering Education*, *27*, 206-216.
[10] Tune J., Sturek M. and Basile D. (2013). Flipped classroom model improves graduate student performance in cardiovascular, respiratory, and renal physiology. *Advances in physiology education*, *37*, 316-320. https://doi.org/10.1152/advan.00091.2013
[11] Vanka A., Vanka S. and Wali O. (2019). Flipped classroom in dental education: A scoping review. *European journal of dental education: official journal of the Association for Dental Education in Europe*.
[12] Lee M. (2018). Flipped classroom as an alternative future class model?: Implications of South Korea s social experiment. *Educational Technology Research and Development*, *66*, 837-857.
[13] Kemmis S., McTaggart R. and Nixon R. (2014). *The action research planner*: Doing critical participatory action research.
[14] Stringer E. T. (2007). *Action research* (3rd ed). Sage Publications.
[15] Singh H., Becattini N., Cascini G. and Škec S. (2021). How familiarity impacts influence in collaborative teams? *Proceedings of the Design Society*, *1*, 1735-1744. Cambridge Core. https://doi.org/10.1017/pds.2021.435
[16] Van der Maren J.-M. (2004). *Méthodes de recherche pour l'éducation.* (2nd ed.). De Boeck.
[17] Authors, 2017.
[18] Schön D. A. (1983). *The Reflective Practitioner: How Professionals Think in Action.* Basic Books.

DESIGNING FOR PERSONAL-HAPPINESS: AN EMPIRICAL CASE STUDY

Aija FREIMANE
School of Art and Design, TU Dublin, Ireland

ABSTRACT
'Put on your own oxygen mask first before assisting others' the flight attendant reminds passengers just before take-off on a flight. When serving others, designers tend to feel overwhelmed, stressed and often without support. An overload of work, external emergencies and conditional situations may cause physical and mental health problems, such as anxiety, panic, or imposter syndrome. Before serving businesses and society, designers should learn to help themselves.
To equip young designers for professional life under uncertain, time-bound, and specific external conditions and to practice mindfulness and happiness in designers' everyday life. An assignment and methodology for designing a solution for long-lasting personal happiness was created in 2015. A subjective theory of value, happiness, and personal satisfaction analysis in line with user experience methods were combined and applied to reveal an empirical study of personal happiness memorabilia, and values, experiences, identifying the potential for design solutions sustaining self-happiness. Identified solutions were prototyped, tested, and examined to reflect a paradigm of personal happiness and contentment.
Master's design students reflected that the design brief of designing for personal long-lasting happiness was the most confusing assignment during their study years but at the same time it was the most meaningful. It allowed them to understand the pros and cons of personal happiness as human beings and professionals. This empirical case study analysis reveals that more than 70% of designed solutions indicate professional procrastination and anxiety. Individually designed time management solutions help to address personal happiness and satisfaction as an everyday routine. Designing for personal happiness is the first assignment that young designers reflected on their own emotional needs. It helped to equip students to be agents of their own self regeneration.

Keywords: Design for personal happiness, design for mindfulness

1 INTRODUCTION
Design is a method of identifying a real need and provides solutions that results in contentment. Happy and satisfied societies and customers should be the purpose of design actions and their end results [1]. In the material world our sense of happiness and satisfaction is the result of a feeling or experience created by positive emotions and memories when products and services and systems are used in line with a social interaction. Happiness is all that matters at the end and a pleasure-purpose principle leads towards happiness [2].
Design among other creative activities is acknowledged as the key value to individual and collective wellbeing [3]. By not thinking of themselves, may lead designers to be overwhelmed, stressed, and often without external support. To create products and services that create a better society and world, designers should empirically understand the concept of happiness and wellbeing by addressing in themselves first. Happiness as a relative concept for every individual is different. It is difficult to express any satisfaction as happiness being a continuous process. To measure happiness as satisfaction and wellbeing, a 'good' or 'bad' measure is used, expressed on a scale of 'very bad' to 'very good'[4]. Assessing life satisfaction on this scale does not include the meaning and significance of human life, nor the connection with the people we love, nor emotional intelligence.
'Any kind of reflexion on the development progress and transformative chances of today's societies must start with empirically proven values and attitudes' [5] rather than by stating business objectives. An individual's happiness or satisfaction does not arise as an external stimulus but rather as purposefully favoured experience and a sense of interpretation. Subjective well-being is closely linked to personal

and social well-being, hence individual reflection of self-emotional intelligence and memorabilia as happiness. Happiness can be expressed as joy, satisfaction with life, positive emotions, meaning of life and overall feeling of contentment [6] that according to Seligman is well-being [7] and is also linked with genetics, relationships with family, belonging, social security and appropriate health care [8]. ‘It is not easy to practice love, friendship, generosity; understanding, or solidarity within a system whose rules, goals, and information streams are geared for lesser human qualities’[9]. To design for happy a society, designers had never been asked to design for themselves, to understand their own experiences and to create a solution that would help themselves to be happier. Some research indicates that one can learn about appropriate behaviour by observing and experiencing situations [10] and to improve our lives, we need to improve our quality of experiences [11].

People’s cognitive and affective evaluations of their lives and overall emotional wellbeing are central to our quality of life as individuals [12], where cognitive appraisal describes how we consider our overall life satisfaction and our satisfaction with family life, career, but affective appraisal concerns our emotional experience [13]. The optimal experience when people spend their time on activities that give them the most satisfaction and when nothing else is as important, created the concept of flow as the basis of happiness, satisfaction and true motivation, collective resilience, and rituals [14]. Emotions’ may shape actions and thoughts and are conscious in certain circumstances. Understanding self-emotional intelligence is key to designing personal long-lasting happiness. Emotional intelligence is defined as an ability which focuses on the perception and expression of emotion accurately and adaptively; along with the ability to understand emotional knowledge, use feelings to facilitate thought, and to regulate emotions, in not only oneself, but also others [15]. Self-emotional intelligence has been linked to various positive outcomes such as leadership, moderating workplace stress, positive work attitudes, team cohesiveness, performance, and work outcomes [16]. To express emotions an object is bound with personal moral and ethical values [17]. Things remind people who they belong to and reveal their personality and symbolic common ties between people [18].

I was wondering why, in design education assignments and design briefs were not questioning empirical and personal wellbeing before training students to solve problems for others or addressing challenges and external complexities. The paper analysis is an assignment to create a solution for long-lasting personal happiness as critical analysis of happiness/satisfaction, value, mindfulness theories in personal life given to master’s students of Design Faculty from 2016-2020.

2 METHODOLOGY AND METHODS: DESIGNING FOR PERSONAL HAPPINESS

To equip young designers for professional life under uncertain, time-bound, and specific external conditions and to practice mindfulness and happiness in designers’ everyday life, I created an assignment and methodology to design a solution for long-lasting personal happiness.

A subjective theory of value, happiness, and personal satisfaction analysis in line with user experience methods were combined and applied to reveal an empirical study of personal happiness memorabilia, and values, experiences, identifying the potential for design solutions sustaining self-happiness. Designers by analysing and designing for themselves individually and anonymously, reflected and tested solutions that help them recognise happiness in everyday life, thus better function as individuals as well as professional teammates. Designing for personal happiness reveals hedonic goodness and allows empirically to establish an instrumental and technical virtues.

Measures to assess happiness and emotional intelligence involved interpretation of specific compelling forces to which people are exposed in their empirically observable life’s, namely what happens when the ‘subject’, a solitary individual, thinks, perceives, and performs [19]. Subjective well-being is strongly influenced by expectations, personality, circumstances, aspirations, and interpersonal comparisons [20]. As there is no single definition of well-being, I left it to the respondents (design students themselves) to decide what the state of satisfaction and well-being would be for each of them thus focussing on subjective well-being as people’s evaluation of their personal life [21]. Self-emotional appraisal tied to others’ emotional appraisal and relationship to things, brought subjective outcomes as design solutions for long-lasting personal happiness.

2.1 Methodology and methods

The triple design process [22] was applied to design for long-lasting personal happiness. In define phase an empirical study of personal values, happiness memorabilia and ‘pain’ points as experiences were identified by applying combined user experience methods such as empathy, user journey and service blueprint maps (Figure 1). Chosen methodology corresponds to the process of allocation one's attention and as consideration how can you make and facilitate better decisions about what to pay attention to, and in what ways. It reflects inputs as various stimuli, the production process as allocation of attention, and outputs as happiness [23]. Methodology and methods urged to apply empathy and experience analysis to themselves and perceive oneself as 'the other' person. Understanding personal values and needs students acknowledged significance of emotional intelligence. As no one ever before had asked of students as young designers to reflect personal values, emotions, happy and not so happy moments, the assignment, its methods and methodology initially was perceived as confusing.

My experience back-casting map

Call back happy feeling (moment) / unhappy feeling (moment)					
What happened before?				What happened at that moment?	What happened after?
	What was I thinking, feeling, doing? What were touchpoints?				
I was expecting something?					
What was I missing?					
Was I wasting too much time?					
What were my priorities?					
What were the biggest pain points?					
What was happiness evoker?					
What should I do to minimize the pain points?					

Figure 1. Template worksheets of design for personal happiness assignment, Aija Freimane, 2018

Happy and unhappy experiences were defined in a back-casting method, calling back the moment as memorabilia, identifying an action, emotions, expectations, touchpoints, thinking, feeling and the time before and after the happy/unhappy moments. Maps helped to identify a goal of the action, experienced emotional journey and reflect self-emotional intelligence. Positive experience in line with pain points or any negative experience were identified as cause and effects of taken activities, social communication, and pinpointed possible interactions to improve personal experience.

Empathy-experience maps (Figure 2) helped to define and to understand multiple pathways and complexities of personal experiences, to empathise, uncover and prioritize values as causes for experiences, wants, needs, thoughts as causes of personal actions, attitudes, and behaviour.

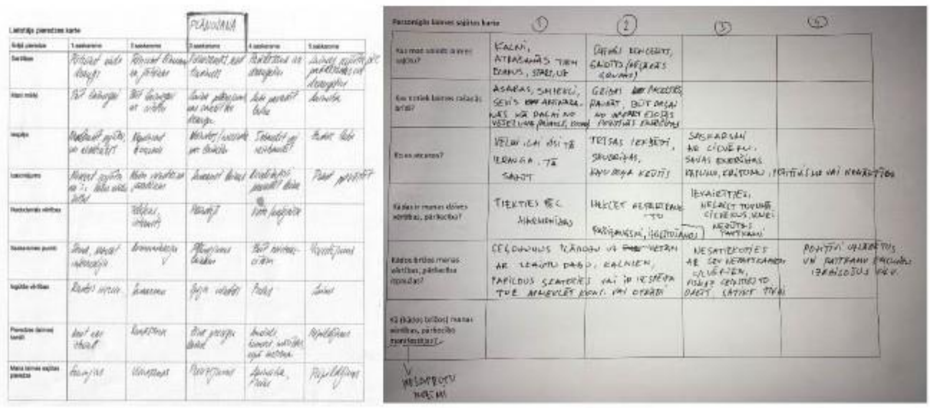


Figure 2. Identified experiences to design for personal happiness, Anonymous students, 2016-2020

Chosen methodology helped to recognize visually activities such as a storytelling experiences and emotions of the journey behind every day professional and personal routine. As a result of personal life satisfaction/happiness analysis students acknowledged personal positive and negative experiences. Further on young designers identified touchpoints and possible interventions for solutions towards long-lasting personal happiness. Following identified high-end experiences, activities and touchpoints that resulted in contentment or personal happiness memorabilia were prototyped and tested to minimize traits by sad and unhappy emotions. Consciousness as mindful actions and touchpoints with material objects were identified and created as memorabilia.

2.2 Designing for personal happiness. Case study analysis

Samples that are portrayed in this paper reflect designed solutions for long-lasting personal happiness in a master's degree module 'Design for sustainability and society' later renamed as 'Designed mindfulness' over a period of five years. The paper reveals that more than 70% of designed solutions indicated a need for individual time management that helped to address meaningful relationships with self and others, and to cope with professional procrastination and anxiety.

Analysis of various situations where people, things and services were involved, respondents acknowledged that to feel and to experience happiness it is important to achieve professional and personal goals. However, in order to achieve goals, to have time for self, time management and structure as routine is important. Respondents also noticed that happiness is when moments and time is shared with loved one. It is very important to write goals and tasks every day and to see them being achieved. Respondents revealed that by notifying emotions linked with activities, particularly hedonic ones, helped to understand the critical points and to mind everyday happiness, that goes hand in hand with personal awareness and the process of achieving goals. Respondents acknowledged that time to self or solitude, as time management is important. Ignorance of self-needs as physical and mental body can deprive the opportunity to experience happiness. An established daily routine with visible tasks, goals, able to visualize them being performed, capture emotions, and to plan time for self, bring respondents to experience long-lasting personal happiness. Personally designed tables are visual reminders (Figure 3) and demonstrates that we as humans are individuals and there are multi-visual perceptions. Students agreed that it is important to understand self in order to find the individual pattern for sustaining long-lasting personal happiness. It was acknowledged that it takes time to change behaviour and habit.

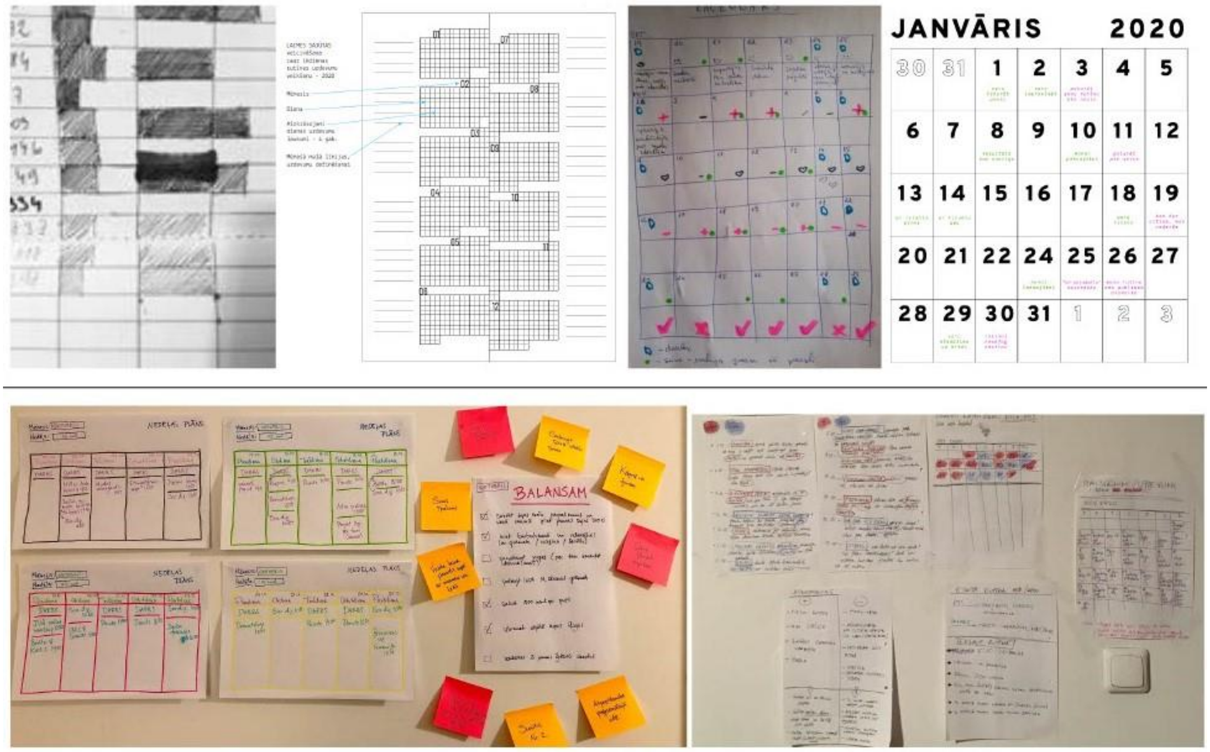


Figure 3. Tested and designed solutions for personal happiness (time management), Anonymous students, 2016-2020

It is possible to categorize prototyped and tested timetables over five years that features daily, weekly monthly job priorities, challenges, sharing and gratitude, personal time, and rest, as well as emotions and experiences.

For about 20% of respondents as a source of their personal long-lasting happiness named family and friends. To sustain long-lasting happiness respondents questioned - what are the aspects that trigger happiness? As a key source for these cases a presence on dedicated time or being present in time was defined. It has become even more topical as in the last years we have been working from home, and even on weekends. The boundaries between work, home and personal life have become blurred. There is no clear line between office and home business, ‘we don’t clock off when we are off the clock’. The tool to witness personal happiness acts as a reminder to stay focused, to recall personal values and to remind oneself of a slow life in every moment. A wristwatch with no time indicators, but with a second tick, is a symbol that arose from feeling happiness in close talks and activities with loved ones. Being kind and saying something good in our daily lives to the people around cheers not only their emotional state, but also self-happiness. To prototype design mindfulness initially smartphone as reminders were used, but later developed to wristwatches that reminds of personal happiness reminders (Figure 4).

Figure 4. Tested and designed solutions for personal happiness (relationship), Anonymous students, 2016-2020

Attention is the glue that holds life together. Our happiness is determined by what we pay attention to. And what we pay attention to determines how we act, and it determines how happy we will be.

In the five years since this assignment has been undertaken, students reflected that it was the most confusing assignment during their studies but at the same time it was the most meaningful. It allowed them to understand pros and cons of personal happiness both as human beings and professionals.

3 CONCLUSIONS

Students revealed that during the assignment process they often found themselves in situations of anger, confusion, embarrassment and questioning: is it necessary to analyse happiness? After constant arguments with themselves and discussions in their minds, they reflected - yes, that analysis was needed. Students revealed that design brief, methodology and methods helped to better understand themselves, they found experiencing moments of happiness more often and consciously, as well as been aware of experience, actions, habits, and behaviours. Students responded that no one ever before asked of them to reflect their personal values, emotions and happiness, nor to link it with professional practice.

Some reflections on the assignments revealed: ‘When I heard the design brief, I thought to myself, this task will not help me. But with each next day working on the assignment, I understood how important it is to me to find myself and to find how to make myself happy.’ The other student: ‘Explored methodology and methods helped to understand what makes me happy and that big moments of joy in my life are in full of swing. Focusing on the lower points for a better understanding of the self-happiness scale, which helped to understand my strengths and values, and incorporate them into my design solution.’

It is much easier to apply design methods to design service or products as solutions to external problems than to mirror them to self. Designers had to accept that this time they will analyse themselves as users.

This empirical case study analysis reveals that more than 70% of designed solutions indicate professional procrastination and anxiety. Individually designed solutions for long-lasting personal happiness and satisfaction reflected students as young designers own emotional needs and helped to equip students to be agents of self-regeneration when working under uncertain, time-bound, and specific external conditions.
Wellbeing as prosperity has not only an economic - rationally quantitative explanation, but also a more important –personal satisfaction, happiness, and social aspect.

REFERENCES

[1] Freimane A. (2020) *Perceived Design value. The Socio-economic impact of Design.* Rīga: Latvijas Mākslas akadēmija.

[2] Dolan P. (2014). *Happiness by Design. Finding pleasure and purpose in everyday life.* Great Britain: Penguin Books.

[3] The Department of Culture, H. a. (2020). *A National Cultural Policy Framework to 2025. Culture 2025.* Dublin: Government of Ireland.

[4] Van Praag B. and Ferrer-i-Carbonell A. (2008). *Happiness Quantified. A satisfaction calculus Approach.* Oxford: Oxford University Press.

[5] German Advisory Council on Global Change. (2011). *World in Transition. A Social contract for Sustainability. Flagship Report.* Berlin: WBGU. p. 67

[6] Diener E. (2009). *Assesing Well-Being, Social indicators reserach series vol 39.* London: Springer.

[7] Seligman M. (2011). *Flourish.* London: Nicholas Brealey Publishing.

[8] Common M. and Stagl S. (2005). *Ecological Economics.* Cambridge: Cambridge University Press.

[9] Meadows D., Randers J. and Meadows D. (2010). *Limits to Growth. The 30-years update.* Oxon: Earthscan. p. 282

[10] Phillion J. (2002). Narrative multiculturalism. *Journal of Curriculum Studies 34(3),* 265–7

[11] Csikszentmihalyi M. (2002). *Flow. The classic work on how to achieve happiness.* London: Rider.

[12] Skevington S. M. and Böhnke J. R. How is subjective well-being related to quality of life? Do we need two concepts and both measures? Soc Sci Med. 2018 June 206:22-30.

[13] Diener E. (2000). Subjective well-being: The science of happiness and a proposal for a national index. *American Psychologist, 55*(1), 34–43.

[14] Csikszentmihalyi M. (2002). *Flow. The classic work on how to achieve happiness.* London: Rider.

[15] Salovey P., Mayer J. D. and Lopes P. N. (2003). Measuring emotional intelligence as a set of abilities with the Mayer-Salovey-Caruso Emotional Intelligence Test. In S. J. Lopez, & C. R. Snyder, *Positive psychological assessment: A handbook of models and measures* (pp. 251-265). American Psychological Association.

[16] Crowne K. A. (2013). Cultural exposure, emotional intelligence, and cultural intelligence: An exploratory study. *International Journal of Cross Cultural Management (1)*, 5-22.

[17] Jasper J. M. (2003). The Emotions of Protest. In J. Goodwin, & J. M. Jasper, *The Social Movements Reader. Cases and Concepts.* (pp. 153-162). Oxford: Blackwell.

[18] Csikszentmihalyi M. (1993). Why we need things. In S. Lubar, & D. W. Kingery, *History from things: essays on material culture* (pp. 20-29). London: Smithsonian Institution Press.

[19] Elias N. (1978). *what is Sociology?* New York: Columbia University Press

[20] Warr P. (1999). Well-being in the workplace. D. Kahneman, E. Diener and N. Schwarz, *well-being: The Foundations of Hedonic Psychology* (lpp. 392-412). New York: Russell Sage Foundatio

[21] Freimane A. (2020). *Postdoctoral study 'Identification system of design's socioeconomic impact towards transformation to a knowledge-intensive economy in Latvia'.* Riga: Latvijas Makslas akademija. Retrieved from https://www.aijafreimane.com/_files/ugd/ed7c53_09da1ba5702449b2adc3fabfe02a3e21.pdf

[22] Freimane A. (2020). *Postdoctoral study 'Identification system of design's socioeconomic impact towards transformation to a knowledge-intensive economy in Latvia'.* Riga: Latvijas Makslas akademija. Retrieved from https://www.aijafreimane.com/_files/ugd/ed7c53_09da1ba5702449b2adc3fabfe02a3e21.pdf

[23] Dolan P. (2014). *Happiness by Design. Finding pleasure and purpose in everyday life.* Great Britain: Penguin Books.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

EVALUATION OF WORKBOOKS AS AN ACTIVE LEARNING TOOL FOR INDUSTRIAL DESIGN ENGINEERING

Peter TÖRLIND[1] and Åsa WIKBERG-NILSSON[2]
[1]Product Innovation, Luleå University of Technology, Sweden
[2]Design, Luleå University of Technology, Sweden

ABSTRACT
Industrial design engineering combines technical rationality and reflective practice, to support students' reflection on their design process a workbook approach has been developed. The workbook approach guides students to reflect on open-ended design projects through cycles of reflections. A typical workbook consists of both written text, i.e., literature reviews and methods employed, and sketches and photos illustrating the process and its results. The workbook approach is currently implemented in five compulsory and several elective courses at Industrial Design Engineering (IDE). During 2020-22 a project was performed to evaluate the implementation of workbooks and get feedback from both active students, alumni and the faculty. Results show that workbooks support students' self-regulated learning, and the workbook's guided reflection is a valuable tool for reaching higher levels of learning in design. However, it seems that there is a need for a workbook framework to support both teachers and students in how to use the workbooks throughout the programme.

Keywords: Workbooks, active learning, self-regulated learning, industrial design engineering, design thinking

1 INTRODUCTION
This paper focuses on the workbook implementation at the Industrial Design Engineering programme (IDE) at Luleå University of Technology, Sweden. A workbook approach is a tool for supporting active and self-regulated learning, reflection-in- and -on-action, allowing for teachers to guide students into doing certain tasks, and providing clear goals in otherwise rather open-ended design projects. The idea of the workbook approach is for students to employ goal setting and performance evaluation, hence a self-regulated learning strategy. It supports students in embarking on design projects in more informed ways. IDE is unique compared to other engineering educations as it combines both artistic and scientific approaches and practices, it combines technical rationality and reflective practice. Typical design projects address the social, economic, cultural, material and technical dimensions of a situation in iterative design thinking cycles of gaining empathy for user needs, visualising and materialising ideas and concepts and testing with users to inform the process. The workbook approach is a tool to guide such open-ended projects through cycles of reflection in- and on- actions.

1.1 Active and self-regulated learning
In brief, active and self-regulated learning deals with how students learn. One aspect of this is the surface versus the deep-level approach to learning [1]. The surface approach involves more descriptive accounts of action versus the deep-level approach that involves more understanding the basics and applying them in a certain context. Neither of these strategies is individual student constructs. Rather, they depend on other students' and teachers' knowledge and prior experiences forming a certain educational culture [2, 3]. Self-regulated learning involves how teachers interact with students in learning activities and how they impact and organise students' education in different ways [4]. The focus is on providing motivation, formative feedback, clarifying responsibilities, and supporting reflection and self-guidance. Students who apply self-regulated learning strategies actively search for information and try things to master a task or subject. They develop their self-regulated strategies to recognise that their performance is worth the effort [5]. This requires an educational culture that promotes students to take their own initiatives

and actively discuss each other's understandings, ideas, concepts, or other expressions. Part of such culture is teachers' flexibility, to be able to interpret students' initiative even if it wasn't exactly what the teacher had in mind and respond to what the student has thought and acted upon [6]. Then students will see that the investment paid off and are more likely to apply similar strategies in upcoming tasks.

A coached reflection can support the previously mentioned self-regulated learning strategies during learning activities [7]. Historically, Dewey restated the relation between reflective thinking and the educative process [8], drawing on the ideas of renowned thinkers such as Plato, Aristoteles, Confucius, and others. Further building on Dewey's work, Schön coined the concepts of reflection-in- and -on-action some forty years ago [9]. Unstructured reflection involves the kind of thinking that happens when faced with unique and perplexing challenges. This means simultaneous reflection and doing, implying that the student has reached a stage where they can think meaningfully about what is going on. It involves criticising, restructuring and testing understandings and experiences. Such on-the-spot reflections can make a difference to the immediate situation at hand, for example, the student realises something and can change accordingly. Coached reflection-on-action, on the other hand, involves making students re-think or look back at an experience to identify what they learned about it [7, 9]. Teachers can support a learning process in which students use different levels of reflection [10].

This can also be encouraged over an extended period to nurture a culture of reflection to develop active and self-regulated learning strategies. Reflection can be related to formative and summative assessments [11]. A formative assessment providing students with feedback on something before the final examination is more likely to make the students reflect on what they have done and how they might improve it. Such formative feedback can support reflection through questions that aim for deepening or widen students' understanding of a particular situation. Also, self-assessment is described as the evaluation or judgement of the worth of one's performance and identifying strengths and weaknesses to improve learning outcomes [12]. It is recommended that self-assessment involve students creating something that requires higher levels of thinking, disciplined inquiry within a specific discipline, and that the assessment is transparent and that the assignment has opportunities for feedback and revision during the task [13]. Motivation for various kinds of self-assessment is that it increases students' engagement, interest, and attention, and it provides information that is otherwise not easily accessed, for example, such as time and effort spent on task.

1.2 Workbooks and portfolios

Design communities often use portfolios for presenting samples of work performed [14]. Typically, portfolios reflect a designer's best work and present the final design, the artefact, and not the scrubby intertwined process, arguments for why specific methods have been developed and the rationale behind the decisions underlying the design process. The latter can be framed as the 'design thinking', which despite the name unquestionably involves the design methodology involved [15]. Design portfolios are one thing, another one is learning portfolios. For students to develop self-regulated learning strategies, it is vital that they understand what they know and where they need to put their efforts in order to get better [16]. The portfolio methodology aims to engage students in their learning to practice increased self-sufficiency by setting their own goals and value their own goal achievement. The metaphor of a portfolio as "something to carry papers in" also illustrates the learning portfolio as a valuable collection of things (texts, images, videos etc.) that illustrates efforts and achievements. One way of using learning portfolios is the self-evaluation diary, in which students can show and tell what they have done during a day or a week, what went well and what problems or challenges they have faced. The learning portfolio should have a different focus during the education [16].

The workbook approach was developed to provide students with support to develop design thinking and link their experiences and expectations to a future, current and historic design context [17]. It can be seen as a mix between a design portfolio and a learning portfolio. The foundation of the approach is the human instinct of reflecting on experiences, which has been framed as 'learning-by-doing' [18]. Reflection provides better control of the actions, both compared with a blind trial-and-error and to a linear process of predetermined activities that takes place without any thought or consideration [9]. A workbook approach thus guides students to plan and perform their work in such ways that reflection occurs both in the event, e.g., document and describe the work performed, and after the event, e.g., reflect on what you have learned linked to particular themes or literature. There are at least three different levels of reflection initiated by the workbook approach [17]. The first one is instinctive, fast and immediate during a work situation or conversation. This involves the student trying something out, be it a sketch or an idea. The second level involves reconsidering the first ideas linked to different aspects and new insights gained through talking to users, peers, and teachers. The next level of reflection concerns a new reconsideration. Accordingly, higher levels of reflection can occur if implemented as part of an individual's routine design thinking process, possibly leading to the reformulation of previous and formulation of completely new design theories.

2 METHOD

During 2020-22 a project was performed to evaluate lessons learnt from the implementation of workbooks in the different courses in the IDE programme and get feedback from both active students and alumni as well as the faculty that has used the workbooks. During the project, a more common understanding of the workbook was developed among teachers, both from a learning perspective and how to present the workbook approach to the students. The study included workshops with 5th year students, feedback from course evaluations, course reflections, and reflections found in the students' workbooks themselves, further described in upcoming sections.

3 WORKBOOKS AT IDE

The workbook approach at IDE is based on theories of active and self-regulated learning, design thinking, design- and learning portfolios and some principles from the CDIO framework [19], and is currently implemented in several courses, see Table 1. The IDE workbook was implemented 2016 as a pedagogical tool for self-regulated learning and formative and summative assessment, over the years, teachers have developed their own approach to the workbook assignment. A recent exploration identified at least five different styles, ranging from the more traditional design portfolio visualising results through nice imagery and layout to the master thesis report. The IDE workbooks generally consist of written text, i.e., literature reviews and methods employed, as well as sketches, photos, and renderings illustrating the process and its results. Typically, it involves sections that deal with a) *this is me*, a page that describes the student and their experiences and competencies related to the IDE competence profile [20]. The workbook is usually structured after the chosen design process, e.g., b) *learn*, c) *design*, d) *build*, and e) *launch*, all of which have theoretical, methodological, analysis and reflection subsections. The final f) *reflections and learnings* deal with learning outcomes in terms of lessons learnt and individual experiences and challenges to address in upcoming projects.

Table 1. An outline of the different courses and workbook approaches at IDE

COURSE	YEAR	STYLE	APPLICATION	FEEDBACK	ECTS
D0030A Design: process and method	1	Workbook that describes "this is me", process, results and lessons learnt in four design projects.	Individual	Midterm workbook sessions – formative feedback. Summative feedback after final hand-in.	4
D0037A Design: theory and practice	2	Workbook focusing on telling process, results, theory and lessons learnt in one design project.	Individual	Midterm workbook sessions – formative feedback. Summative feedback after final hand-in.	7.5
A0013A Product- and production design.	3	Self-evaluation	Team	Peer feedback from team members.	3.5
D0026A Graphical User Interfaces	3	Workbook, describing process and result of a UI design project.	Individual	Summative feedback after hand-in.	7.5
D7007A Form giving	4	Workbook describing the implementation of the assignments, results and lessons learnt.	Individual	Summative feedback after hand-in.	3
M7016T Creative concept development	4	Video recording telling of learning experience.	Individual	N/A	1.5
D7008A Advanced graphic design and Computer Graphics	4	Design portfolio focusing on storytelling and visualising process and results in one design project.	Individual	Formative feedback before final hand-in.	3
D7017A Interaction design	4	Workbook where the student chooses their area for reflection.	Individual	Summative feedback after hand-in.	2
D7011A Advanced prototyping	4	Storybook focusing on the evolution of a product and the rationale for the decisions.	Team	Eight feedback sessions	2
		Personal Diary, describing, process, results and reflection	Individual	N/A	1
D7017A Product visualisation	5	Design portfolio focused on product renderings, from analogue to digital.	Team	N/A	2
D7006A Advanced Product design	5	Workbook focused on the process, results from each of the four design sprints, and reflection on learnings from each phase linked to literature.	Individual	Supervision every second week, formative feedback sessions at four times during the semester.	7.5
D7014A Master thesis project IDE	5	Master thesis report describing a design project from start to finish, describing each phase, theoretical underpinnings, results and lessons learnt.	Individual	Supervision each week + two formative feedback sessions with peers and other teachers.	30

3.1 Workbooks – bachelor level

The bachelor level design courses that implement the workbook approach, of course, have different content, but a similar focus on providing students with basic knowledge and skills in design thinking methodology, design tools and techniques such as sketching, analogue and digital modelling, colour and form theory, and so forth. The more traditional workbook approach is implemented in 3 courses.

The course content in these courses is generally divided into different modules addressing a single design project that integrates some of the learning objectives. The workbook function as an opportunity for reflection-on-action on the methods and tools and the learning outcomes the result and project gave.

3.2 Workbooks – master's level

In one of the master's level courses (D7011A), students are asked to do a project diary, focusing on describing the process and the individual students' contribution to the team's work. Students should attach illustrations and pictures to illustrate the work performed. A reflection is that some students use the diary approach and are brutally honest in the project diary. In the diary students also summarise the number of hours they do in the course, which should be about 200 h. It is quite interesting to see the reported time student spends in the course 180 h is much less than the perceived amount of time 300+ h (estimation in course evaluation). In D7017A, a portfolio workbook is implemented. The focus is the evolution of the idea/concept in the different phases, from early idea sketches, concepts and final product. The students are asked to reflect on lessons learnt in writing and primarily pictures. They should argue for and motivate their design and visualisation choices, see extract in Figure 1.

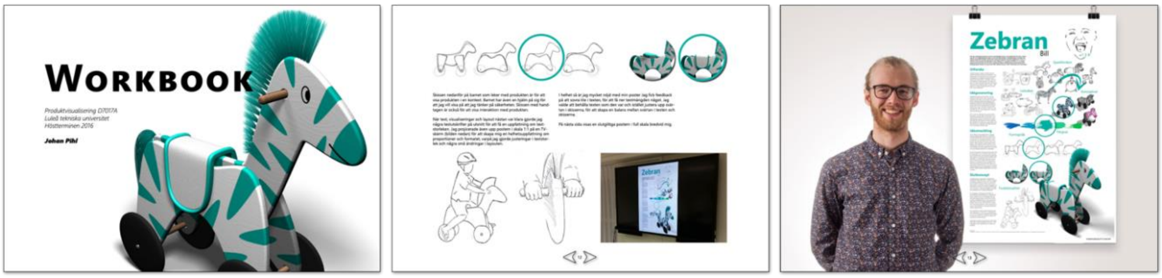


Figure 1. An extract from a D7017A workbook. Workbook: Johan Phil 2017

The more traditional workbook approach is implemented in 3 courses*: Form giving; Interaction design; Advanced Product design*. The focus is on students' describing themselves and what creative habits of mind they want to progress, the process in the different design phases, the outcomes and the results of the various phases and a final reflection, see extracts in Figure 2.

Figure 2. An extract from a D7006A Workbook demonstrating how to make decisions and perform usability evaluation. Workbook: Axel Johansson

Students express that it is easier to reflect in the final master studio course, where they have one large project for the whole semester. The students work in teams but do the workbook on an individual level.

4 RESULTS

Master students were asked to reflect on their experiences of the different workbook approaches in the courses. Now, in their fifth IDE year, they generally appreciated the approach. They were also critical to some of the workbooks. For example, if they experienced that the teachers hadn't given them the right input or tools. One teacher reflection after the workbooks have been used for the past five years in the first bachelor course is that students need to practice reflection: students' accounts of the projects tend to be descriptive rather than reflective at the beginning of the education. A summary of the student's account of the different workbook approaches can be seen in Table 2.

Table 2. An outline of students' reflections on different workbook approaches

COURSE	YEAR	STUDENTS' REFLECTIONS (Authors' translation)
D0030A Design: process and method	1	*"It was so difficult to reflect the first time in the first course. Now, after five years, I have so much to reflect upon."* *"In the first-course year one, it was more about the "how's" rather than the "why's".*
D0037A Design: theory and practice	2	*"In the second workbook, we lacked the theory to describe form, and we neither had the language nor the tools to evaluate and describe it. What was the point of that? It just made me frustrated. The teachers must plan better for this, give us the right tools if they want us to reflect properly".* *"[It was difficult to reflect on a more general level as there were many smaller tasks that were not interconnected"*
D0026A Graphic User Interfaces	3	*"In some of the courses, there is not enough time for reflection, and the assignments are too short. You need time to reflect."*
D7007A Form giving	4	*"When you simply present the end-results, it feels like the whole learning experience is missing. You only show that you can use the tools and the software, not that you actually know something about design."*
M7016T Creative concept development	4	*"Video recordings are good if you're good at talking and can brag about yourself; otherwise, you have to write a script and then what's the point of making a video recording?"*
D7017A Interaction design	4	*"In some of the courses, we can choose what to reflect upon. Then you cherry-pick some parts that you know you are strong at, not the things you actually should improve."*
D7011A Advanced prototyping	4	*"It was really a challenge for us. Let me say that we were more at odds than ever before. Stupid to do a project like this with a best friend. So far, it has been a test of friendship."* *"I really liked to use the personal diary that focused on the reflection [not the visual presentation], easy to continuously add content after each day, then the workbook focused on the presentation of the team effort"*
D7017A Product visualisation	5	*"I appreciated doing an individual portfolio-based workbook."*
D7006A Advanced Product design	5	*"It is totally impossible to describe a joint team effort in a workbook. Usually, you divide the assignment and then you don't know all the things the others have done and learnt. You can only describe your own learning process."* *"It was really valuable to describe a whole design project from start to finish, to be able to see all of the things that were done."*
D7014A Master thesis project IDE	5	*"Now, in my master thesis project, I have returned to all of my previous workbooks. I re-discovered methods, and I saw my own progression. It gave me so much; it was a real boost!"*

All-in-all, now in their fifth and final years, they were quite passionate about the workbook approach and had a lot of ideas of how to improve it even more. Some of them had developed self-regulated strategies along the way. For example, having a physical notebook and writing down what you have done every day makes it easier to write the workbook later on. They all claimed to go back to their older workbooks and get inspiration, some more regularly than others. The workbook approach was something these students appreciated, as some of them stated that they now see it as a very good way of describing and reflecting on the work they had done. A preliminary framework for the workbook approach can be seen in Table 3.

Table 3. A preliminary framework for the IDE workbook approach

Year	Objectives	Workbook content
1-2	Developing motivation for learning, positive self-image, developing emotional competence in caring for users, communication and collaboration skills, basic design knowledge and good working habits	Self-reflection, sketches, renderings, photos, short texts with a different focus relating to course content. Creative habits of mind. Reflections after each section. Workbook dialogues with formative feedback sessions.
2-3	Consolidating and deepening knowledge in design subjects, implementing tools for learning and reflective thinking, group maturity and collaborative learning, and deepening the communicative skills and abilities to present and represent oneself and one's project.	Deepened self-reflection, sketches, images, photos, and reflective texts relating to course content, collaboration and project methods and results. Reflection-on-actions in projects and teams. Lessons learnt. Workbook dialogues with formative feedback sessions.
4-5	Deepening the knowledge in the different design subject areas' uniqueness and structure, increasing profiles or specialisations based on students' interests, and involving more independent experimentation and challenge-based learning experiences.	Self-profile, sketches, images, photos, models, and descriptions about projects/assignments. Reflection-on-action in the whole course. Workbook dialogues with formative feedback sessions.

5 DISCUSSION

One learning experience of the current project is a need for a more overarching structure and progression in the different IDE workbook approaches. A framework could, for this reason, be to have workbooks focusing on some skill development and reflection in the first years and gradually increase the reflection. All-in-all, the student's gratification shows that something in the workbook approach is worthwhile. It seems to take them a while to understand the approach, but over the years, they develop self-regulated learning strategies as a result. Teachers can guide the learning process and support students in descriptive writing, descriptive reflection, dialogic reflection, and critical reflection [10]. The first level, descriptive, is not reflective, as it just involves a report of a project, situation, or other events. The second, descriptive, is an effort at providing reasons, for example, based on personal judgements or linked to course literature – this is what students employ in the bachelor-years workbooks. The third level of dialogic concerns exploring reasons for what has happened. The fourth level should consider a broader ethical, historical, social, cultural, technological, and sustainable context. The teacher experience from IDE is that the two first levels are more easily mastered and utilised compared to the two more challenging forms of dialogic and critical. The latter requires knowledge and an experiential base that takes some time to develop but is at IDE seen as vital for future design engineers.

6 CONCLUSION

Conclusions of the current workbook approach project are first that there is a need for an overarching framework of the workbooks to support both teachers and students in understanding the task and how it can be utilised. Secondly, the workbook approach supports self-regulated learning strategies and is, therefore, an active learning tool. Thirdly, the workbook's guided reflection is a valuable tool for reaching higher levels of learning in design.

REFERENCES

[1] Marton F. and Säljö R. On Qualitative Differences in Learning: outcome and process, *British Journal of Educational Psychology*, vol. 46, no. 1, pp. 4-11, 1976.

[2] Gibbs G., Knapper C. and Piccinin S. Departmental Leadership of Teaching in Research-Intensive Environment, London: *The Leadership Foundation for Higher Education*, 2009.

[3] Prosser M. and Trigwell K. Understanding Teaching and Learning. *The Experience in Higher Education, Buckingham: Society for Research into Higher Education*, 1999.

[4] Zimmerman B. Self-Regulated Learning and Academic Achievement: An Overview, *Educational Psychologist*, vol. 25, no. 1, pp. 3-17, 1990.

[5] Pressley M., Borkowski J. and Schneider W. Good Information Processing: what it is and how education can promote it, *International Journal of Educational Research*, vol. 13, no. 8, pp. 857-867, 1989.

[6] Osberg D., Biesta G. and Cilliers P. From representation to emergence: complexity's challenge to the epistemology of schooling, *Educational Philosophy and Theory*, vol. 40, no. 1, pp. 213-227, 2008.

[7] Seibert K. Reflection-in-Action: tools for cultivating on-the-job learning conditions, *Organizational Dynamics*, vol. 27, no. 3, pp. 54-65, 1999.

[8] Dewey J. How we think: a restatement of the relation between reflective thinking and the educative process, Boston: D.C. Heath, 1993.

[9] Schön D. A. Educating the Reflective Practitioner: toward a new design for teaching and learning in the professions, Hoboken, N.J.: Jossey-Bass, 1987.

[10] Hatton N. and Smith D. Reflection in teacher education: towards definition and implementation, *Teaching and Teacher Education*, vol. 11, no. 1, pp. 33-49, 1995.

[11] Biggs J. B. and Collis K. Teaching for qualitative learning at university: what the student does, Maidenhead: Open University Press, 2011.

[12] Klenowski V. Student self-evaluation processes in student-centred teaching and learning contexts of Australia and England, *Assessment in Education*, vol. 2, no. 2, pp. 145-163, 1995.

[13] Ross J. The Reliability, Validity, and Utility of Self-Assessment, Practical Assessment, Research, and Evaluation, vol. 11, pp. 1-14, 2006.

[14] Marriott C. A. Assessment Methods and Tools for Architectural Curricula, Illinois: Illinois Institute of Technology, 2012.

[15] Brown T. Design thinking, *Harvard Business Review*, vol. June, pp. 84-92, 2008.

[16] Ellmin R. Portfolio: ways of working, thinking and learning (In Swedish: Portfolio: sätt att arbeta, tänka och lära)., Stockholm: Gothia, 2001.

[17] Kohblanck H. Att arbeta med workbook (Working with workbooks) (In Swedish), *Högskolan i Kalmar, Kalmar*, 2007.

[18] Dewey J. Democracy and Education, *Students Hand-out Inc*, Toledo, Ohio, 2008.

[19] Crawley E., Malmqvist J., Östlund D., Brodeur R. and Edström K. Rethinking Engineering Education: The CDIO Approach, Cham: Springer International Publications, 2014.

[20] Wikberg Nilsson Å. and Törlind P. *Student Competence Profiles: a complementary or competitive approach to CDIO?*" in 12th International CDIO Conference Proceedings, Turku, Finland, 2016.

HOW TO PROFESSIONALISE A SERIOUS GAME? APPLICATION TO "LINO HAS AN IDEA!"

Robin ENOC, Romain KERLOC'H, Camille JEAN and Nicolas MARANZANA
Arts et Metiers Institute of Technology, LCPI, HESAM Université, F-75013 Paris, France

ABSTRACT
Serious games are soaring. Their objectives are to develop skills and teach concepts in a ludic way. They are more and more popular with companies, families, and schools. Few of them focus on innovation and creativity for children. To address this lack, a project was carried last year to design a new serious game called "Lino has an idea!". It was tested with 2 groups of pupils (29 in third grade and 20 in fifth grade) and feedback shows great results. However, this game is still a prototype and needs to be enhanced. The purpose of this article is to present the method we use to get a professional version of the game that could be sold in a game shop. The different steps of the game process are modified to make it clearer for children and teachers according to feedbacks. A new corporate identity and style guide are issued to foster the immersion of the children to enhance their investment.

Keywords: Innovation, creativity, serious game, children, immersive universe

1 INTRODUCTION
Creativity and innovation are key factors that companies want to develop for their employees. However, as educational games are emerging, very few are focusing on children to give them an experience on creativity and innovation skills [1]. Furthermore, among these few games created [2, 3], some struggle to pass the prototype stage. The main purpose of this paper is to present a method to professionalise serious games and apply it over an example [2, 3]. Section 2 will remind the status of educational games. Section 3 will describe the methodology we develop to professionalise serious games. The application of the methodology on the case study "Lino has an idea!" will be found in Section 4. Finally, the concluding Sections 5 and 6 will discuss the perspective and recommendation.

2 STATE OF THE ART
Educational games aim to enhance the players with educational purposes. We can find them with multiple forms and concepts (card games, board games, video games…) but they contribute to acquire skills and knowledges [4]. Moreover, every category of people can be targeted from children to elders [4]. These games are soaring because this activity brings a panel of emotions, interactions, and thoughts during learning sessions. While serious games are booming in companies and high level of education, there are used very little at an early stage in primary school or in middle school (Figure 1) while it would be the very best moment because child are very receptive to these activities because of their brain development.

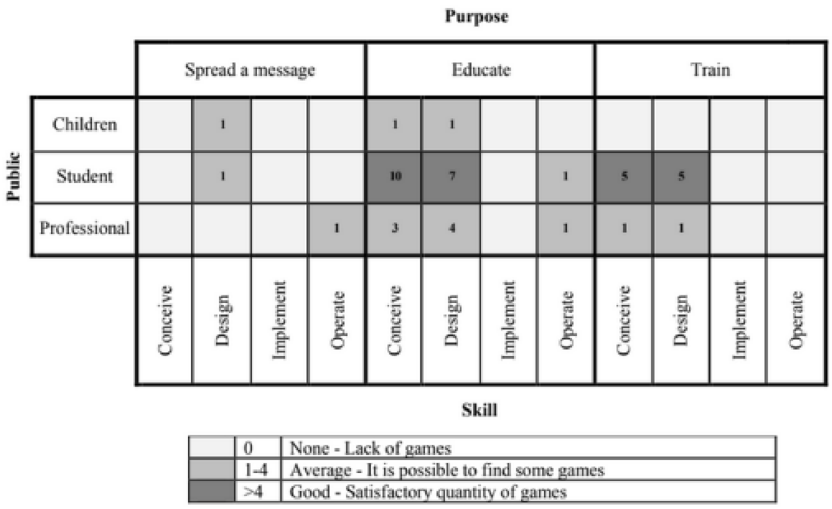


Figure 1. Taxonomy of different serious games in the Design Society database from Cortes Sobrino et al (2017) [1]

To make the learning process the most effective, an interesting way is to make the game the more dynamic as possible [4-6]. As the children don't fit traditional teaching methods, the games must be adapted and imagined with new principles and methods.
With that statement, research has been made and prototypes of games directed to children have been designed and tested [2]. So, how to professionalise a serious game?

3 PROPOSITON OF A METHODOLOGY TO PROFESSIONALISE SERIOUS GAMES

Designing a game can be very difficult because of the whole process and the commitment to make it as clear as possible for players. This is even harder for serious game as amusement must match the learning process. That is the reason it can be hard to find great serious games. However, people have tried to make their own and prototypes have been made.

Figure 2. Five steps method to professionalise serious games

Nevertheless, prototypes of games are not complete games. They must achieve a higher level of design to be considered as games which could be sold in any game shop. From that point of view, we decided to think about a method to enhance concepts or prototypes of games to another level. Based on the work of Witton [7], Nicholson [5] and Djaouti [8], we developed a five steps methodology to follow to reach the highest level possible.

3.1 Divergent phase: find a concept

As obvious it can be, the very first step to design the game is to have a concept or an idea of the game. As you want your game to be educative, you have to enlighten the problem or the skills you want to focus on. You must think about the public you want to address your game, the learning content you want to share with them and how you want it to be fun. It will be the foundation of all your work beside this point. To be as creative as possible, you can use creativity tools to find or fortify your concept (Association of ideas, Brainstorming, Analogies, Purge, etc).

3.2 Convergent phase: define the rules, narrative and aesthetics

Once you managed to find your concept of the game, you have now to make it real. For that, you have to take your precedent assumption and to imagine how you want it to exist. It can be a card game with

descriptions, a board game with an adventure you follow, an interactive video games or a combination of several mediums. There is no limit to your imagination about your game.
Now you have the idea of the support of your game, you have to make the rules of your game to describe a game. Your game must be structured to ensure the players will focus their attention on the aspect you want them to learn. To help you, you can imagine new items that will bring help or will be used to follow the process of your game.
Once both the supports and the rules are defined, the next step is a new phase of creation: narrative and aesthetics. To make a game fun, you have to make sure the players are fully receptive to the gameplay so you can design a story or a guideline to help players to immerge themselves in the process and be more receptive to learning. You can add drawing, photos or any visual supports to help you tell your story during the game.

3.3 Make it real: prototype

This could be described as one of the most difficult steps of the creation process. To make a first version of your game, you should have strong bases. The convergent phase has to be finished in order to know the guidelines of the game. Now you can imagine what you want your game to look like for real.
What is really important is to take time to do this step carefully, so next steps would be easier to get in. All the point there is to make choices. You are going to choose items that will create your game identity. Once this is done, it will be really difficult to change this. You could for example focus on the public the game target to be the most effective possible.
The aim there is also to be able to imagine what the final version of the game would be. So, the idea is to create cards, board, pawn, etc. without thinking too much about convenient aspect, it would be the goal of the upgrade step. So, try all your ideas with the lowest cost possible and with simple processes to get fast and cheap preview of the final game.
This step is really powerful because you will be able to have something concrete in hands, but you would also be able to test your game in conditions. Despite the game is not perfect at this stage, it is possible to show it to people that would give you advices and feedback on what they like or not in the way you apply your learning process.

3.4 Test and upgrade

This step is based on a critical aspect of the development of a game: details. The goal there is to analyse every part of the existing game and to find how to improve it. Most of the time, it will be possible thanks to details. From that point you already have all basis needed, so just little adjustments are required. When we say "little adjustments", it is in comparison to all game aspects because, in fact, these could be really important and could be the source of a lot of work.
Feedbacks are one of the most effective tools to get successful at this stage. It gives you a fresh view of the work you have done. It could also help you find what should be improved as a priority, thanks to the number of criticisms per object or thanks to a system of marks.
Then, another genuine tool is consistency. To make something strong, powerful and easy to grasp, it is important to give it consistency by creating a real identity. It could be a graphic identity, a concept identity, or an innovative identity, but the best stays all of these.

3.5 Make it available

Finally, when your game is completed, you can now make it available to reach its public. It could be in local game shops to a worldwide diffusion, depending on your target audience and your means. Look for your commercialization strategy and make everything to expand your game and enhance people's creativity and innovation.

4 CASE STUDY: "LINO HAS AN IDEA!"

To demonstrate our method, we applied it to a serious game made in our school last year: "Lino has an idea!" [2]. "Lino has an idea!" is a game for children to enhance their creativity and innovation with the story of Lino, a little fox who dreams about ideas and wants to build them with his friends.

4.1 Prototype

The game is destined to be played by children in the age of 6 to 11 during classroom time. The teacher plays the Gamemaster role to help them to conduct the game. The children constitute groups (up to 7 children) and get their own space to work. Each child in every group gets a role to help them understand the role in a group of work. The support of the game is a spiral board with a Lino pawn which goes higher in every step of the game.

Figure 3. Game board prototype [2]

These steps tell the story of a school day of Lino: First, Lino awakes and remembers an idea he had during his sleep, each group throws dices to define the scale of their product. Then, the children propose their vision and choose a product. They use creativity tools to design the product. After a little break to make the endgame efficient, they draw up a list of advantages and disadvantages to make final modifications. Each group makes a presentation of their product to the class. Finally, a feedback phase is conducted to make them remember the game and what could have been better.
The students who designed the game managed to produce the game with its supports and its rules with the narrative and game aesthetic. With this prototype, they conducted a case study in two classes (third and fifth grades) so they got feedback and could explain the perspectives of the current version of their game.

4.2 Application of the method

First of all, we used feedback as a way to understand on which aspect we could work to make this game more professional. In addition, we used our own feelings about all the work that has been done before us. This analysis step gave us three major axis where improvement was necessary: the rules, the graphic identity and the game board.
There was inconsistency in the rules, so we firstly worked on this. The goal there was to make it a little bit easier to understand for children and easier to apply for teachers because it was identified as a critical point in feedbacks. It is a difficult task because we had to examine every aspect of existing rules in order to find what we should change, what we should delete and what we should keep, but without damaging the soul and the aim of the game. We also changed the name of our main character and the game: it was now written “Linno” and “Linnovation”. This choice was made for more consistency with the word “Innovation”.
Then, we began to work on a new board for the game. The one that already existed (Figure 3) was perfect while playing, but it was a huge problem when the time to store it in its box came. That is why we created an all-new board game (Figure 4) that could fit in the minimum space possible thanks to parts that fit together.

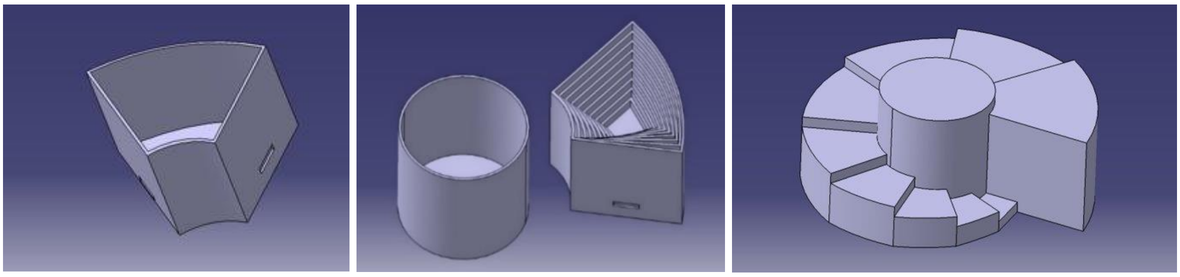


Figure 4. New game board pieces

These parts have been created with the idea that each would be assembled with others thanks to magnets. Once assembled, we had a full board game that kept the spiral look and the functionalities it needed.

Figure 5. New game step-up

Finally, we worked on the visual and graphic identity (Figure 6). This was the point on which there was the most work. It was good news because we could create almost everything we wanted. The first thing that we changed was the graphic chart. In fact, to make a game more professional we needed to respect some rules such as the use of royalty-free visuals. That is why we changed the fonts used in all the game and we changed the drawing of animals used previously. For these animals we drew some animals previously chosen in the step of improvement of rules. Thanks to this work we were able to create brand new visuals royalty-free and that fitted perfectly with the idea we had for this game.

Figure 6. New animals visual (a), front box visual (b) and back box photo (c)

We just had then to create as many visuals as we needed with keeping in mind that the graphic chart we established must be followed. Moreover, we printed in 3D an all-new pawn with the new look for Linno. We also created a real box to host every piece of the game and all the cards that we had. It was designed with the aim to make the game look the more professional possible. That is why we used a laser cut foam inside that fit perfectly with each part. We also created a complete cover for this box that brings the customer all the information he needs if he wants to buy the game. In addition, cards have been made in big scale to help children to read easily and have been plasticized to be more durable.
All our serious game was then complete and as professional as we wanted it to be, with a strong identity and a coherent whole.

5 DISCUSSION AND PERSPECTIVES

Thanks to our method (Figure 2), creators can now try to apply it to their own ideas and prototypes. If the first parts are classical to an innovation process, they still need to happen to reach the maximum capability of creativeness. Furthermore, we add a complete upgrading part based on our experience with “Linnovation” to point out the lack of coherence and identity, to focus on details and be aware of the use of copyrighted content. The addition of new point of views could contribute to enhance the method. For “Linnovation”, we went as far as we could with handcrafted methods and the use of few machines through methodical processes. The game has yet to be tested to gather new feedbacks and upgrade it until completion. Then, another step of industrialization with the normalization of the process could help create more copies with clean aesthetics in shorter time. It would also be a key step to make the game available to the market and allows schools to use it for their classes.

6 CONCLUSIONS

In this article, we present a method to answer the lack of development of serious games to enhance creativity and innovation, especially for children. We organized it with five points, with usual creativity tools and critical aspects to make clean and complete serious games.

We applied it on a prototype game previously made which had feedback thanks to tests in primary school. We managed to improve the game focusing on three key points that lack development or which was reported by the classes. With our upgrade, it showed great improvements to the quality and the professionalism perceived by a future player. Yet, the game would need more time to reach completion and be available to its public with an official release.

ACKNOWLEDGEMENTS

We thank Victor JAQUE, graphic designer, who drew our visual for animals and made them as we imagined. We also thank Benoit SCHAEFFER from LCPI who helped us with all the manual work we had to do for our prototype and all the previous students who worked on the game before us.

REFERENCES

[1] Cortes Sobrino A., Bertrand M., Di Domenico E., Jean C. and Maranzana N. (2017). Educational games for design and innovation: Proposition of a new taxonomy to identify perspectives of development. In *DS 87-9 Proceedings of the 21st International Conference on Engineering Design.* Vol 9: Design Education, Vancouver, Canada.

[2] Boyer E., Couture L., Granier L., Roudes T., Vidal A., Maranzana N. and Jean C. (2021). Creativity and innovation for children: presentation and first experiment of new (serious) game. *Proceedings of the 23rd International Conference on Engineering and Product Design Education,* VIA Design, VIA University Herning, Denmark.

[3] Libe C., Grenouillat A., Lagoutte J., Jean C. and Maranzana N. (2020). Creativity and innovation for children: presentation and first experiment of new (serious) game. In *DS 104 Proceedings of the 22nd International Conference on Engineering and Product Design Education*, VIA Design, VIA University Herning, Denmark.

[4] Breuer J. and Bente G. (2010). Why so serious? On the relation of serious games and learning. *Journal for Computer Game Culture*, 4(1), 7-24.

[5] Nicholson S. (2015). A recipe for meaningful gamification. In: *Gamification in education and business*. Springer, Cham, 1-20.

[6] Roth S., Schneckenberg D. and Tsai C. W. (2015). The ludic drive as innovation driver: Introduction to the gamification of innovation. *Creativity and Innovation Management*, 24(2), 300-306.

[7] Djaouti D. (2020). DICE: A Generic Model for the Design Process of Serious Games. *International Journal of Game-Based Learning (IJGBL)*, 10(2), 39-53.

[8] Whittonn N. (2011). Game Engagement Theory and Adult Learning, Simulation and Gaming, 42(5), 596-609.

[9] Ma Y. (2021). Design of serious games for teaching industrial engineering methodologies: A design process based on V-model and an application in innovation engineering, *PhD Thesis*, CentraleSupélec, Université Paris-Saclay.

[10] Educause Learning Initiative. (2014). 7 Things You Should Know About Games and Learning.

RADICALLY INNOVATING THE AUTOMOTIVE DESIGN PROCESS WITH IMMERSIVE TECHNOLOGIES

Juan Antonio ISLAS MUÑOZ[1], Ehsan BAHA[1] and Gjoko MURATOVSKI[2]
[1]University of Montréal, Montréal, Canada
[2]Deakin University, Melbourne, Australia

ABSTRACT
The automotive design process prevalent in industry that dictates transportation design education, is optimized to facilitate the frequent aesthetic renewal of personally owned vehicles for car-oriented cities. With its origins in the late 1920s, this hyper-specialized design process has barely changed from its original form. In this paper, we provide a brief account of the automotive design process from its origins (analogue) to the present day (digital technologies), followed by a new paradigm instigated by immersive technologies. A passenger drone project is used as an example to describe the possibilities of immersive technologies in this radically innovated process. Enhancements from 2D and 3D to immersive and interactive 4D, enable a lean, yet contextualized process to design radically innovative vehicles.

Keywords: Automotive design process, future mobility, immersive technologies, radical innovation, transportation design education

1 INTRODUCTION
In the late 1920s, General Motors (GM) decided to fight the dominant Ford Model T with style rather than pricing and technological innovation [1]. To create their next generations of cars, GM developed what we know today as the automotive design process[1]. Used by the design studio(s) of automakers, the automotive design process is a sequence of established operating procedures to create commercially successful vehicles that justify the resources required for their production [2]. This process has largely remained unchanged from its original form [3]. Indeed, automakers could afford to capitalize upon designing personally owned cars for a stable context, until recently that city infrastructures and mobility business models have started to change. This process is mainly similar in all automotive design studios while described somewhat differently by each. For the purpose of this paper, we subscribe to [3], but abstract their nine-phase model into a six-phase model where we introduce our own terms. These six phases are: 1) Technical package, 2) Ideation, 3) Development, 4) Refinement, 5) Final model or prototype and 6) Approval.

Figure 1 provides an overview of the first four phases which we focus on in the remainder of this paper. In phase 1, the car's technical packaging is created based on the precisely dimensioned seating positions, layout of the driver and passengers, and the car's technical components. In phase 2, multiple design proposals are ideated using 2D freehand (and thus, dimensionless) sketches and renderings. In phase 3, a design shortlist is selected for development where the 2D dimensionless design proposals are translated into dimensioned 3D volumes using models. Once a direction from the shortlist is selected, in phase 4, final models are sculpted and iterated on until reaching a desired, precisely dimensioned outcome. In phase 5, these sculptures are used to create a final model or prototype that looks exactly like the real car. Phase 6 concludes the process with approval for production coming after feasibility is assessed.

[1] The term automotive design is also used in engineering focusing on the technical aspects of the vehicle (i.e., chassis, suspension, aerodynamics). In this paper we focus on the creative design aspect (i.e., aesthetics, usability). Specifically, we focus on the vehicle's exterior and interior which largely follow the same procedure.

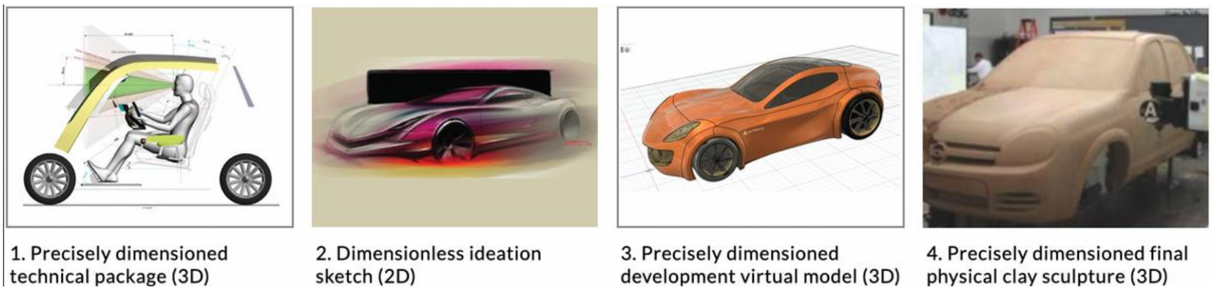


Figure 1. Snapshots of the first four phases of the current automotive design process (varied projects)

Described by [1], the original version of the automotive design process used analogue paradigms of the 2nd industrial revolution and was mostly 2D in its first three phases: 2D technical drawings in the technical package phase; 2D sketches and renderings in the ideation phase, and 1:1 scale orthographic drawing in the development phase. It was only after these phases, in phase 4, that 3D physical models in full-size were produced using clay. Through the decades, the automotive design process was incrementally innovated through the integration of digital technologies until the contemporary version. CAD had the biggest impact by permitting the use of 3D virtual models in phases 1 (technical packaging), 3 (development), and 4 (refinement). However, the ideation or phase 2, remained based on freehand dimensionless 2D sketches. Moreover, despite being streamlined, the resource-intensive translation from 2D to 3D remained (Figure 1).

The most recent developments for this process are the emergence of immersive technologies. In recent years, these technologies are starting to radically advance the automotive design process into a new paradigm. Indeed, virtual reality (VR) and augmented reality (AR) provide the ability to design vehicles virtually at full scale using mid-air sketching. Additionally, video game engines (VGEs) facilitate adding interaction to immersive 3D models, effectively making them 4D [4]. The industry is already experimenting with immersive technologies, however in the present day, these technologies have not holistically and formally been integrated into the established automotive design process. As the automotive design studios possess a large and highly specialized workforce who are used to an established procedure and its related infrastructure, it becomes challenging for them to integrate immersive technologies throughout the entire process and at a large scale.

In this paper we present an automotive design process, developed free from industry constraints where 3D and 4D immersive technologies are integrated holistically. This process was generated at the University of Cincinnati Future Mobility Centre, where the first and third author were previously affiliated. At this Future Mobility Centre, 13 academic transportation design studio courses were co-developed and/or its output presented to the automotive industry and technology collaborators. The remainder of the paper is therefore structured as follows. In the next section (Section 2), we provide a brief account of the original automotive design process, its contemporary form, and the emerging paradigm using Schwab's industrial revolutions model [5]. We then describe our radically innovative automotive design process using a project from one of the 13 academic transportation design courses as an example – i.e., the design of a passenger drone (section 3). The paper ends with a discussion of how 3D and 4D immersive technologies enable a lean yet contextualized automotive design process appropriate for radically innovative vehicles of the future.

2 THE EVOLUTION OF THE AUTOMOTIVE DESIGN PROCESS

The brief evolutionary account of the automotive design process in this section forms a non-exhaustive basis for understanding our work. The summary provided here, is based on literature review reported in Section 2.1 and 2.2; Complementary observation of the latest developments in the field, and dialogue with the members of the automotive design community of practice, reported in Section 2.3. An overview of all research is provided in Figure 2.

2.1 The 2nd Industrial Revolution: from 2D to 3D through analogue means

The original version of the automotive design process was created at the Art and Colour Section of GM between 1927-1950 by Harley Earl [1]. With this process, GM introduced effective style changes for annual car models, utilizing a car archetype (engine, cabin, cargo, four wheels, etc.) that would cash in on a century of personal ownership business model and decades of established city infrastructure. Earl's process was mainly analogue and 2D. The technical package was a 2D drawing based on an established car archetype prioritizing the driver (phase 1). Ideation was based on 2D freehand dimensionless paper sketches that dramatized the vehicle's proportions and showed design intent (phase 2). Since the ideation sketches were 2D, they had to be developed into 3D dimensioned form [6], going through a complex and resource-consuming translation [7]. The translation from 2D dimensionless to 3D dimensioned, required the creation of 1:1 full scale 2D drawings (phase 3). These drawings were then used as a template to create full-sized hand-made clay sculptures, iteratively refined towards a precise-dimensioned final vehicle model (phase 4). The same sculptures were used for the final model and prototype (phase 5), before being approved for (phase 6).

2.2 The 3rd Industrial Revolution: from 2D to 3D through digital technologies

Although the digital revolution started to impact the automotive design process in the 1960s [5], the automotive design process remained largely unchanged. The main reason for this stability was the personal ownership business model and related car-oriented city infrastructure. Therefore, the arrival of digital technologies only instigated an incremental change. In other words, digital technologies mainly tridimentionalised the process. Moreover, CAD advanced the technical package with 3D geometry (phase 1). Ideation remained 2D (phase 2), but now 3D models could be developed in CAD (phase 3), before creating final clay models (phase 4). As a result, the effort needed to translate 2D dimensionless sketches into 3D dimensioned form was reduced, but not eliminated. Since the translation from 2D to 3D is resource intensive [7], several attempts exist by scholars to tridimensionalise the ideation phase through digital technologies (phase 2). For example, [8] has proposed the projection-mapping of traditional 2D orthographic sketches into a CAD geometry used as an underlay for multiple viewpoints of the ideated design proposal which used to only provide one viewpoint as a paper sketch. [6] digitized tape drawing as an attempt to achieve more precise and editable 1:1 orthogonal drawings. [9] explored digital clay – sketching on 3D geometry, to ideate directly in 3D.

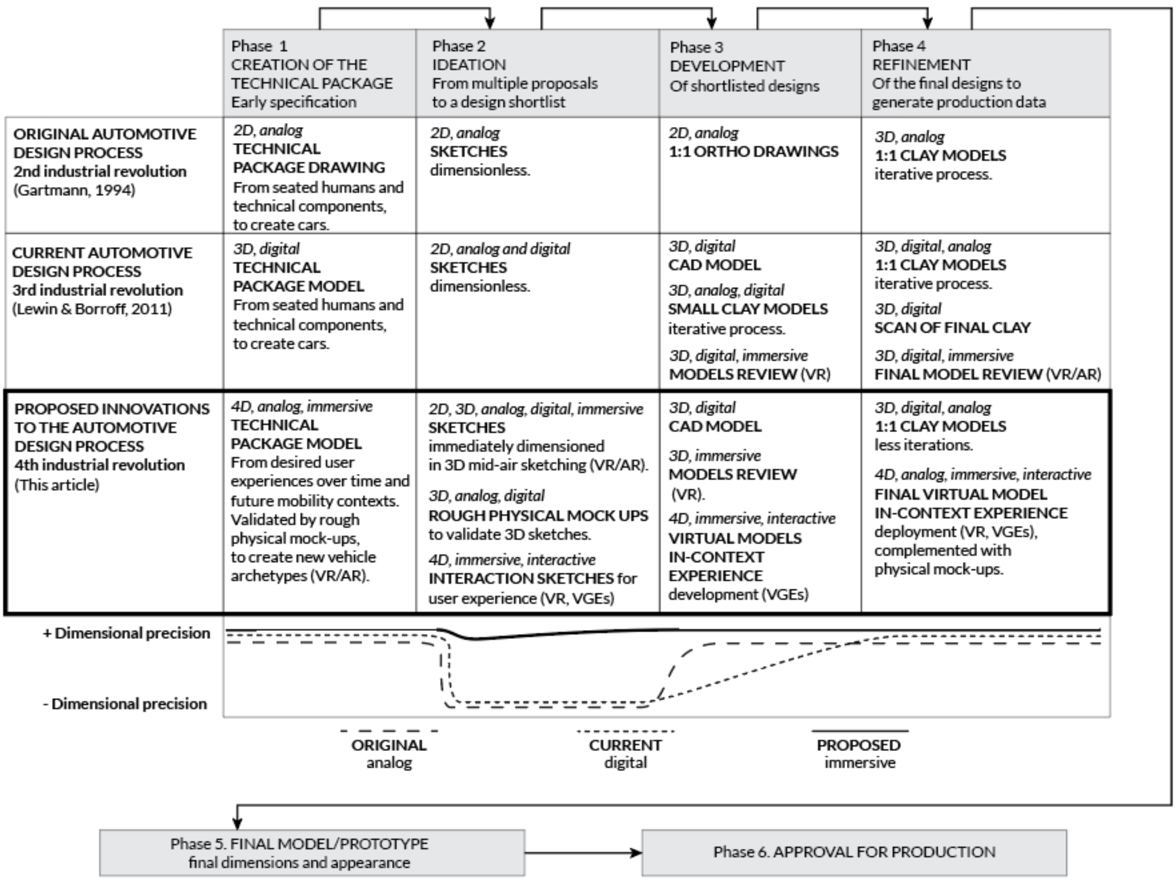


Figure 2. The three main paradigms of the automotive design process: analogue or original (row 1) digital or current (row 2), and immersive or the radically innovated automotive process (row 3)

2.3 The 4th Industrial Revolution: the emergence of immersive technologies

Where before, the automotive design process largely remained unchanged, in the 4th industrial revolution the process is increasingly being disrupted. Significant change here is twofold. First and foremost, a new mobility paradigm is arising. The century-old personal ownership and car-oriented city infrastructure is transitioning into multimodal, autonomous, and shared mobility within sustainable cities [10]. Once specialized in developing cars, automakers need to rethink vehicle archetypes for their very survival [11]. This new scenery requires consideration of unestablished operations in sometimes not yet existing contexts. Returning to the automotive design process, we now must deal with new postures, layouts, and user experiences affecting the technical package to give an example. Second, the 4th industrial revolution comes with a series of "compounding effects of multiple exponential technologies" [12, p. 215]. The democratization of VR and AR for immersive 3D mid-air sketches, and the use of VGEs for 4D immersive and interactive in-context experiences present themselves as potential game changers in the automotive design practice. Early implementation of immersive technology in the established automotive design process is reported by [13] with the Powerwall – an electronic patio where one or more full-scale digital car models can be projected for surface evaluation, and CAVE – rooms with multiple projection surfaces that collectively display images that surround the viewer with the interior of a car, as examples (phase 4). More recent examples are the HYVE 3D – a not specifically automotive multi-user social co-design VR system for ideation (phase 2), developed by [14], and more democratized VR head-mounted displays developed among others by HTC and Oculus. As mentioned earlier however, to date, these technologies have not been holistically implemented in the automotive design process and at a large scale.

3 RADICALLY INNOVATING THE AUTOMOTIVE DESIGN PROCESS THROUGH IMMERSIVE TECHNOLOGIES IN ACADEMIA

3.1 Research context and rationale

In the field of automotive design, including the automotive design process, industry has always led education. The automotive design process is a highly optimized and hyper-specialized process which has become widespread in a community of practice [15] where design is viewed as craft rather than a discipline. Indeed, literature on the automotive design process, especially when it comes to education, is scarce which has resulted in a master-apprentice pedagogy. To ensure proficiency in this process, transportation design programmes work closely with and follow the workflows of automotive design practitioners in the industry. However, in the 4th industrial revolution, industry disrupted in such a way that it is finding its limits. It has then not been a surprise for us to experience a high interest of industry to collaborate and experiment with immersive technologies within an academic setting. The research reported in this paper is therefore a serious attempt to not only follow but inspire, even lead the industry. Free from the infrastructure and day-to-day constraints of automotive design studios, at the University of Cincinnati Future Mobility Centre, a practice-led research approach was deployed [16]. Immersive technologies were explored in different phases of the automotive design process through 13 academic transportation design studio courses. All courses featured projects addressing future mobility challenges through vehicle concepts. Developed between 2016 and 2021, each project was executed in a semester. Among others we worked with GM, Fiat Chrysler Automobiles, Tata motors, Pininfarina, Jaguar Land Rover, Hankook Tire and Technology, Gravity Sketch, Autodesk, among others.

3.2 The radically innovated automotive design process: from 2D and immersive 3D to immersive and interactive 4D

The third row of Figure 2 provides an overview of the radically innovated automotive design process. The radically innovated automotive design process maintains the same general phases as the prior two processes (the original and the contemporary). The difference is the integration of immersive technologies. In phase 1, instead of creating a 3D model behind a computer screen and departing from static seated figures to design a car, we propose the creation of the technical package in VR and at 1:1 scale. Moreover, the technical package is created considering new and non-existing mobility contexts in which the resulting occupant position and that of the technical components of the vehicle are driven by experience flows (4D), resulting in disruptive innovation (e.g., new vehicle archetypes beyond the car) [17]. In phase 2, ideation is advanced from 2D to 3D by using immersive sketching while validating the virtual model's dimensions with rough physical mock-ups. Expanding ideation from 2D to 3D using

VR and/or AR, augments the dimensional precision in comparison to prior versions of the automotive design process (Figure 2). In addition to the ideation of the physical vehicle, 4D immersive interactive sketches using VGEs are proposed to design the vehicle's desired use experience (e.g., operating a vehicle with unconventional controls). In phase 3, for the development of shortlisted design, we propose the substitution of small clay models with VR reviews which saves resources. At this phase, the assets necessary to create a 4D immersive and interactive virtual model experienceable in-context are developed (i.e., coding the vehicle interactions, creating a virtual city context where the vehicle situates). In phase 4, the refinement of final designs is still done with full scale clay models. However, the number of iterations is now reduced, and more resources are saved, since a part of the refinement is taken care of in VR-reviewed CAD during the previous phase. At the end of this phase the final version of the 4D immersive and interactive experience is deployed (i.e., a trip through a city). Finally, the 4D immersive and interactive experience can inform about further refinements before investing time and resources to create the final model and prototype (phase 5) before approval for production (phase 6).

3.3 Describing the radically innovated automotive design process through a project example: the passenger drone project

We now describe the holistic integration and benefits of immersive technologies for the automotive design process using a project from one of the automotive design studio courses: the design of a passenger drone. This is a new type of vehicle to move a person in the city from roof to roof with a maximum 30-minute flight range. In a project with a collaborative component, two students were briefed to approach a passenger drone design from different angles: the design of the physical drone, and how to fly it. Figure 3 shows the student work samples of this project. Both students began by using rough physical mock-ups to create a vehicle package that provided a comfortable, yet adventurous, "superhero" flight user experience (phase 1). The design of the physical vehicle used both 2D ideation sketches and immersive 3D mid-air sketching in VR (phase 2). Having 3D geometry as output from the ideation phase accelerated the creation of the final dimensioned CAD (phase 3 and 4). On the other side of the project, the design of how to fly the drone was created by using a rough physical model, an HTC Vive tracker, and the Unity video game engine to design, test, and refine the flight experience and the type of controls required (phase 2). A 4D immersive contextual model was developed to simulate the drone operation experience. To achieve this experience, a virtual city was modelled, the vehicle virtual model was inserted in the scene and coded, and the rough physical mock-up was used to simulate the passenger posture (phase 3). The experience was deployed (phase 4) and the project critics were able to sit on the physical buck and fly the vehicle versus seeing the project on a poster or behind a screen.

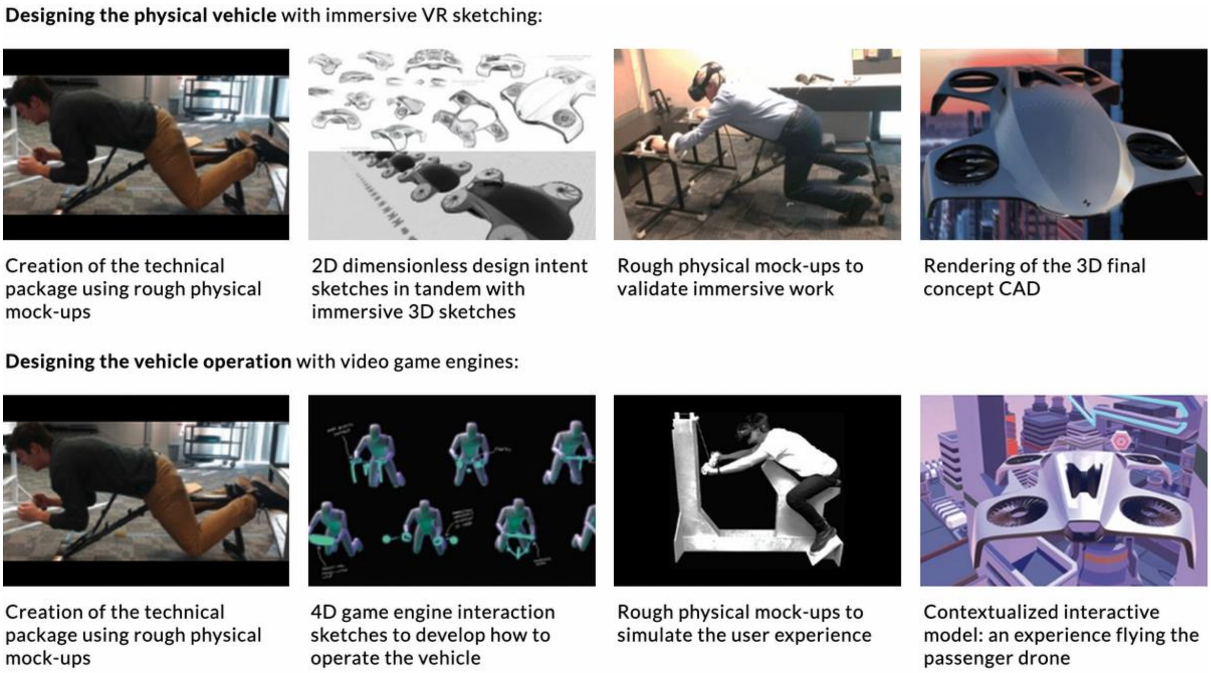


Figure 3. The automotive design process applied in a passenger drone project

4 DISCUSSION AND FINAL WORDS

We applied immersive technologies to 13 transportation design courses at the University of Cincinnati Future Mobility Centre between 2016 and 2021. In a constant state of dialogue, the courses were co-developed and/or their output was presented to the automotive design community of practice and technology collaborators. The accumulated insights allowed us to propose a radically innovated automotive design process where immersive technologies are holistically integrated. Our work has three main contributions: 1) We provided a brief account of the original automotive design process (analogue, mainly 2D), followed by the incrementally innovated contemporary process (digital, mainly 3D), and finally the emerging new paradigm (immersive and interactive 4D); 2) We proposed a radically innovated lean automotive design process by tridimensionalising the ideation phase and holistically upgrading all four phases through the integration of 4D.immersive and interactive technologies. Our process allows for the creation of radically innovative vehicles beyond the car and for new or not yet existing mobility contexts; 3) Finally, we presented a project example featuring the physical and interactive design of a passenger drone as a design precedent. Using university-level courses to (radically) innovate the automotive design process for industry use also comes with some limitations. Academic projects are usually a semester long (15 weeks), executed by one student or a small student team, and run with small budgets. Creating physical full-scale models is then not feasible. Nevertheless, academic student projects benefit from a freedom not available in industry while interesting enough to feed it.

REFERENCES

[1] Gartman D. Harley Earl and the Art and the Art and Colour Section: The Birth of Styling at General Motors. *Design Issues*, 1994, 10(2), 3-26.

[2] Crea N. *Advanced Transportation Design*. In: Celi M. *Advanced Design Cultures*, Chapter 7, 2015 (Springer International Publishing, Switzerland).

[3] Lewin T. and Borroff R. *How to Design Cars Like a Pro*. 2010, (Motorbooks, U.S.A.).

[4] Automotive & Transportation. Available: https://www.unrealengine.com/en-US/solutions/automotive-transportation [Accessed on 2022, 13 March]

[5] Schwab K. *The Fourth Industrial Revolution,* 2016 (World Economic Forum, Switzerland).

[6] Bae, S. H. and Kijima, R. Digital styling for designers: in prospective automotive design. In *Proceedings of Virtual Systems and Multi Media 1,* October 2003, pp. 546-553.

[7] Clarke A. From 3D Design to 3D Clay: Our Industry Insider Peels Back the Studio Curtain.

[8] Tovey M. Concept design CAD for the automotive industry. *Journal of Engineering Design,* 2002, 13(1), 5-18.

[9] Zammit, R. and Munoz, J. A. I. Has Digital Clay Finally Arrived? *Computer-Aided Design and Applications*, 2014, 11(sup1), S20-S26.

[10] Zahrehi S. M., Kurniawan J. H. and Cheah L. A Foresight Study on Urban Mobility: Singapore 2040: Methodologies and Preliminary Insights. *Foresight*, 2020, 22(1), 37-52.

[11] Nieuwenhuis, P. and Wells, P. *The Death of Motoring. Car Making and Automobility in the 21st Century*, 1997, (Transportation Research Laboratory).

[12] Penphrase B. E. *The Fourth Industrial Revolution and Higher Education.* In: Gleason N. (eds) *Higher Education in the Era of the Fourth Industrial Revolution, 2018.* (Palgrave Macmillan, Singapore).

[13] Buxton, W., Fitzmaurice, G., Balakrishnan, R. and Kurtenbach, G. Large displays in automotive design. *IEEE Computer graphics and applications.* 20(4), 68-75.

[14] Dorta, T., Kinayoglu, G. and Hoffmann, M., 2016. Hyve-3D and the 3D Cursor: Architectural co-design with freedom in Virtual Reality. *International Journal of Architectural Computing,* 14(2), 87-102.

[15] Tovey, M., Bull, K., and Osmond, J. Developing a Pedagogic Framework for Product and Automotive Design. *DRS International Conference 2010*. Montreal, Canada, July 2010. P. 3. (DRS Biennial Conference Series).

[16] Candy, L., 2006. Practice based research: A guide. *CCS report, 1*(2), pp.1-19.

[17] Wu, J., Dale, H., Katrine, H., Samuel, J., Sheila, C. and Daniel, Q., 2020. Process matters: from car owner experiences to automotive design proposals. *DRS2020 Proceedings*. Brisbane, Australia, 2020, 554-571.

MULTIDISCIPLINARY INNOVATION ARMENIA: EXPLORATIONS IN DESIGN-LED MULTIDISCIPLINARY ENTERPRISE EDUCATION

Mark BAILEY[1], Arman ARAKELYAN[2], Nick SPENCER[1] and Justine CARRION-WEISS[1]
[1]Northumbria University, United Kingdom
[2]American University of Armenia, Armenia

ABSTRACT

This paper addresses the question to what extent can rapid design-led interventions support enterprise education? The work is based on a three-year engagement with students and recent graduates in Armenia. It was inspired by a course of innovation-readiness workshops called Get Ready to Innovate used to support established small and medium-sized enterprises operating in North East England.
The paper provides a critical assessment of the adaptation of the GRTI model for the Armenian situation and its strengths and limitations for addressing the requirements of innovation readiness (the willingness, creative mindset and plans to make a positive change) amongst budding Armenian entrepreneurs.
Mixed-methods are used, combining inductive thematic analysis of participant surveys, co-reflective workshops and semi-structured interviews.
Findings suggest that there are a number of benefits associated with adopting a design-led approach, including enhancing creative confidence and multidisciplinary team working. In comparison with other forms of enterprise education, participants and facilitators identified a greater emphasis on front-end exploration and stakeholder focus.
It is also clear that there were shortcomings in the approach associated with a mismatch in expectations between the facilitators and participants. The authors identify the challenges associated with this mismatch and some steps they took to overcome these. Finally, they identify scope for future research that considers implications for educational and enterprise-creation policy as well as discrete programme development.

Keywords: Enterprise education, design-led education, co-created knowledge, innovation readiness, design facilitation

1 INTRODUCTION

In 2018, through a British Council Creative Spark programme, Northumbria University School of Design partnered with the American University in Armenia to develop and deploy a design-led Enterprise Education programme. Supporting principles of the programme aligned with design thinking included establishing a deep understanding of stakeholders; welcoming multiple different disciplinary perspectives; a willingness to frame and reframe the enterprises' situation; rapid ideation; a focus on trying things out; and reflexivity. These principles were employed all with the purpose of enhancing creative confidence - 'the natural ability to come up with new ideas and the courage to try them out' [1].
The programme was based on a successful suite of design-led business support workshops designed and developed by a team of design academics and researchers at Northumbria University as part of the Creative Fuse North East action research programme [2], [3]. This programme, called Get Ready to Innovate (GRTI) [4], focused on promoting innovation-readiness (the willingness, creative mindset, and plans to make positive change) in established SMEs in NE England with the purpose of supporting those SMEs to deliver regional growth. The design-led approach was adopted for its focus on strategic development. The GRTI programme comprised a total of twelve hours of support spread over three workshops and one review meeting and was firmly targeted towards established, trading enterprises.
The decision to employ this approach in developing a new programme of enterprise education was based on three factors:

1. the team was experienced in using design-led approaches to educate Master's students for and about innovation and had seen; a, a significant development in these students' creative confidence and b, that the approach was useful in supporting entrepreneurial growth [5], [6].
2. independent evaluation of the Creative Fuse North East GRTI had demonstrated that it was effective in supporting individuals and enterprises to develop both their business ideas and their own confidence as entrepreneurs.
3. the programme had been designed in response to a regional economic development agenda which was very similar to the underlying policy agenda underpinning the British Council's work in Armenia (and surrounding countries in that region).

1.1 Programme design

The original GRTI proceeded through four stages with design facilitators using defined templates and a combination of pre-prepared and ad-hoc prompts to encourage participant enterprises to uncover and explore creative opportunities for the development of their venture. Adapting the approach for the Armenian programme, Get Ready to Innovate Armenia (GRTIA), the team recognized that they would need to adapt it to take account of the fact that the Armenian participants were younger and less experienced and were not necessarily trading. They determined that longer sessions and more scaffolding devices would be required. Keynote lectures were introduced at the start of each block, additional and more detailed templates were developed and 'homework' was set between sessions. Table 1. compares the two programmes.

Table 1. Comparison of the two programmes

GRTI	GRTIA
#1 Triage: Exploring the business as a whole, whilst also understanding who the individuals within the organisation are.	**#1 Modelling the Situation:** build a picture of you, your vision, ideas, value-chain and the idea's environment. Understand how change, uncertainty and risk are influencing factors in order to consider your challenges, opportunities and where excitement lies.
#2 Opportunity Mapping: Explore the organisation's challenges and opportunities and find early-stage solutions to the goals they identify.	**#2 Modelling Opportunities:** Explore and clarify a range of opportunities that relate and build towards your vision. Design-thinking activities help articulate ideas, clarifying impacts and consequences of innovation opportunities and their enablers.
#3 Road Mapping: Exploring the goals of the organisation in more depth, looking at the barriers and enablers. Create a roadmap of activities to help understand next steps.	**#3 Detailing the Opportunity:** Creatively probing different timelines and eventualities, user-journeys and stakeholder maps to develop a deep, holistic understanding of innovation readiness.
	#4 Transition Plan & Communications: Evaluate opportunity which has developed and make plan for the future development. Mentors support creating a plan of action to enable change and move positively towards vision, with clarity about how to communicate proposal to different audiences.
#4 Review: Drill down deeper, reflect on the process and the key learning points.	**#5 Unpack:** A series of direct prompt questions used to clarify and consolidate learning and hone entrepreneurial purpose.

Critically, the programme was designed to be delivered by local mentors who would shadow the UK team in the first delivery and who would be provided with comprehensive training resources and templates with which to run subsequent sessions. They would support participants between the sessions which would run in three-day blocks over the course of six months. The plan was that participants would be working in multidisciplinary teams developing a pre-existing business idea with which they may, or may not, have been trading.

2 METHODOLOGIES

Three methods of data collection were employed, the first two to aid understanding of the participant experience, the third to gain insights regarding the facilitators' perspectives.

A survey, conducted in a face-to-face setting during the final 'Unpack' session was undertaken with twenty-four participants, with a 100% return. The survey was designed to support participant reflection and to aid them in internalising their learning, whilst simultaneously acting as an initial data collection method. There were seven questions in all, with participants coached to consider in detail how they would now describe their business; who their stakeholders were and what matters to them; to think about immediate action plans; and what potential pitfalls that they should avoid. They were also asked to consider three open-ended questions: 'What have you learned?'; 'How have you changed?'; and 'What must you do next?'. Answers to these three questions informed this study. Written responses to the survey were collected so that they could be reviewed, coded and subjected to inductive thematic analysis.

Purposeful sampling was then used to engage six participants in semi-structured interviews which explored, in greater depth, the answers that they had provided to the survey. Field notes were made during these interviews, again to support thematic analysis.

Two co-reflective workshops involving the authors were conducted with an independent research assistant acting as scribe and also to help ensure that the risk of researcher-bias was minimised. The authors had all been involved as facilitators of the GRTIA programme, four were also involved in delivering GRTI in the UK and two were responsible for devising the original programme. The workshops were structured to promote collaborative reflection. The first, by working methodically through the GRTIA programme session-by-session, aided the facilitators in recalling the specifics of the programme and the participants involved. The second workshop explored each of the themes emergent from the analysis of participant data and considered these alongside the facilitators' own experiences enabling general conclusions to be drawn, backed up by participant evidence. Notes and direct quotations were captured in the form of virtual sticky-notes on a digital white board further aiding subsequent analysis.

The emergent findings were then considered in light of a broader data-set drawn from field notes taken during the original GRTIA workshops, notes of semi-structured interviews with young entrepreneurs, higher education leaders, business leaders and policy-makers all conducted by the authors in Armenia over the course of the GRTIA programme.

3 FINDINGS

The findings can be broken down into two quite separate categories: the self-reported strengths and limitations of the programme as experienced by the participants and the reflective experiences of the facilitators. We will initially consider these separately.

3.1 Participants' Perspectives

We find that the programme succeeded in helping participants develop in four main ways:

1. All twenty-four participants provided responses that indicated that the programme had aided them to establish clarity in the next steps to be undertaken as well as consideration and/or development of a strategic plan for their business.
2. Enhancing their creative confidence - by the end of GRTIA, field notes indicated that around 80% of participants had stated that they felt more confident to generate, articulate, analyse, criticise & share their ideas. In written survey responses, however, participants didn't specifically mention the term 'creative confidence', although 11 out of 24 mentioned characteristics that align with Kelley & Kelley's (2012) definition [1].
3. The programme's design and delivery allowed the participants to learn how to use new approaches (to them) such as Design Thinking (DT) and creative problem-solving. Specifically, nine mentioned DT, two creative problem-solving, and one both.
4. Uncovering the power of teamwork and multidisciplinarity, whether it was with stakeholders or with their teammates, as it challenged views and brought different areas of expertise to the table.

3.2 Facilitators' Perspectives

Co-reflection allowed the facilitators to consider how they had adapted the programme to suit the funder's enterprise education agenda and to explore what had gone well and what was lacking. In terms of what went well, achieving the participant outcomes set out above could all be considered successes, but it is important to look beyond these and to consider the backdrop against which they were achieved. The authors find:

1. A mismatch in the expectations of facilitators and participants – facilitators designed the programme to be delivered to existing teams with established business ideas. Participants joined the programme looking for guidance in how to establish teams and business ideas, with a clear emphasis on front-end stages of innovation
2. The local mentors, whilst exceptionally enthusiastic, experienced and engaged, did not share the same level of design knowledge or expertise as the facilitators. Thus, the dual challenges of introducing new concepts of design-led enterprise coupled with some linguistic limitations presented difficulties
3. The episodic nature of delivery (four, three-day blocks over six months) caused unhelpful inertia
4. Due to their different disciplinary backgrounds and limited experience, some participant teams lacked certain fundamental business know-how or knowledge which hadn't been anticipated in the programme design

The facilitators became aware of these factors as programme delivery progressed – this was an evolving story and one to which they had to respond in real-time.

4 DISCUSSIONS

We have seen that the design-led approach adopted in GRTIA did achieve the aim of enhancing creative confidence, but in considering the extent to which GRTIA usefully supported enterprise education in Armenia, we need to consider more broadly what successful enterprise education programmes might achieve and how design may contribute. The UK Quality Assurance Agency for Higher Education, QAA, states that the 'overall goal of Enterprise and Entrepreneurship Education is to develop entrepreneurial effectiveness'. They define enterprise as 'the generation and application of ideas, which are set within practical situations' and Entrepreneurship Education as 'the application of enterprise behaviours, attributes and competencies into the creation of [...] value' [7]. Jones et al (2014) suggest that enterprise education is 'positioned increasingly as the foundation of entrepreneurship education' [8] and, therefore, propose that the term Enterprise Education is used to refer to this collective domain. QAA presents a model towards entrepreneurial effectiveness which encompasses entrepreneurial awareness, competencies and mindset. Fundamental to developing the entrepreneurial mindset, confidence-building, as noted by Penaluna and Penaluna (2012), 'is crucial' [9]. As a minimum, then, growth in the confidence to generate, experiment with, and exploit ideas, can be seen as a measure of success of enterprise education.

4.1 Expectations

Aside from the evident mismatch in expectations described previously, it is worth considering other innate expectations that may be influential. We might term these cultural expectations and they relate to certain characteristics associated with prior educational experience and disciplinary alignment. Outside GRTIA, the authors were involved in action research to inform the production of enterprise education policy recommendations for Armenia. Through this, they gathered data from young entrepreneurs, higher education leaders, business leaders and policy-makers in Armenia regarding their experiences and expectations of the education system. This research suggested that they are familiar with a more didactic and theory-heavy approach than the dialectic, Socratic, and practice-based mode typical of the UK-based design education approach that underpinned GRTIA. Possibly more influential was the disciplinary upbringing 'constituting different signature pedagogies, mores and behaviours' [10] which can adversely influence both access to unfamiliar learning opportunities and multidisciplinary team interaction. This does not mean that the participants were unable to access or learn from GRTIA, but that they required more reassurance in the approach and adaptability on behalf of the facilitators to provide them the necessary scaffolding.

4.2 About Learning

It is easy to draw parallels between the aims, outcomes and approaches adopted in the Enterprise Education domain and those employed in design and innovation education. Indeed, QAA's aforementioned definition of enterprise could equally well be used as a definition of innovation. Further, QAA qualify their description of enterprise as combining 'creativity, originality, initiative, idea generation, design thinking, adaptability and reflexivity with problem identification, problem solving, innovation, expression, communication and practical action' all very familiar attributes that design and innovation education seek to develop. Further, Rauth et al (2018), [11] position DT as an effective model for education in support of enhancing creative confidence which Kelley and Kelley describe as lying "at the heart of innovation" as it requires us to face challenges and take risks [2]. Such confidence is closely related to Bandura and Jourdan's concept of self-efficacy - an individual's belief in their capabilities "to mobilise the motivation, cognitive resources and course of action", required to reach their goals [12].

Jones et al. (2019) propose that entrepreneurial agency ('the agency individuals demonstrate in directing their conscious thinking and action toward an alignment of their inner and outer worlds in order to succeed in life') is developed through a combination of pedagogic (educator-directed), andragogic (student self-directed) and heutagogy (student-negotiated) educational approaches [13]. The design of GRTIA, which relies on educator and learner engaging in a heutagogic approach, coupled with the innate Socratic orientation of the educators, was at odds with the cultural expectations of the cohort and this created a situation in which the educators had to be both adaptable and creative in real-time in order to support the different needs of the different learners (as well as the trainee mentors) in the workshop situations. The unique nature of design facilitation is of interest here as Mosely et al (2021) [14] suggest that '[d]esign facilitation is a highly complex, integrative, emergent practice that is innately linked to design process knowledge and understanding'.

The authors rely on this design process knowledge and understanding in their facilitation of such programmes and further research is indicated with regard to the potential of design facilitation as a pedagogic device.

Arguably, as seen in our findings, the design-led approach places greater emphasis on stakeholder needs and desires. Through re-framing ideas with a stakeholder lens, participants are encouraged to be more experimental with their ideas, and in doing so, gain more confidence both in the idea and themselves. This emphasis tends to focus attention on front-end innovation, ensuring that the challenge being addressed is the 'right' one and that the supporting value-proposition takes account of multiple perspectives. Indeed, none of our survey data mentioned any hard business outcomes resulting from involvement in GRTIA.

5 CONCLUSIONS

This research is limited in that there is no counterfactual analysis to tell us how these participants might have fared without GRTIA, the size of the sample group is relatively small and no longitudinal study into the long-term impact of the programme has yet been conducted. All of these factors represent further research opportunities.

We can see that on some levels the design-led approach did deliver. However, the programme, in not recognising cultural mismatches and expectations, or the need to scaffold learning more effectively with a blend of pedagogic content knowledge - 'the command of the content within a given domain' [8] with andragogic and heutagogic approaches made progress slower and more challenging. Arguably, the desired degree of transformation of a learner within this context may be too ambitious for such a short, episodic programme.

To keep the programme on track the facilitators had to be highly adaptable in real-time in order to create an environment in which participants felt safe to take creative risks. Carrion-Weiss et al (2021) suggest that participants perceive the design-facilitator's natural tendency to offer ideas as a means to draw-out knowledge, as generosity [15]. This approach of the facilitators meant that, when participants were struggling with aspects of the programme, facilitators were able to help them understand troublesome concepts by co-creating new knowledge (in the form of ideas) [10] about their own business proposition, thus making the concept more relevant to their situation and thereby more accessible.

How useful is this research and to whom? We suggest that two valuable contributions result from this:

- Adopting design-led approaches to enterprise education can enhance the creative confidence, stakeholder focus and future-focus orientation of participants. This is beneficial for those planning enterprise education programmes who hope to achieve some participant transformation at a mindset level
- For those planning such activities working with participant groups with diverse cultural backgrounds, disciplinary upbringings, or in an overseas location, detailed background research and planning is suggested together with investment of adequate time to fully understand the level and context within which they are operating.

The authors have continued to work together supporting the British Council's Higher Education Policy Dialogue sessions (facilitated by the authors using a very similar approach to GRTIA) and establishing and running a number of design-led innovation certificate programme projects. These action research activities are helping to build a broader picture of the role that design-led innovation approaches can play in enterprise education, creation and policy.

REFERENCES

[1] Kelley T. and Kelley D. Reclaim your creative confidence. Harvard Business Review, 90(12), 2012, pp. 115–118.

[2] Creative Fuse North East. Creative Fuse North East. Available at: https://www.creativefusene.org.uk/ [Accessed on 2022, 27 Jan] n.d.

[3] Lampitt Adey K., Bailey M., Carrion-Weiss J. and Gibbons F. Building entrepreneurial creative confidence in novice facilitators and enterprises, Proceedings of The International Association of Societies of Design Research conference: DESIGN REVOLUTIONS, Manchester, 2-5 September 2019, pp.163–177 (IASDR)

[4] Gribbin J., Spencer N. and Bailey M. A Rapid Design-Led Approach to Innovation Readiness: Advantages and Challenges. Design Management Journal, 13(1), 2018, pp.4-16.

[5] Bailey M., Dziewanowska K., Harney B., Mihelic K., Pearce A. and Spencer N. Beyond Disciplines: can design approaches be used to develop education for jobs that don't yet exist? In DS 93: Proceedings of the 20th International Conference on Engineering and Product Design Education (E&PDE 2018). Loughborough, October 2018, pp. 538–545 (Design Research Society, London)

[6] Bailey M., Harney B. and Pearce A. Designing a design thinking approach to HRD. International Journal of HRD Practice, Policy and Research. 4(2), 2019, pp.9-23.

[7] The Quality Assurance Agency (QAA) for Higher Education. *Enterprise and entrepreneurship education.* Available at: https://www.qaa.ac.uk/docs/qaas/enhancement-and-development/enterprise-and-entrpreneurship-education-2018.pdf?sfvrsn=15f1f981_8#:~:text=Enterprise%20is%20defined%20here%20as,of%20education%20and%20professional%20life. [accessed on 8 February 2021], (2018).

[8] Jones C., Matlay H., Penaluna K. and Penaluna A. Claiming the future of enterprise education. *Education + Training*, 2014, 56 (8/9), pp. 764-775

[9] Penaluna K., Penaluna A. and Jones C. The context of enterprise education: insights into current practices. *Industry and Higher Education*, 2012, 26 (30), 163-175.

[10] Bailey M. Supporting knowledge creation in design-led multidisciplinary education. Diss. University of Northumbria at Newcastle (United Kingdom), 2021.

[11] Rauth I., Köppen E., Jobst B. and Meinel C. Design thinking: An educational model towards creative confidence', In *DS 66-2: Proceedings of the 1st international conference on design creativity (ICDC 2010)*. Kobe, December 2010, (The Design Society).

[12] Bandura A. and Jourden F. Self-regulatory mechanisms for governing the impact of social comparison on complex decision making. *Journal of Personality and Social Psychology*, 1991 60(6), pp. 941–951.

[13] Jones C., Penaluna K. and Penaluna A. The promise of andragogy, heutagogy and academagogy to enterprise and entrepreneurship education pedagogy. *Education+Training*, 2019, 61(9), pp.1170-1186.

[14] Mosely G., Markauskaite L. and Wrigley C. (2021). Design facilitation: A critical review of conceptualisations and constructs. *Thinking Skills and Creativity*, *42*, 100962.

[15] Carrion-Weiss J., Bailey M. and Spencer N. Design Listening: what designers hear and how they respond. With Design: IASDR 2021 conference proceedings (in-press)

EXPERIENCES WITH EMOTIONAL DESIGN

Jeanette Helleberg DYBVIK
OsloMet, Oslo Metropolitan University, Norway

ABSTRACT
Emotional design is a designer method as well as a tool for transforming and analysing design objects during the process of design. The focus is on the emotion created between the design object and the user. The paper is further based on raising the awareness of the students of the design process and their reflections and experiences in relation to emotional design. The Design, Arts & Crafts students at the Primary School Teacher programme at OsloMet, the Oslo Metropolitan University, were given the task of designing a cup made of clay. They had to emphasize the various idioms that could give the cup a personal touch in both visual and emotional terms. This can help graduate students resolve challenges associated with the shaping and use of emotional design. The programme seeks out educational and learning experiences for developing pedagogical concepts and strategies that help newly graduated teachers cope with current and future challenges. Donald Norman refers to his theory of human cognitive and emotional characteristics that are linked to our experience of products. This is how you can explain human emotional relationships with products for achieving a deeper understanding of the user's total product experience. Everyday objects always have a history, a reminiscence and something that ties us emotionally and personally to this particular object, this special thing we have.

Keywords: Emotional design, emotion, design process, everyday objects and creative joy

1 INTRODUCTION
The content of the education at Oslo Metropolitan University (OsloMet) for design, arts, and crafts is based on what graduate teachers are going to teach in primary school. The teaching students were selected as participants because they should carry out a work requirement and the design project would help their practice as a graduate teacher. In this case share and improve design and education teaching and learning experiences with a focus on emotional design. This will also develop pedagogical strategies that help teacher students to meet new challenges in their upcoming teaching job.
In her article *Emotions and Design*, Helle Kristine Hoem writes about a broader understanding and method of the human aspects in product development: *'The way we relate emotionally to products and suggestions for how designers can utilise their knowledge of human emotional aspects in order to design products that appeal to a more nuanced user'* [1].
The research questions in this paper will be:
What experiences do teacher students in art, crafts and design get when they work with emotional design?

2 EMOTIONAL DESIGN AND THE DESIGN PROCESS
In this context, emotional design is a method for students in art, crafts and design when they act as designers. This is also a tool that allows students to subsequently analyse the design process. The focus is on the emotional aspect created between the design object and the user. Emotional design is a concept in the field of design. The students have designed a cup in clay and applied criteria for emotional design and the design process. Emotional design strives to create products that evoke appropriate emotions in order to create a positive experience for the user. To do this, designers evaluate the connections that can arise between the users and the objects they use as well as the emotions that can arise out of these. If they are strong, the emotions evoked by a product can affect a user's beliefs. Emotions play a key part in human ability to understand and learn about the world. Positive experiences arouse our curiosity, while negative ones protect us against repeating mistakes. According to Alexander Manu [2], humans form emotional connections with objects at three levels: the visual, behavioural and reflective one. A designer should address human cognitive ability at every level — in order to evoke appropriate feelings

and thus produce a positive experience. A positive experience can comprise positive emptions such as joy and trust or negative ones such as fear and anxiety. Emotional design appeals to the first reactions we experience when we see a product.

3 THEORETICAL APPROACHES: EMOTIONAL DESIGN

The main features have been borrowed from emotional design theory that describes emotional design. Here it is appropriate to borrow from the theories of Alexander Manu and Donald Norman.

3.1 Alexander Manu

Alexander Manu (1954) is a professor at the Ontario College of Art and Design. He has formulated a methodology he refers to as ToolToys. ToolToys are designs that communicate with the user's emotional side [3]. This emotional side furthers play through desire and joy. Designers must consider their role and the relationship between designer, product and user. It is important to establish direct contact between the end-user's positive experiences. This sees to emotional needs such as creativity, curiosity, wonderment, etc. Moreover, the designer creates good design that is tailored to functional needs.

3.2 Donald Norman

Donald Norman (1935) is a Professor of Cognitive Science. Topics within product design have been prominent throughout his writing, and he has focused on the relationship between product and user. Functionality and cognition hold particular relevance here. He has written about the emotional relationship between user and product in his book *Emotional Design, Why We Love (or Hate) Everyday Things* (2004)[4].

Don Norman's study of the emotional properties of the human mind distinguishes between three different levels in the brain.

- The automatic, pre-wired level referred to as *visceral design (inner automatic thinking and visual design)*.
- The part that contains cerebral processes governing everyday behaviour referred to as *behavioural design*.
- The contemplative (thinking) part of the brain, or *reflective design.*

These three levels are interwoven with each other, and it is impossible to create a design without involving all three of them. The components work together with human cognition and emotion. Each level plays different roles in the overall functioning of the human mind [4:21].

4 METHOD

The research questions were collecting data from a practical implementation. The students worked innovatively with the theme of emotional design, where they should design a personal cup designed in clay. And emphasize the different expressions that can give the cup a personal touch, both visually and emotionally. They should work with a design process with written reflections and answer some questions. The method also includes observation of the practical work. Students achieve a basic education that will equip them to teach emotional design in primary and lower secondary schools. Examines examples from a qualitative approach—research-by-design. Sevaldson presents a definition of *experimental practice*: 'The practice is experimentally changed and modified to explore and evolve concrete enquiries, research questions or effects' [5:28]. In this context, its research through the ethnological research method of participant observation [6:248-261], [7]. Research-by-design is used as exploration through practical creative work with clay in the design process, where one's own observations in an educational setting and the experiences of the students in the process with emotional design. Research-by-design is then implied in aesthetic terms [5]. The method is used to explore the students' engagement in material consciousness. In this context, it is interesting to note that Bresler emphasises that empathy, execution, and sensibility are qualities that are directly relevant to the research [8], [9]. According to Schön, reflection is silent and unconscious; therefore, it is difficult for the outside world to see when reflection is present [10]. This reflection involves a dialogue between the hand, the head, and regenerate experience through the sensory apparatus. The design project is based on Richard Sennett's[11], [9:120] use of the term 'engaged material consciousness', which is material consciousness that initiates a conscious, craft-based effort to achieve good quality work. This work is dependent on a curiosity about the materials at hand. Primary school teachers are also obliged to lay the foundation of knowledge for designers as well as for those who collaborate with them or who will utilise what they design.

5 DESCRIPTIONS OF THE STUDENT PROJECT

The students were supposed to design a personal cup in clay using emotional design. They had to emphasize the various idioms that could give the cup a personal touch in both visual and emotional terms. They were supposed to use the design process and build up experiences related to it. *The cups were supposed to further an experience of presence for the user through the sense of touch. An experience through an everyday ritual.* Working with the various surfaces of the cup, creating a solution that provides a good grip and drinking function. Figure 1.

35 students answered 4 questions. Underneath are some selected responses from the students. Their experiences were very individual.

Which feelings and emotions have you worked with when you were making the cup?

- 'I have worked with somewhat bleak feelings, anger and sadness. The colours of the cup show a dark exterior. This shows a contrast between how you can appear on the outside and how you feel on the inside.'
- 'My point of departure has been chaos and order. Organic so that the cup is more lively.'
- 'I have worked with joy, stress, excitement as well as harmony. I have employed tools such as repetition, contrast, texture and harmony.'
- 'The idea was to trigger an emotion in order to bring a sense of peace to a stressful everyday life.'

How did you emphasize the various idioms that could give the cup a personal touch in both visual and emotional terms?

- 'As far as emotions go, the cup is personal, because this is an emotion I have felt growing up a lot — an expressionless outside, but a screaming inside.'
- 'I used various tools to create texture and movement in the clay. I created a tactile surface, with a more exciting expression and personality.'
- 'I grew up in the woods and wanted to bring this nature into an everyday life that is otherwise full of asphalt. This makes me happy.'
- 'I believe that the shape and the "handle" give the cup a personal touch. I've never seen myself a cup with such a handle and such a shape. The cup's personal touch visually gives a personal touch emotionally. With different senses one can experience the cup whimsical and fun expressions. The colour of the cup emphasizes the playful shape.'

How have you worked to promote a presence for the user through touch and the surfaces of the cup?

- 'The cup furthers the user's inner state. The lower edge of the cup fulfils the function of a grip and will thus lie securely in the user's hands when using the cup.'
- 'I wanted to bring out a feeling of relaxation while using the cup and have therefore opted for a simple design where the user's touch and grip take centre stage.'
- 'When the cup is glazed, it will become completely round and smooth. It is also small; this can make you think of how you should hold it in your hands. You cannot just pick it up like an ordinary cup. I believe that this can help create an emotional presence for the user.'
- 'I think the cup evokes an emotion such as calm.'

Human cognitive and emotional characteristics are linked to our experience of products. What do you think about that?

- 'I think that the way we perceive products often corresponds to our cultural background and our associations to various objects. Therefore, people's cognitive and emotional characteristics will be based on their own experiences and cultural background.'
- 'I believe people will experience the product differently. Colours, for example, can speak and mean different things to different people. And the feeling of drinking from a cup and the meaning thereof can vary. For example, I find it pleasant to drink from a glass with an extremely thin edge.'
- 'The cup has a playful feel. This playfulness creates joy and a sense of adventurousness.'

Figure 1. Student creations, ceramic cups

5.1 Form and Function

Important considerations include the relationship between the shape, function, use and material properties of the products. This allows the student to communicate through the design. Product design is largely about identifying and then fulfilling a need. Creating a cup is a method of doing this that will help students develop their creativity and thinking skills in new ways.

5.2 Emotional Design

Emotion, agitation, feeling, affect are a person's reaction to experiences. Emotion is closely linked to a person's motivation. Cognitive (intellectual) conditions are important for emotions, as the respective person's interpretation — *in this case, the cup* — of the situation is decisive for determining which particular emotion is being triggered. For example, patterns can be inspired by nature's surfaces and symmetry or by medieval architecture and ornamentation. Design can affect our feelings. There are lots of products and solutions that create feelings in people. They may be pretty, ugly, exciting or vulgar. Products can also be neutral. Students were very conscious of what they wanted to achieve with their creations. They were aware of what kind of feelings they would play on and how they would affect recipients. This can be done using aesthetic tools such as shape, colour, sizes, etc. Some students went even further. They played with elements such as history, heritage, image, belonging, dreams, romance and much more.

6 FINDINGS

Students as designers should not just design objects in order to meet functional needs. They should think of the user as a whole and fulfil needs that go beyond what is visible. When it comes to feelings and emotions that the students worked with, they highlight the following: emotions, anger, sadness, chaos, order, disorder, stress, harmony, texture, contrast and harmony. A cup should not only be designed to have a good drinking function, but should also have properties — tactile, aesthetic — and meet the user's subjective needs. What is the surface of the cup like? What is the shape like? What is the colour of the cup? How is the handle designed? Via their theories, Jordan, Manu and Norman emphasize the need for a transformation of the role of the designer. What are the user's actual needs? Manu wants to give the designer a new role; he is preoccupied with the aesthetic aspect [2]. The students had to look for a meaning and a story in the design of the cup. Some of the students mention their own cultural background as meaningful. Students considered it important to shape a meaning in order to fulfil a user's needs. Most of the students were interested in designing a cup that had a functional grip. And the user's touch and tactile surface around the cup, and a smooth touch. For example, how to hold the cup, it can evoke an emotion as calm. Donald Norman identifies the user's emotional connection to the object [3]. The students experienced what meaning this had for the product — the design and expression of the cup. Some students mention colour as an important component. Colours speak different to different people.

To succeed in their design, the students used emotion as a tool. A criterion the designer must take into account to succeed. I will now detail Norman's three levels and note some observations and experiences.

6.1 Visceral Design
Visceral design is about appearance and what nature does to us. The cup here is an excellent example — the students have enjoyed creating it, in particular, when they were in the process of designing it. Visceral design may also have to do with advertising, folk arts and handicraft. It is about physical properties such as appearance and feeling. When the students were working with clay, they had experiences and automatic reactions that had to do with an immediate emotional impact.

6.2 Behavioural Design
Behavioural design is known as *The Design of Everyday Things*. Behavioural design is made up of four components: function, comprehensibility, user-friendliness as well psychological feeling. Feeling was the most important reason behind the product for some of the students. This is supported by Norman's theories. This leads to what Emotional Design means. Behavioural design is about the joy of creating. Focus areas here are both the process of designing the cup and the result. The zest of creation was visible in the ceramics workshop. Behavioural design is also about using. Achievement and own efforts played a key role for the students. This is the aspect of design that users in society focus on.

6.3 Reflective Design
Reflective design is about the motivation, rationalisation and intellectualisation of a product. Can the student tell a story about the cup? Does it appeal to the self-esteem and pride of the student? The students liked to show how the cup works and explain how the appearance of the cup shows its condition. The cup also shows us a reflection. It is perhaps not beautiful, and it is most certainly not useful, but what a wonderful story it tells!

6.4 Visceral, Behavioural and Reflective Design
These three, extremely different dimensions are intertwined in each and every design. It is not possible to design without the involvement of all three. But more importantly, note how these three components intertwine with both emotions and cognition[3:6]. Emotions are an inseparable and necessary part of cognition. Everything we do, everything we believe is coloured by emotions, much of it at a subconscious level. Older emotions change the way we think and function as a constant guide for appropriate behaviour, leading us on a path away from the bad and guiding us towards the good. The students felt that certain objects evoked strong, positive feelings such as love, connection and happiness.

6.5 ToolToy as Playful Motivation
One of the challenges facing the teacher is to choose materials and tools that give the students opportunities for playful and emotional forms of expression. Some students writes that the cup has a playful feeling. This playfulness creates happiness and a sense of adventurousness. Further senses such as whimsical and fun expressions. ToolToys is a method formulated by Alexander Manu[2] for showing the designer the need for redefining the design process. Play and its value expand the perspective of design. The students experienced the usability associated with the pleasures of the play, which Manu considers to be important in relation to user experience. Tool represents a function and a need; Toy represents a desire. The design process is re-evaluated by the designer; in this case, the student, where play takes centre stage. This is a method for the student as a designer to design a cup that gives the user pleasure. Play can bring positive qualities to people. The students amassed knowledge of materials and showed playful approaches to making choices about the kind of emotional expression they should give the cup.

6.6 Creative Joy
Creative joy is a topic that became visible in the course of creation of the cups. Emotion and creative joy are triggered by the joy of creative work. Students who have had their own experience and perception of the emotional design process of an everyday object experience creative joy. This is how we can say that creative joy is associated with the process of mastering. What gives creative joy to one person does not necessarily give the same good feeling of mastering to another person. The process of creating a cup, an everyday object, results in a visible production. The problem-solving of the design process leads to creativity and deeper emotional competence. Donald Norman opines in *Emotional Design. Why we Love (or Hate) Everyday Things* that to produce the best effect possible, objects must bring joy to the owner [3:17]. As is the case with Donald Norman's theories, the emotional processes govern the

cognitive. Aesthetically beautiful products generate good experiences [3:15]. The students experienced that the favourite cup they made themselves feels much better than other cups. I saw that the students were glad about working with clay and creating an everyday object. I noticed that some of the students felt that the shaping of the clay can bring out a meaning, an emotional expression or a message using a variety of instruments

7 CONCLUSIONS

The students in art, crafts and design have designed a personal cup, whereby they have gained experiences in emotional design. They have experienced the cup getting a personal touch, in both visual and emotional terms. Some have emphasized presence so that the user would get a "here-and-now" experience through touch. Most of them have worked with the various surfaces of the cup, and most have created a solution that provides a good grip and drinking function. Four components in behavioural design: function, comprehensibility, ease of use and mental feeling [4]. For the students, emotion was important. What was new in this study was that the students were supposed to identify and solve a need, that they experienced the joy of creation and applied a playful approach. Moreover, some of the students were more conscious of what they wanted to achieve with what they were creating. Individual students became aware of the kind of feelings they would play on and how they would affect the recipient. Most of the students experienced, via Manu's theory, that a tool is a function and a need, while toy is a desire [2]. The student as designers experienced that play takes a central role. This is a method for the student as a designer to design a cup that gives the user pleasure. The students gained different experiences with emotional design. The students in arts gained the basic understanding through the work with emotional design. I saw that students showed joy in working with clay and creating an everyday object [11]. I saw that the students experienced that shaping in clay can bring out a meaning, an emotional expression. In this experience students achieved a basic education that will equip them to teach emotional design in primary and lower secondary schools. I will argue that emotional design is a field for further exploration. It can further be investigated how students experienced this basic understanding about emotional design. Importantly, patterns were inspired by nature's surfaces, and symmetry, architecture and ornamentation were of relevance for the work process. This can be done using aesthetic tools such as shape, colour, sizes, etc. Some students went further on by playing on elements such as history, culture, image, dreams, romance, peace, etc. They were overjoyed of having crafted a product, a cup, with which they were satisfied. Students as designers amassed experiences and understanding that emotional design can be of major relevance for how the user receives objects.

REFERENCES

[1] Hoem H. K. *Emosjoner og design En utvidet forståelse av menneskelige aspekter I produktutvikling*, 2005, Institutt for produkt design, NTNU.

[2 Manu A. *Towards a New Model for Industrial Design.* Design DK 1999,

[3] Manu A. *From Tools to Toys – Industrial Design in the 1990´s. Design for the Future* CETRA 1992

[4] Norman D. A. *Emotional Design. Why we love (or hate) everyday things.* (New York: Basic Books, 2004)

[5] Sevaldson B. A systems approach to practice research in design. *Discussions & Movements in Design Research*, 2010, 3(1), pp. 28. doi: http://dx.doi.org/10.7577/formakademisk. 137.

[6] Atkinson P. and Hammersley M. Ethnography and participant observation. *Handbook of Qualitative Research*, 1994, 248–261.

[7] Hammersley M. and Atkinson P. Ethnography: principles in practice (3rd ed.), 2007 (Routledge, London).

[8] Bresler L. Towards connectedness: aesthetically based research. *Studies in Art Education*, 2006, 48(1), 52–69. Available at: http://www.tandfonline.com/doi/abs/10.1080/00393541.2006.11650499?needAccess=true. [Accessed on 2 February 2018].

[9] Knowles J. G. and Cole A. L. (Eds.) *Handbook of the Arts in Qualitative Research: Perspectives, Methodologies, Examples and Issues,* 2008 (Sage Publications, Los Angeles).

[10] Schôn D. A. The reflective practitioner: How professionals think in action. *International Social Work*, 1983, 28(1), 53-55. doi:10.1177/002087288502800110

[11] Sennett R. *The Craftsman*, 2008, (Penguin Books, London).

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

DO AS I DO, NOT JUST AS I TELL YOU: TAKING STUDENTS ON A RESEARCH JOURNEY

Matthew Alan WATKINS and Maryam Bathaei JAVARESHK
Department of Engineering, Nottingham Trent University, United Kingdom

ABSTRACT
This paper explores four key case studies involving 2nd and final year BSc Product Design students in academic research projects, engaging with the public, industrial clients, and the public sector on live externally funded research projects. Undergraduate students are often taught how to undertake research or required to engage in meaningful primary research on their own projects. However, the opportunity for students to engage on real live projects working alongside academics is explored in this paper alongside the benefits and pitfalls of engaging in such projects as active design researchers. The case studies range from 2018 to the present day and concern two Road Safety projects and a Circular Economy study. Students were led through a research process as apprentices collecting and analysing their own research alongside academics, receiving guidance and support from a range of qualitative research techniques including interviews, observations and focus groups. A key benefit of conducting research collaboratively is that students gain a genuine appreciation and understanding of the rigour required in research. The inclusion of undergraduate students also demystifies the research process for the students and has benefits for the academics and external agencies involved.

Keywords: Research process, live projects, case studies, qualitative techniques, cognitive apprenticeship

1 INTRODUCTION
In recognition of the importance of undergraduate research emerging from the US [1 2] as a result of the Boyer Commission over the past 20+ years [1] as well as the long-established dissertation or capstone project in the UK [1]. There is a growing emphasis and requirement for undergraduate students to incorporate primary research within their dissertations or capstone projects. However, such requirements are becoming ever more challenging due to the increasing numbers of undergraduate students, further compounding the difficulties of access to appropriate research participants and actors [3]. Such issues can invariably lead to students' overuse and reliance on poorly executed quantitative surveys or questionnaires [4], commonly posted on social media as a tokenistic measure to fulfil this requirement. Such quantitative measures often lack the rigorous consideration of appropriate demographic sampling [4] required for representative quantitative analysis and leave students with an incomplete understanding of the robustness and rigor that is required in research studies. This can give a false impression and even confidence at the point they are due to graduate and start their careers lacking an understanding of the fullness of academic research.
This paper presents a rich qualitative research approach instead and details opportunities undertaken with 2nd and final year BSc Product Design students to involve them in real life active research projects through a cognitive apprenticeship model [5]. The cognitive apprenticeship model emphasises the traditional 'Master' and 'Apprentice' approach whereby the lead academic transfers expert knowledge to students modelling research behaviours to improve and develop the students' expertise and skills via collaborative learning in contextual activities [5]. Four cases are given as examples on how this has been developed over a 4-year period, presenting models of engaging by involving students in real life research practice through live projects. The approach adopted provides close mentoring and supervision to students to give them a realistic and robust research framework, within which to conduct their own research amongst research and academic staff as apprentices, demonstrating the use of appropriate qualitative research methods, with the required rigour in a safe and nurturing environment.

The premise behind a cognitive or research apprenticeship approach is not new and is noted as being used with undergraduate students in human services [2], the sciences [5] and psychology [6 7] and is also described as being applicable to creative subjects [5]. Furthermore, the ideal of a 'Master' 'Apprentice' model in design is as old as design education itself being a cornerstone of the discipline, relating to the Bauhaus. However, the inclusion of undergraduate Product Design students as active user centred researchers, in collaboration with commercial, industry and council partners lacks documentation.

Guberman et al., (2006) describe 6 responsibilities of mentoring in scientific research, these are outlined in table 1 below, with an indication of which actors performed what role for the students involved in the research.

Table 1. Mentoring UG students in research (adapted from Guberman et al., 2006)

Role	Responsibility	Agent
Advisers	People with career experience willing to share their knowledge.	External Stakeholders
Supporters	People who give emotional and moral encouragement	Peers
Tutors	People who give specific feedback on one's performance	Academic
Masters	Employers to whom one is apprenticed	Academic/PI
Sponsors	Sources of information about opportunities and aid in obtaining them	Research Assistant Research Fellow
Models of identity	The kind of person one should be to be an academic or a professional scientist	Research Assistant Research Fellow

This paper considers several opportunities made available to students to engage them meaningfully within the research process using qualitative research methods alongside active mentoring. The interventions described go beyond the realm of traditional live industry projects as previously explored [8]. These case study interventions encourage students individually to adopt both 'inquiry-based learning' and 'problem-based-learning' approach [1]. Being involved as active researchers in real life research and or consultancy projects with academic staff and researchers, as opposed to solely 'problem-based-learning' in live projects where students typically in groups are provided with pre-prepared research and background. Including students in this way gives them first-hand experience and rich insights into qualitative user centred design research, providing students with a real-life understanding of what is involved rather than relying on superficial attempts at survey based quantitative research as described above [4]. Qualitative research methods are ideal, due to their potential for small sample sizes and rich data, introducing UG students to a thorough approach to sampling, data collection and rigorous analysis methods giving them a more complete and appropriate understanding of user centred research approaches relevant to the Product Design discipline.

2 METHODOLOGIES

This paper explores the inclusion of students on live funded research and or consultancy projects, offering students the opportunity to engage with external stakeholders including experts in industry, councils, and public research participants. The study represents a series of projects from 2018 to 2021, with the students involved being engaged in qualitative research studies, conducting interviews, focus groups and observational research. Each of the students involved was supported by an academic supervisor who was research active and 1-2 researcher assistants or fellows depending on the project in question. The project supervisor was the principal investigator on the funded projects who acted as in the role of 'Master' and 'Tutor' [5 7 9]. Whilst the research assistants or fellows acted in roles of 'Sponsors' and 'Models of Identity' [7 9].

The students' engagement and involvement in such project ranged as follows:

- 2017-18 – Eight 2nd year students worked alongside a research fellow and project supervisor on a Circular Economy Study of Children's Toys [10]. The students undertook a structured plan of research tasks under the supervision of the academic, as more novice students require greater structure [9]. They engaged in a range of data collection including interviews of store owners, parents and childcare workers, simplified life cycle analysis and the implementation of CE analysis tools developed by the research fellow [11].

- 2018-19 - Two final year students were involved in a consultancy funded cycle safety research. They assisted on a cycle safety day in the running of four mixed HGV driver and cyclist focus groups and an exchanging places event with HGV drivers and urban cyclists. In addition, the students also conducted their own semi-structured interviews of HGV drivers, driver trainers, local council planners and cycling representatives to inform their projects. Their experiences fed into their live capstone project with a large multinational construction materials and logistics company designing safety innovations for HGVs and cyclists respectively.
- 2019-20 – An individual student worked alongside the Road Safety Research Group including his project supervisor and two researchers investigating and trialling the effectiveness of new road flooding signage in Nottinghamshire. This student had previously been involved as a second year in 2017 toys research and was keen to be involved in further live research opportunities, rising to the challenge, and demonstrating a far higher level of autonomy. This project involved liaising with the local road management agency and the County Council, with the student attending and preparing materials for focus groups, meetings, undertaking expert interviews, conducting observational research on site visits, and being involved in a funding pitch to the council for the continuation of the work.
- 2019-20 – Two students were involved in an industry funded research project, that focused on cycle safety, building on the earlier 2018 work. The students' live capstone projects focused on developing innovative safety warning for HGVs. The students' work involved liaising closely with the industry sponsor, their HGV drivers and cycling infrastructure experts at Transport for London, with the students conducting semi-structured interviews, observation research on site visits and travelling in their vehicles. These students were also invited to attend a very high-level management meeting regarding cycle safety at the company HQ.

The students involved in the above projects were approached in early 2022, typically 18 months to 2 and half years after they graduated. Five were sent a message on LinkedIn by their project supervisor requesting their reflections on the experience both in relation to what went well and what could be improved. Four students responded all of whom are now in graduate level employment in the automotive or aerospace industries and each provided between half and a whole page of insight. The delay in seeking these reflections meant that they also have reflected on and contextualized their experience in relation to their career since.

3 DISCUSSIONS

Whilst involving undergraduate students in live research projects introduces an element of risk, the students in all cases rose to the challenge with the utmost professionalism and robustness in their approach and behaviour, with the external stakeholders viewing the students very positively, engaging with them as research assistants and treating them accordingly. Whilst there was a difference in the engagement autonomy as expected between the 2nd year and final year students, all students benefitted from the experience and reflected positively on the opportunity to be included.

Through engaging with live research projects, the students recognised the opportunities this brought in being able to access individuals in high level positions that they wouldn't usually be able to reach and engage with [3]:

"Providing links to people with a lot of both experience and knowledge around the subject, a good example of this was 'senior manager' for Transport for London. I personally believe that without being involved in this research project, it would have been very difficult to get a meeting with him, however as he was able to see that it was part of a research project, we were taken seriously" (S1)

Students also attended and sat in on very high-level executive meetings giving the students tremendous insight into the project and company and client policies.

"During this meeting we were also looking to secure some funding from the council to help fund the project going forward, involvement in this meeting was extremely helpful in knowing how to phrase and ask questions to get the best response from council members who hear pitches like this on a daily basis" (S2)

In addition, the demographic sample and observation experiences that students were exposed to was far richer because of being involved on a live research project.

"*This gave me a strong pool of people to interview and discuss their concerns and ideas around the topic, directly feeding my research and the direction of my project" (S3)*

"The supervisor's knowledge of how to arrange a focus group, how to find the best sample of drivers and how to keep the drivers engaged during the focus group made the event into a success and helped us gather valuable data we would never have found otherwise. I know from speaking to other students on my course who held focus groups without the help of a lecturer that theirs were no way near as successful and the data they collected was not as helpful to their project." (S2)

"When working on a cycle safety project around HGV's I found it incredibly valuable to be exposed to and able to explore 'company' fleet first-hand and be able to take journeys in their vehicles."

The experiences and insights gleaned from these opportunities also increased the students' confidence, knowledge and insights benefiting both their projects and subsequent employment.

"Away from the major project my involvement with 'company' was a beneficial selling point when applying for jobs post-university. Being able to demonstrate the ability to work successfully with industry was picked up on by companies in the application process." (S4)

Furthermore, the benefits to the both the academic staff and external stakeholders involved included additional resource and the ability to explore additional smaller projects that the students engaged with as part of the project.

4 CONCLUSIONS

These case studies describe the inclusion of students on live funded research projects demonstrating how undergraduate students can engage in meaningful projects gaining valuable experience, knowledge and insights whilst also benefitting live research projects from a resource perspective enabling additional complementary projects to be undertaken alongside the main study. Furthermore, involving students in qualitative research enabled students to engage with richer understanding of experiences, phenomena, and context and provided them with an opportunity for them to collect, analyse and interpret data in a robust way that couldn't be reduced to numbers [12].

Our findings showed that the experiences of the students and external stakeholders was positive in all respects, the inclusion of students as apprentices in the research greatly benefited the existing relationships and provided further opportunities for collaboration and in some cases providing additional student projects in subsequent years alongside new or existing funded research with the same external partners.

The exercise as performed with the final year students undertaking their capstone projects was more natural and effective than that performed with the 2nd year students in a studio project, who required a more structured and focused task. The key distinctions were in the maturity of the final year students who, having completed a placement, were two years older, in addition to the fact that the capstone project was longer and more valuable to their degree outcome. These aspects were demonstrated through high levels of autonomy, greater responsibility for their work, a pro-activeness in following leads and engagement with the researchers in developing the breadth of their projects accordingly, a difference even evident in the student who had completed both.

5 FUTURE WORK

Following the success of this approach, further postgraduate curriculum development has enabled bespoke live research opportunities to be included on a suite of new MSc Engineering courses. In a 20 credit Research Methods module as part of their qualitative research methods instruction all students are given the opportunity to be participants in focus groups on live research projects to gain an enhanced understanding of the approach. Further opportunities for individual capstone project opportunities as explored in this paper will also be continued where possible in future.

ACKNOWLEDGEMENTS

The authors also wish to thank the following students who gave their valuable insights and reflections provided for this paper: Daniel Perez, Tobias Jarratt, Alex Merrick, Joseph McCracken. Plus, the research staff who supported the students so well: Dr Ana Mestre, Joseph Meeks, and Paul Watts.

REFERENCES

[1] Healey M. and Jenkins A. (2009). *Developing undergraduate research and inquiry*. Higher Education Academy.

[2] Fair C., King C. and Vandermaas-Peeler M. (2004). *A cognitive apprenticeship model of undergraduate research in human services.* Human Service Education, 24(1), 61–68

[3] I'Anson R. A. and Smith K. A. (2004). *Undergraduate Research Projects and Dissertations: issues of topic selection, access and data collection amongst tourism management students.* Journal of Hospitality, Leisure, Sport and Tourism Education, 3(1), 19–32.

[4] Grant D. and Grant C. (2017). *Missing out: Does Masters Students' Preference for Surveys Produce Sub-Optimal Research Outcomes?* In European Conference on Research Methodology for Business and Management Studies (pp. 484–487). Academic Conferences International Limited.

[5] Vandermaas-Peeler M., Nelson J., Ferretti L. and Finn L. (2011). *Developing expertise: An apprenticeship model of mentoring undergraduate research across cohorts.* Perspectives on Undergraduate Research Mentoring, 1(1), 1–10.

[6] Maunder R. E., Gordon-Finlayson A., Callaghan J. and Roberts A. (2012). *Behind Supervisory Doors: Taught Master's Dissertation Students as Qualitative Apprentices.* Psychology Learning & Teaching, 11(1), 30–38. https://doi.org/10.2304/plat.2012.11.1.30

[7] Guberman J., Saks J., Shapiro B. and Torchia M. (2006). *Making the Right Moves: A Practical Guide to Scientific Management for Postdocs and New Faculty* (L. Bonetta (ed.); 2nd ed.). Burroughs Wellcome Fund, Howard Hughes Medical Institute.

[8] Watkins M., Ebbert C., Arthur L. and Attwood E. (2017). *Collaborating with impact: A live industrial product design project.* Proceedings of the 19th International Conference on Engineering and Product Design Education: Building Community: Design Education for a Sustainable Future, EPDE 2017.

[9] Thiry H. and Laursen S. L. (2011). *The Role of Student-Advisor Interactions in Apprenticing Undergraduate Researchers into a Scientific Community of Practice*. Journal of Science Education and Technology, 20(6), 771–784.

[10] Watkins M. and Mestre A. (2021). *A comparative and exploratory study of toy products in the circular economy*. In N. F. Nissen & M. Jaeger-Erben (Eds.), PLATE: Product Lifetimes and The Environment 2019 (pp. 835–842). Universitätsverlag der TU Berlin.

[11] Mestre A. and Cooper T. (2017). *Circular Product Design*. A Multiple Loops Life Cycle Design Approach for the Circular Economy. The Design Journal, 20(sup1), S1620–S1635.

[12] Anderson C. (2010). *Presenting and evaluating qualitative research*. American journal of pharmaceutical education, 74 (8).

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

GROUP IDEATION WITH BRAINWRITING – A COMPARISON OF CO-LOCATED AND DISTANCE COLLABORATION

Markus VOß[1], Hulusi BOZKURT[1], Thorsten SAUER[2] and Marc NUTZMANN[2]
[1]DHBW Cooperative State University Mannheim, Germany
[2]DHBW Cooperative State University Ravensburg, Friedrichshafen, Germany

ABSTRACT
This article examines the influence of physical proximity (co-location vs. distance) and the medium (paper vs. online) on idea generation. It especially focusses on a popular brainwriting technique – namely Method 6-3-5. For this, an experiment with altogether $N = 134$ Engineering Design students was conducted. The results show that the mode of interaction generally does not bias the quantity of ideas generated, but that the rate of graphical representations drops slightly.

Keywords: Creativity, idea generation (Ideation), conceptual design, brainwriting techniques (Method 6-3-5), distance collaboration

1 AN UNFORESEEN CHANGE IN COLLABORATION
During the coronavirus pandemic, the modes of collaboration in the working world in general and of engineers and product developers in particular drastically changed. Also in academia, all actors faced a hitherto unparalleled challenge. From literally one day to the next, confinement regulations urged many learners and educators to switch over from conventional classroom teaching to unexplored online formats. This article studies the role of idea generation under these changed circumstances.

2 METHOD 6-3-5, A COMMONLY USED BRAINWRITING TECHNIQUE
Idea generation takes place in the early phases of design and is crucial for the rest of the process. Numerous techniques have been developed for structuring idea generation. This article concentrates on a popular technique for brainwriting – called Method 6-3-5 – which dates back to the end of the 1960s and which is attributed to Rohrbach [1].

The digit sequence 6-3-5 gives the method a telling name that refers to how it should be implemented, see Figure 1: The method is designed for $n = 6$ group members, usually gathered physically round a table. Each of the participants receives a printed form. The worksheet mainly consists of a table (with $n = 6$ rows and $c = 3$ columns). In the first iteration, every participant looks individually for $c = 3$ solutions. The three developed solutions should be described in the first row of the table. Each solution thus fills one field. In the most current interpretation, the number 5 in the name of the method contains a recommendation for how long this individual working phase should take – namely 5 minutes. The moderator (or a designated group member) should assure timekeeping and make corresponding announcements, cf. [2].

Then the form is handed over to the next group member, e.g., clockwise. During the whole session, the group members should not change seats, and neither alter the order nor the direction in which the forms are passed on round the table. Now, each group member develops further three solutions and describes them in the second row of the table. After every five minutes, the forms are passed to the next person in the round until all six rows of the form are filled with solutions.

The complete turnaround thus takes just half an hour. Considering the short amount of time it needs, Method 6-3-5 leads to a particularly high number of solutions. One could say that scarcity of time creates 'creative stress'. Amabile et al. [3] call that phenomenon 'creativity under the gun'. The maximum number of distinct solutions that a group can create during a brainwriting session corresponds to the total number of fields on the worksheets. Thus, the $nc = 6 \times 3 = 18$ fields on $n = 6$ worksheets contain up to $n^2c = 108$ solutions (if all fields are completed, of course). Another inherent advantage of that brainwriting method is that it does not consume any extra time for documenting the solutions.

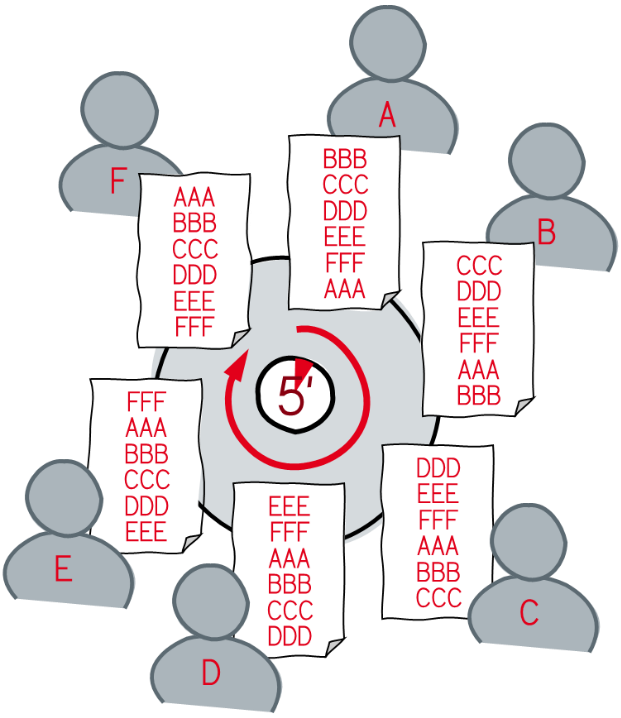


*Figure 1. With help of Method 6-3-5 **six** group members generate **three** ideas each within **five** minutes per round*

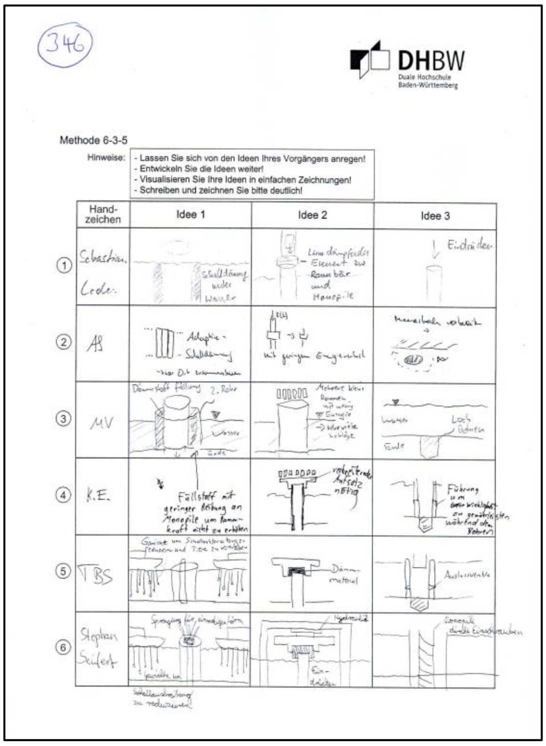


Figure 2. Fully completed brainwriting paper form from the workshop

When receiving a form sheet, every group member is free to feel inspired by the solutions already described above. In this way, the solutions can be refined bit by bit. Ideas can be picked up by others, developed further, seen under changed conditions, be complemented, sectioned, parallelised and even inverted. On the other hand, there is no obligation to bear associations to the ideas of others in mind when formulating new ideas. If desired, simply a new idea can be introduced.

Of course, creativity cannot be maintained endlessly. It is reported that the idea productiveness in creativity workshops already drops noticeably after a quarter of an hour, see Figure 3. Typically, participants collect rather conventional ideas during that first wave. If a workshop uses other creativity techniques that require an experienced moderator, a decline in the frequency in which participants utter their ideas is often an indication for a new impulse should be set. But interventions of that kind would rather interrupt the workflow when working with Method 6-3-5. Inspired by Yilmaz et al. [4] we experimented in previous research [5] instead if heuristics can serve as 'cognitive shortcuts that encourage exploration of novel directions. The current experiment is interested in exploring how this characteristic evolves without such an intervention. Interestingly, the time needed for a complete turnaround in Method 6-3-5 coincides with the moment where finally creativity drops drastically (after – according to experience – innovative solutions were created in a second wave), as also depicted in Figure 3.

In contradistinction to conventional brainstorming where associations are uttered freely (and sometimes at top of the voice), Method 6-3-5 is a rather 'silent' creativity technique, see Figure 4. This comes in handy for 'taming' dominant participants and for encouraging persons that are more withdrawn. This combination of collaborative and individual elements of working within one technique is broadly seen as a major advantage of Method 6-3-5. It is also said that, compared to 'jumpy' and 'whirling' discussions in brainstorming sessions, participants work far more systematically with this brainwriting technique. The other side of the coin is that Method 6-3-5 for sure engenders less 'creative dynamics' in the workshop since the group members do not interact directly but just in the writing process.

Another disadvantage of the method is that fields left empty at the top by a team member tend to 'propagate downwards' in the worksheet since the succeeding team-mates have less rich inspiration. 'Empty fields are contagious', can be concluded.
Finally, an obvious but imposing advantage of Method 6-3-5 in design-related disciplines is that its format allows visualising ideas in simple annotated sketches. This obviously supports visual communication, provided that all participants write and draw clearly, of course.

3 EXPERIMENTAL APPROACHES

Is the finding of creative solutions in a virtual environment as easy as in co-located workshops? In order to find out how important physical proximity (co-location vs. distance) and the medium (paper vs. online) are in the field of ideation, we conducted an experiment. We embedded the experiment in our Engineering Design lecture taught in the fifth semester of our three-year Mechanical Engineering bachelor's programme at DHBW Cooperative State University.
Altogether $N = 134$ Engineering Design students participated in the experiment. $N = 78$ of them gathered in a common classroom setting and worked on paper forms. The workshops took place during the pre-Covid academic years 2016 to 2019 and four cohorts with altogether 13 groups were engaged. The size of most of the groups was six, as preferably required for Method 6-3-5. But as the division in groups did not always come out even, a few groups consisted of four, five or seven students. Figure 2 shows an exemplary paper form, filled in manually by a student work group during the workshop.

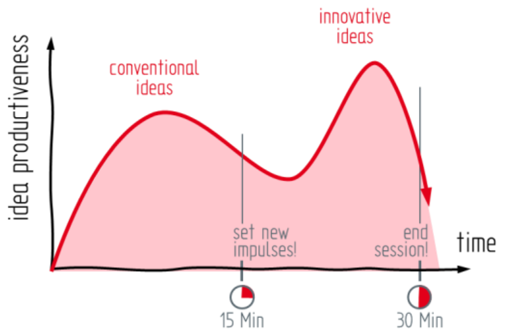


Figure 3. Typical characteristics of the idea productiveness during creativity workshops

Figure 4. Method 6-3-5 reconciles individual with collaborative ideation

The experiment was repeated in the academic year 2020 when no presence gathering was possible. The $N = 56$ students of that cohort had to collaborate in a virtual environment. The students were split up into ten groups. Seven had the ideal group size of six participants, but for the known reasons two groups were made up of five and one of four students respectively. For the workshop we prepared digital worksheets in a browser-based online collaboration whiteboard tool named Conceptboard [6], see Figure 5. Apart from the collaboration mode, the virtually collaborating study group worked under the same conditions as the one gathered in situ. The brief for the workshop was unchanged.
It is a common misunderstanding that people can be more creative if they are told as little as possible about a problem. Brem [7] maintains the contrary: 'As a rule of thumb, the more specific the question, the higher the chance for concrete and directly usable ideas.' Therefore, the problem was framed adequately in a design brief. The experiment confronted students with a real-world large-scale application: a research platform on offshore wind farms in the North Sea and the Baltic that rests on a monopile, cf. [8]. The group assignment asked the students to explore innovative noise abatement measures to prevent marine mammals (mainly porpoises) being harmed by ramming the monopiles 30 metres deep into the seabed during construction, cf. [9]. During the interventions, the students were not told about the solution applied in the real project.

4 RESEARCH QUESTIONS

For studying if an alteration of the way in which the workshop participants meet (co-location vs. distance) and on which medium they communicate (paper vs. online) influences the ideation process the study in hand investigates more specifically the following research questions:

(Q1) Does idea productiveness drop when the participants are physically isolated?
(Q2) Does the change of media influence the repartition of textual and graphical representations?
(Q3) How does idea productiveness evolve during the workshop time?

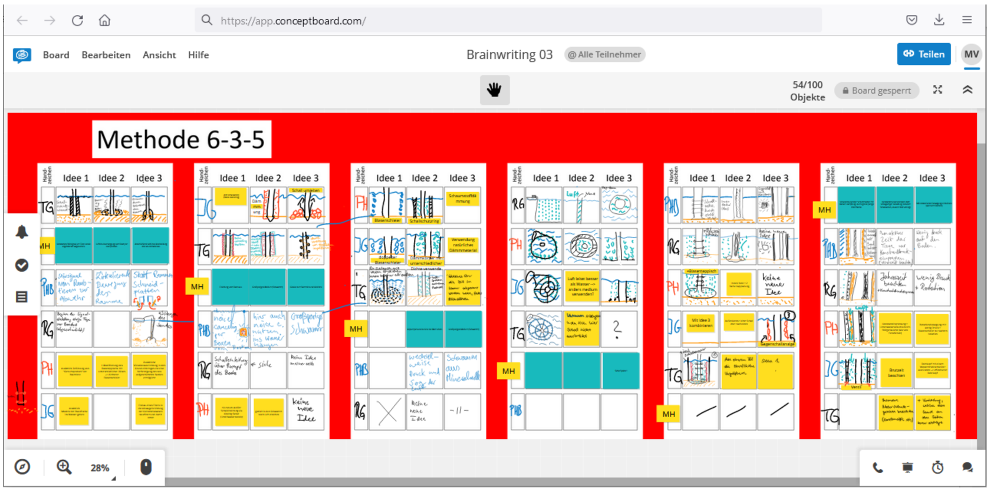


Figure 5. Brainwriting in the online collaboration tool Conceptboard [6]

5 RESULTS

The presented research is based on a close inspection of the worksheets produced in the experiment and is using quantitative metrics. For analysing if idea productiveness has been affected, the number of fields $\bar{x}$ left empty and the number of fields x completed were counted on the n worksheets of a group.

$$\bar{x} + x = n^2c = 108 \tag{1}$$

If the group size deviated from the standard group size $n' \neq n$, the field count ($\overline{x'}$ signifying empty fields and x' completed fields) had to be normalised correspondingly by the correction factor $(\mathrm{n}/\mathrm{n}')^2$.

$$\left(\overline{x'} + x'\right)(n/n')^2 = n^2c = 108 \tag{2}$$

For displaying how many fields the groups left empty and completed respectively, the corresponding numbers $\bar{\mathrm{x}}$ and x were related to the total number of fields $\mathrm{n}^2\mathrm{c}$, see Figure 6. From the results, it can be concluded that the alteration in the mode of interaction and change in the medium did not affect idea productiveness. In average the paper-based working groups that gathered in presence completed $\mu_{x/n^2c} = 84$ % of the worksheets and the virtual meeting groups using the digital tool even a bit more (86 %). With a standard deviation $\sigma = 11$ % the results from the group working on paper 'scattered' marginally more than those from the group working digitally ($\sigma = 7$ %) but were still comparable.

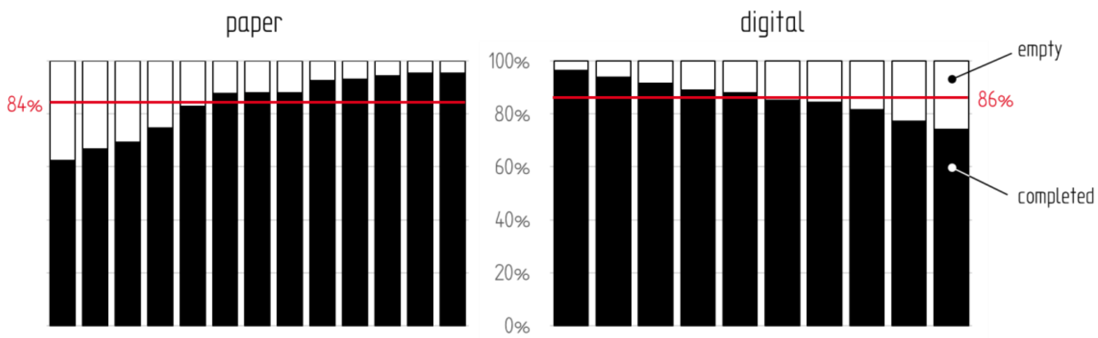
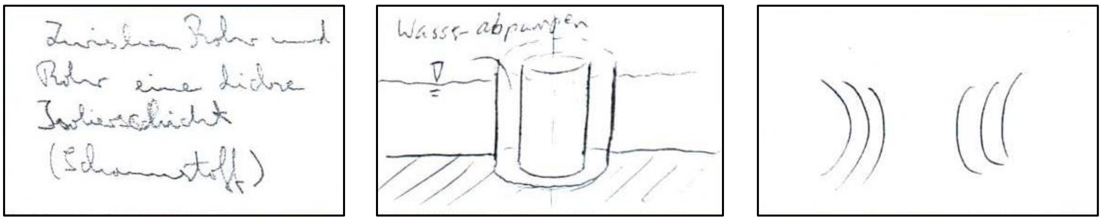


Figure 6. Distribution of the empty and completed fields on the worksheets as a measure for idea productiveness

For measuring if the amount of pure textual description has increased with the switch to digital tools, all worksheets were re-examined and the number of fields t containing textual and g graphical elements was counted, cf. Figure 7. Annotated drawings that blend graphical representations and textual descriptions were accounted as graphics. As a relative measure, the respective field count (normalised if necessary) was related to the corresponding number x of non-empty (i.e., completed) fields.

$$t + g = x \tag{3}$$



(a) (b) (c)

Figure 7. (a) Textual description, (b) annotated drawing and (c) graphic from students on paper worksheets

On the digital whiteboard, different types of text production were encountered, see Figure 8. Some students (a) used the available text editor in the web-based tool, while others (b) improvised and wrote with the computer mouse or could – if they owned tablets or notebooks with tactile displays – (c) write directly by hand. All three of them have been classified as pure text in the examination.

(a) (b) (c)

Figure 8. Text production (a) using text editor, (b) written with mouse and (c) handwritten on the virtual collaboration whiteboard Conceptboard

The results revealed that, compared to paper based-work, digital tools increased the use of textual elements by around 9 %. While on paper an average of $\mu_{t/x} = 40$ % text fields was found, it was 49 % on the digital whiteboard. An obvious reason for this deviation is that not every student had a suitable graphical input device (e.g., a notebook computer with a stylus pen) within reach in this impromptu workshop.

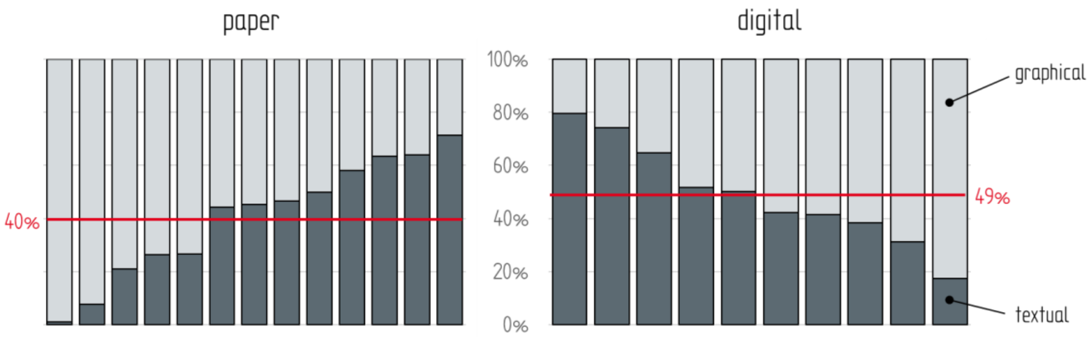


Figure 9. Use of textual and graphical representations in the experiment

To find out how idea productiveness evolved over the duration of the workshop, a further examination counted non-empty (i.e., completed) fields. Since every row $\forall i \in [1, n]$ corresponds to a time interval $t_i = (i - 1, i]5$ min, the field count was split up row-wise (again normalised for non-standard groups). As a result, the characteristic curve in Figure 10 is nearly identical for both study groups (paper and digital) over time. Nevertheless, contrary to the expected characteristics described in literature, cf. Figure 3, the diagram does not exhibit any significant 'rebound effect' in the second half of the timeline. Instead, the curves decline steadily from around 95 % during the first to 72 % during the last time interval.

Whereas interpreting the ‘resurgence of ideas’ in a qualitative way, this study can partially validate this expected characteristic. Because interestingly, some teams managed to develop a solution that comes close to the one applied in the real-world project. The latter attenuates the noise with help of a ‘bubble curtain’ around the monopile sprayed from a ring-shaped pipe installed on the seabed, cf. [10]. In all three cases where the evolution of ideas led to a bubble curtain-like solution, the decisive idea appeared in the second half of the workshop.

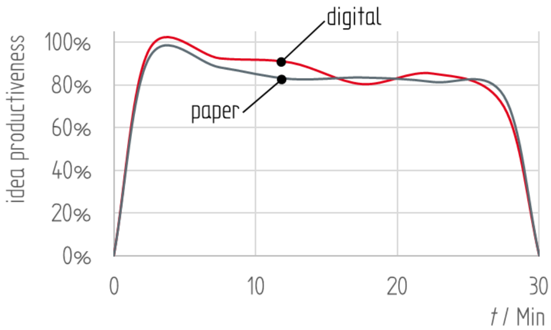


Figure 10. Experimental findings on the idea productiveness during the brainwriting sessions

6 CONCLUSIONS

With our experiment we could prove that – seen from a quantitative angle – participants are equally productive in a brainwriting workshop regardless of their mode of collaboration (co-location vs. distance) and their medium of communication (paper vs. online). At the same time, we observed a drop of graphical representations of about 9 % in online meetings. Which is nonetheless highly remarkable, since our students neither have been trained at length using the online tool nor have been equipped with special graphical input devices. Regarding the quantitative evolution of idea productiveness during the 30-minute workshops we could not confirm the hypothesis from literature assuming that idea productiveness rises to an even higher level after decreasing temporarily towards the half of the workshop.

REFERENCES

[1] Rohrbach B. Kreativ nach Regeln. Methode 635, eine neue Technik zum Lösen von Problemen (In German: Creative by rules. Method 635, a new technique for solving problems.). *Absatzwirtschaft*, 1969, 19, 73-75.

[2] Pahl G. and Beitz W. *Engineering Design, a systematic approach*, 1996 (Springer, London).

[3] Amabile T.M., Hadley C.N. and Kramer S.J. Creativity under the gun. *Harvard Business Review*, 2002, reprint R0208C.

[4] Yilmaz S. Daly S.R., Seifert C. and Gonzalez R. Comparison of Design Approaches between Engineers and Industrial Designers. In *International Conference on Engineering and Product Design Education, E&PDE’13,* Dublin, September 2013, pp. 178-183 (Design Society, Glasgow).

[5] Voß M., Sauer T. and Bozkurt H. Using design heuristics in idea generation. Does it take expertise to benefit? In *International Conference on Engineering and Product Design Education, E&PDE’14,* Enschede, September 2014, pp. 574-579 (Design Society, Glasgow).

[6] *Conceptboard Cloud Service*. *Company website.* https://conceptboard.com/.

[7] Brem A. Creativity on demand. How to plan and execute successful innovation workshops. *IEEE Engineering Management Review*, 2019, 47(1), 94-98.

[8] *FINO3. Research platform in the North Sea and the Baltic No. 3*. https://www.fino3.de/en/.

[9] Gerdes F. *Acoustic field. Investigating the spatial and temporal variability of the acoustic field at FINO3 while recording the presence of porpoises*. https://www.fino3.de/en/research/acoustic-field.html.

[10] Rolfes R. *Minimising noise for mammals. Research and application of minimisation measures when driving the FINO3 monopile*. https://www.fino3.de/en/research/noise-protection.html.

DEVELOPMENT OF ASSISTIVE TECHNOLOGIES TO ADDRESS THE NEEDS OF INDIVIDUALS WITH MILD COGNITIVE IMPAIRMENT IN THE PURSUIT OF INDEPENDENT LIVING

Young Mi CHOI[1], Wendell WILSON[1], Brian JONES[2], Jennifer DUBOSE[3] and Kayci VICKERS[4]
[1]Georgia Institute of Technology, School of Industrial Design
[2]Georgia Institute of Technology, AWARE Home Initiative
[3]Georgia Institute of Technology, College of Design
[4]Department of Neurology, Neuropsychology Section, Emory University School of Medicine

ABSTRACT
Mild Cognitive Impairment affects significant numbers of people aged over 65. It is growing in prevalence and poses many challenges to independent living. This project examines the case of a multidisciplinary group of subject matter experts engaging graduate design students to investigate and solve specific challenges in this area. Goals included exploration of new solutions and enhanced training of the student participants. Results highlight the importance of end user involvement in development and training.

Keywords: Mild cognitive impairment, assistive technologies, industrial design, independent living, iterative design process

1 BACKGROUND
Mild Cognitive Impairment (MCI) is a clinical condition characterized by subtle cognitive decline in one or more domains of cognition (e.g., memory, executive function, etc.) without significant functional impairment [1]. While people with MCI retain the ability to take care of their basic needs, studies have found that there is a noticeable decline in their abilities to perform Instrumental Activities of Daily Living (IADLs) [2]. IADLs are activities that require multiple steps and tap into executive functioning, so they are the first activities impacted by cognitive declines. Examples of IADLs include shopping, managing finances, maintaining appointments, and keeping track of objects. Most often, an MCI diagnosis is applied when an individual has a suspected or confirmed underlying neurodegenerative disorder (e.g., Alzheimer’s disease), and MCI represents an intermediate stage between the expected cognitive decline of normal aging and dementia. MCI affects 15-20% of people over the age of 65 [3] and is growing in prevalence. Of those diagnosed with MCI, 14.9% will go on to develop dementia in 2 years and relative risk of dementia 2-5 years after MCI diagnosis was 3.3x that of those without MCI [4].

Although there is no cure for MCI, current treatments focus on longitudinal monitoring of cognition and functional status, reduction of modifiable risk factors (e.g., cerebrovascular risk factors, depressed mood, and medication effects), and engagement in lifestyle behaviours that support cognitive functioning [5-8]. Specifically, healthcare professionals are encouraged to counsel individuals with MCI to engage in regular exercise and cognitive stimulation [4, 9, 10] and growing evidence supports the use of comprehensive behavioural interventions, such as that offered at Cognitive Empowerment Program (CEP), to provide maximal benefit.

The Cognitive Empowerment Program (CEP) at Emory University educates members and caregivers on strategies to compensate for cognitive decline. The CEP is exploring how technology can further this training and support for members during everyday activities at home. As specific areas of design needs are identified, they present opportunities to further define the background and basic design requirements for project briefs that may then be presented to student design courses [11].This project is a collaboration between the CEP, the Wireless Inclusive Technologies Rehabilitation Engineering Research Center

(Wireless RERC) and the Georgia Tech Aware Home Research Initiative (AHRI). The goal was for subject matter experts to define design requirements & opportunities to engage students.

2 METHOD

The student design project was conducted within a graduate design studio class in the School of Industrial Design at Georgia Tech. This particular studio was comprised of first year graduate students who come from non-design backgrounds and were completing a foundational training year of study in design. The multidisciplinary team comprised of subject matter experts from AHRI and CEP provided problem briefs detailing specific challenges experienced by individuals with mild cognitive impairment (MCI) in living independently. Two student design teams of three members (6 total students) were formed to address the two major issues outlined in the following briefs “Item Tracker Pad” and “Ambient Alerting/Cueing”:

2.1 Item Tracker Pad Brief:

Individuals with MCI frequently lose items due to memory difficulties. This can be a huge source of frustration for the individual with MCI as well as their care partners, who may need to assist with finding the objects. In cognitive rehabilitation, individuals are trained to keep important items in a single location that is located near a site where the item will be used (e.g., keeping keys near the door) in such a manner that it is difficult to miss or overlook (out in the open, often a bright colour). The most frequent example of this is creating a spot near the door where an individual keeps the items they need when leaving the house – this could include some combination of a purse/wallet, keys, cell phone, calendar/schedule, eyeglasses, and hearing aids.

2.2 Ambient Alerting / Cueing Brief:

Individuals with MCI often have difficulties keeping up with everyday activities at home due to the cognitive difficulties they experience, including things like forgetting, declines in problem solving, and trouble completing complex tasks that require multiple steps. Moreover, some individuals with MCI experience depression or other mood difficulties, which can interfere with task initiation and follow through. For example, individuals with MCI may forget to take medications without assistance, neglect household chores or complete them incorrectly, and even may struggle to complete safety-related tasks like turning off the stove or locking the doors without reminders. Many of these activities are difficult to track and do not have built-in feedback about whether the individual completing the task did so correctly, which presents a problem for both individuals with MCI and their spouses or care partners. Presently, many care partners report that they are either the ones to complete these types of activities (e.g., they are the only ones who cook or will administer medications to the individual with MCI) or that they must always check to ensure the tasks have been completed. This can result in a decrease in feelings of autonomy and empowerment for the individual with MCI, can lead to reduced peace of mind for the care partner, and can cause tension in their relationship.

The assigned goal for each team was to conduct sufficient background research (through literature and interaction with subject matter experts) in order to adequately understand the problem, the needs of the users, the state of the art of current solutions and related technologies that might be leveraged to develop proposed solutions to address the needs of users. Due to COVID 19 restrictions and time constraints, it was recognized that any design solutions resulting from this study would be conceptual in nature, being presented digitally without physical prototypes needed for subsequent testing/validation.

Once the teams sufficiently understood the needs of their users, they developed basic problem statements and objectives to guide subsequent design efforts. Both teams presented their background research, problem statements and design goals to the class and project sponsors who provided feedback and further guidance. The teams then undertook an iterative design process to develop solution proposals. The final design proposals were then presented and evaluated by subject matter experts (3 in total).

Two surveys were distributed after the project: one to students and one to the expert evaluators. The goal of the student survey was to understand their background and previous experience with the topic, learn how the design was executed and tested, determine what was learned, and find out how students rated their designs. The expert survey was aimed at more objectively assessing the designs and to learn more about the stronger or weaker aspects of the final designs and to compare the perceived outcomes between the two groups.

3 RESULTS & DISCUSSION

A total of 6 students and 3 expert reviewers participated in the project. The students were divided into two teams: “Ambient Alerting” and “Lost Item Tracking”. Each team developed a proposed design solution to the objectives outlined in the project briefs – as illustrated in Figures 1 and 2:

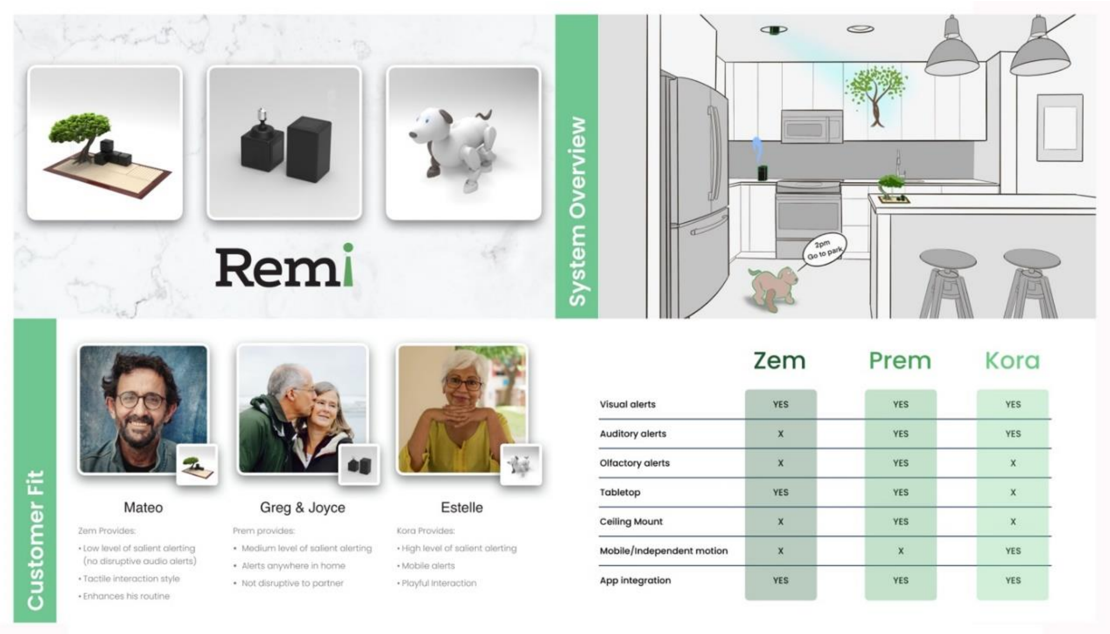


Figure 1. Final design solution developed by “Ambient Alerting” team

Figure 2. Final design solution developed by “Lost Item Tracking” team

Four students (two from each team) completed a post-project survey. As a part of this survey students were queried as to whether they felt they had increased their knowledge of the needs of individuals with MCI, what methods they had used in an attempt to understand the needs of individuals with MCI, and how students perceived the effectiveness of their designs. Questions were multiple choice where answers were on scales of: (a) yes/no; (b) A lot/some/none; (c) completely/mostly/somewhat/not at all.
The 3 subject matter experts involved with the project also assessed the output of each of the two student teams. The expert survey contained 3 questions mirroring the last three on the student survey in order to contrast the student perception with those of practitioners, compare how well the design objectives were met, and to gauge the actual level of student learning. The subject matter experts also provided written assessments of each team’s design.

Table 1. Results of post project survey

Question:	**Team:**			
	Lost Item Tracking Team		Ambient Alerting Team	
	Student (n=2):	Expert (n=3):	Student (n=2):	Expert (n=3):
Ever known or provided care for someone with MCI?	1 with experience		None	
Simulation strategies or devices employed during design process?	No		No	
Did you speak directly to persons with MCI?	During initial research & design		No	
Overall knowledge of MCI needs BEFORE project?	2-Knew a little bit		None	
Overall knowledge of MCI needs AFTER project?	2-Knew a little bit		2-Knew a little bit	
Do you feel better equipped to discover needs for very different user groups after project?	Mostly, Aware of need to learn more		Mostly, Aware of need to learn more	
Methods used to understand MCI user needs during project?	Literature research, SME interviews, MCI user survey & interviews		Literature research, SME interviews	
Were observation, surveys or other methods used to understand user needs?	No		No	
How effective does solution meet project brief objectives?	Mostly	1-Completely 2-Mostly	Mostly & Somewhat	1-Mostly 2-Somewhat
How effective does solution meet MCI user needs?	Mostly	3-Mostly	Mostly	2-Mostly 1-Somewhat
How practical is the design for MCI users to integrate into their lives?	Somewhat	2-Completely 1-Mostly	Mostly & Somewhat	1-Not practical 2-Somewhat

The expert reviewers rated the "Lost Item Tracking" team's designs more highly in general with respect to meeting original project objectives, meeting user needs, and practicality. Interestingly the students on this team rated their own performance in these areas somewhat lower than the experts. This team included a member with a friend/family member with MCI. This was also the team that engaged users with MCI during concept development. One or both of these factors may have contributed to the improved design. Deeper engagement with real user issues may also have contributed to the student perception that their design could be better because they were able to uncover more detailed and nuanced problems.

The "Ambient Alerting" team rated their design effectiveness somewhat higher than the expert reviewers. This team had no prior experience with MCI and did not engage users directly. Their lack of prior personal experience may have contributed to a perception that direct user engagement was not as necessary to discover needs and issues faced by individuals with MCI. By not engaging users, it likely prevented the team from discovering detailed or non-obvious needs, reducing the effectiveness of their design and the perception that their final solution was better than it was.

It was also suggested by the expert reviewers that, since the range of MCI limitations varies significantly, a more meaningful survey of student learning and design effectiveness should assess specific user capabilities or pose a series of questions focusing on the needs of MCI sufferers of different limitations.

4 CONCLUSIONS & RECOMMENDATIONS

One of the biggest distinctions between the teams' outcomes was the engagement of users with MCI. The team that did (Lost Item Tracking) minimized their assessment of outcomes (meeting objectives, effectiveness of the solution, and practicality). Experts evaluated this team's output the same or higher. The team that did not engage users (Ambient Alerting) tended to give higher self-evaluations of their outcomes compared to expert reviewers. There is much which can be learned through experience, background research and second-hand observation. This can still be insufficient to expose the nuance of a use case and lead to expectations that a design solution is better than it actually is. This was supported through the expert reviewer feedback to both teams:

The design solutions from both teams demonstrated an appreciation for the delicacy needed to support people with cognitive challenges while respecting their knowledge and intelligence. As a person with MCI noted, the solutions were not 'punitive'. Design solutions from both teams maintained a high degree of flexibility for users, which is especially important for integration in their lives. Both teams did a remarkable job developing solutions that were respectful of the intended users and addressed the challenges experienced by people with mild cognitive impairment, especially considering limitations on interactions with stakeholders due to COVID precautions preventing face-face interaction and making it more difficult to grasp the impact of MCI as well as to solicit input and feedback on ideas. (In similar class projects done prior to COVID, students were able to meet with people living with MCI and their care partners and were often invited to visit their homes. Within the scope of this project, teams were not able to meet with people face-to-face and that certainly made.

While the "Lost Item Tracking" team's "Colour Block" concept (Figure 2) *benefited from its simplicity, the integration of technology was "somewhat forced" and "unclear". Individuals with MCI typically prefer the opportunity to customize product(s) to a greater degree to fit with the existing aesthetics of their homes. Additional technical work is needed on the "Colour Block" product to develop the interactivity needed to encourage the user to pull out a cubby to retrieve an item and to push it in once an item is returned. Through user testing and greater automation of cubby components, it may be possible to identify a mechanism which removes the need for people with MCI to remember to move blocks when an item is taken or replaced. Working with users could help determine how the audio reminders would work (what would trigger it, the content of message(s), and if it would change (depending on the status of objects). Overall, this design was extremely responsive to the needs with people with MCI and would be easy to integrate into the lives of individuals with MCI and provides a great basis for supporting compensatory strategy training focused on use of the colour block. With further design development, this is a viable product for people with MCI.*

The Ambient Alerting team's solution "Remi" (Figure 1) product system is further from completion, requiring substantial design & engineering development. While the range of products would allow for expansion as the needs and abilities of users with MCI change and the product suite could be helpful for keeping track of appointments, it does not address the issue of alerting people to risks around the house. (Note from authors: the team assumed the use of IOT enabled appliances, integrated with the system to provide such alerting). *This team would benefit from more input from potential users to fully understand the problem space. People with MCI should be asked to provide examples of types of things they want to be reminded about and what kind of systems, both paper-based and electronic, that they are already using to keep track of appointments, if that is what they want to be reminded about. Similarly, the Remi system will need to identify the role that the care partners will play in the reminder system and adjust designs accordingly. Overall, this design was mildly responsive to the specific needs of people with MCI and would likely be somewhat difficult for many people with MCI to integrate into their daily life. The design relied heavily on interfacing with technology (e.g., entering digital appointments), which many older adults find challenging. Given this, the care partners of people with MCI would likely be interacting with these technologies more often than the people with MCI. Although this can support autonomy and daily function, this design would benefit from simplification so dyads can determine the extent to which interaction depends on the member versus the care partner and to provide greater autonomy for high functioning individuals diagnosed with MCI.*

Suggestions for future projects of this nature include additional instruction on the needs and issues faced by individuals suffering with MCI. Further efforts should facilitate direct communication between students and individuals with MCI to better understand relevant design parameters and to facilitate input and feedback within an iterative design process. A longer project duration that allows prototype fabrication for usability testing would be ideal. While 2D representations are helpful, they do not replace what can be learned through prototype-based testing.

REFERENCES

[1] Petersen R. C. (2011). Clinical practice. Mild cognitive impairment. *N Engl J Med, 364*(23), 2227-2234. doi:10.1056/NEJMcp0910237

[2] Jekel K., Damian, M., Wattmo C. *et al.* Mild cognitive impairment and deficits in instrumental activities of daily living: a systematic review. *Alz Res Therapy* **7,** 17 (2015). https://doi.org/10.1186/s13195-015-0099-0

[3] Heister D., Brewer J. B., Magda S., Blennow K. and McEvoy L.K. Alzheimer's Disease Neuroimaging Initiative. Predicting MCI outcome with clinically available MRI and CSF biomarkers. Neurology. 2011 Oct 25;77(17):1619-28. doi: 10.1212/WNL.0b013e3182343314. Epub 2011 Oct 12. PMID: 21998317; PMCID: PMC3198979.

[4] Petersen R. C., Lopez O., Armstrong M. J., Getchius T. S., Ganguli M., Gloss D., Gronseth G. S., Marson D., Pringsheim T., Day G. S. and Sager M. 2018. Practice guideline update summary: Mild cognitive impairment: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. *Neurology, 90*(3), pp.126-135.

[5] Anderson-Hanley C., Barcelos N. M., Zimmerman,E. A., Gillen R. W., Dunnam M., Cohen B. D., Yerokhin V., Miller K. E., Hayes D. J., Arciero P. J. and Maloney M. 2018. The Aerobic and Cognitive Exercise Study (ACES) for community-dwelling older adults with or at-risk for mild cognitive impairment (MCI): neuropsychological, neurobiological and neuroimaging outcomes of a randomized clinical trial. *Frontiers in aging neuroscience*, *10*, p.76.

[6] Kalbe E., Roheger M., Paluszak K., Meyer J., Becker J., Fink G. R., Kukolja J., Rahn A., Szabados F., Wirth B. and Kessler J. 2018. Effects of a cognitive training with and without additional physical activity in healthy older adults: a follow-up 1 year after a randomized controlled trial. *Frontiers in aging neuroscience*, *10*, p.407.

[7] Yang C., Moore A., Mpofu E., Dorstyn D., Li Q. and Yin C. 2020. Effectiveness of combined cognitive and physical interventions to enhance functioning in older adults with mild cognitive impairment: a systematic review of randomized controlled trials. *The Gerontologist*, *60*(8), pp.e 633-e642.

[8] Sherman D. S., Mauser J., Nuno M. and Sherzai D. (2017). The efficacy of cognitive intervention in mild cognitive impairment (MCI): a meta-analysis of outcomes on neuropsychological measures. *Neuropsychology review*, *27*(4), 440-484.

[9] Gavelin H. M., Dong C., Minkov R., Bahar-Fuchs A., Ellis K.A., Lautenschlager N. T., Mellow M.L., Wade A. T., Smith A. E., Finke C. and Krohn S. 2020. Combined physical and cognitive training for older adults with and without cognitive impairment: A systematic review and network meta-analysis of randomized controlled trials. *Aging Research Reviews*, p.101232

[10] Xu Z., Sun W., Zhang D., Chung V. C. H., Sit R. W. S. and Wong S. Y. S. (2021). Comparative effectiveness of interventions for global cognition in patients with mild cognitive impairment: a systematic review and network meta-analysis of randomized controlled trials. *Frontiers in aging neuroxcience,* p13.

[11] Jones B., Gupta N., Persaud E. and Phillips C. (2021). Rapid design of inclusive wireless technologies: a participatory workshop process. *Assistive Technology*, 1-7.

COMPUTATIONAL DESIGN, ADVANCED VISUALISATION, AND THE CHANGING NATURE OF CAD

Lewis URQUHART, Konstantinos PETRAKIS and Andrew WODEHOUSE
Department of Design, Manufacturing and Engineering Management, University of Strathclyde, Glasgow, United Kingdom

ABSTRACT
Computational design and advanced visualization are two key avenues of development that are changing the landscape of CAD for engineering designers and much of the work in computational design has been pioneered and applied most enthusiastically in the field of architecture. Known informally as the 'computational turn' that started to make a significant impact around the early 2010s, the associated modelling methods can significantly affect the methodology for the construction of CAD geometry and the nature of forms that are achievable. When combined with VR and AR interfaces, these allow potential designs to be explored in 3D and in real time to further affect the design process. To this end, relevant literature and emerging trends will be set out. A case study will then be presented based on the PRIME-V2 research project, which is concerned with the delivery of bespoke VR controllers to allow users to perform physical rehabilitation. The main insights derived in terms of the design process, capturing user requirements, generation of bespoke data, prototyping and testing, and technical limitations will be highlighted. The implications for the delivery of CAD teaching for postgraduate engineering designers will then be considered. This will be via the experience in redesigning a module at the University of Strathclyde. Titled 'Product Modelling and Visualisation', the module has sought to move beyond basic feature creation skills towards an understanding of where and how advanced computational techniques can be deployed in the design process at large.

Keywords: Computational design, visualisation, CAD, design process

1 INTRODUCTION
Teaching of CAD is an essential part of product design engineering courses. However, simply learning to use a basic parametric system for the construction of geometric models is no longer enough. Given the rapidly shifting nature of the CAD landscape, and in order to provide more strategic contributions, graduate design engineers should understand the rationale behind how models are constructed and have an awareness of how emerging techniques can be deployed within industrial settings.

This paper firstly sets out the history and context of CAD. It then describes two important aspects of development that are changing the landscape of CAD for design engineers: computational design and advanced visualization. Computational approaches to CAD differ from conventional practices in the level of dynamism and intelligence present in the construction of the geometry. Often constructed using visual programming paradigms and utilising interactive technologies such as VR and AR, it offers new possibilities in both modelling and interaction through the design process. In terms of design education, this has implications for the teaching of CAD and for the way in which facilities are presented to students. A number of illustrative examples are outlined via the PRIME-VR2 project on VR for rehabilitation. In the generation of novel control interfaces, this work has used computational approaches in order to create bespoke and optimized design configurations. The effect of an algorithmic approach on the design process, as well as instances of design detaining and model interaction, are described.

Secondly, the paper reflects on the pedagogy of CAD. How can we teach both the basic skills of CAD and convey its context, use and application in a single-semester class? We have approached this by providing a foundational exercise designed to be attainable for novice users, but with enough creative opportunities for more advanced users: cutlery. While at first glance this is a basic challenge, the details of tines, contours of surfaces, joining details etc. provide a range of challenges in achieving a truly convincing design, and a great deal of flexibility in the rendering thereof. The rationale for the configuration of the module is set out, and a number of recommendations on the future teaching and use of CAD in design engineering education provided.

2 CONTEXTS OF CAD

2.1 History and emerging trends

CAD is a form of digitally displaying geometric information and principally emerged as a way to emulate the practices of the professional draughtsman. Principally, it took the system of lines and coordinates used to create representations in a physical drawing and translated that into computer code that could be visualised and interacted with directly using computer hardware [1].

The key breakthrough in CAD methods was the application of NURBS (non-uniform rational b-splines) into the software architecture, which allowed for the definition of free-form surfaces such as complex curves to be modelled. This advance led to a rapid transition to feature-based model making and structuring CAD through a process of parameterization. This meant that the models could be built using a “tree” of interrelated features allowing designers to establish dimensional constrains and explore design space more freely.

As CAD modelling has become more complex, there has been more of a push towards menu-driven interaction with highly-developed user friendly interfaces, but it remains a demanding task to become fluent in a particular CAD package [2, 3]. In contemporary use of CAD, we can identify two key developments: algorithmic modelling and advanced interaction (Figure 1). One is related to the logic and intelligence implicit in the construction of the design model. The other is oriented around crossing the physical-digital barrier and effective means of digital capture, communication and visualization allowing designers to explore design space more easily and fully.

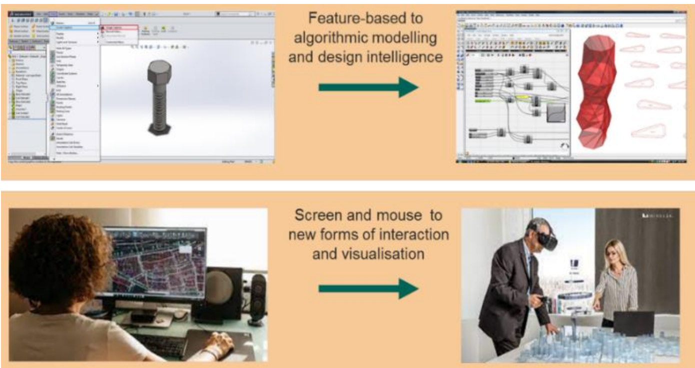


Figure 1. Algorithmic modelling (top) and interaction trends (bottom)

Computational design is a new way of generating form in CAD. Much of the work in computational design has been applied most enthusiastically in the field of architecture [see 4]. Known informally as the “computational turn” that has its foundations in the topological optimisation strategies developed from the 80s, it has made a significant impact in the last decade, with the associated modelling methods able to significantly affect the methodology for the construction of CAD geometry and the diversity of forms that are achievable. Although terminology is somewhat fluid within this field, Stasiuk’s [5] breakdown is useful; **parametric design** - creating geometry through a hierarchical, feature based model**, computational design** - creating geometry though a logic-based algorithm and **generative design** - creating multiple options through recursive development and intelligence within design system. “Generative design” is a narrower description but can be thought of as a subset of computational design where the solutions are more open-ended and will emerge from the solving process.

It is best to approach understanding computational models by making direct reference tools and perhaps the most widely used is the Rhino 3D plug-in Grasshopper. Grasshopper facilitates complete command over the parametric build of the 3D model, allowing the designer to directly control the geometric constraints and build the logic of the model in a precise way they desire. The command over the geometric data can then be combined with form finding algorithms (of which there are many available as applications within Grasshopper itself and freely downloadable).

When combined with VR and AR, computational methods allow potential designs to be explored in more dynamic ways such as direct use simulation or in-situ visualisations. Grasshopper itself presents an interesting way of constructing CAD where the designer can use a range of drag and drop functions, connection nodes and value sliders to edit the model parameters. Taken into a VR context, this process becomes even more interesting whereby the designer can view and interact with the concepts in specific environments and settings. Conceptual work in VR interface design has demonstrated this potential in the context of design reviews for example [6]. Furthermore, architects are increasingly using VR to properly visualise and experience the spaces they design, and the fashion world is experimenting with the use of AR all of which present opportunities for interface reimagining and pedagogical considerations [3].

2.2 Case study: customised VR controllers

A range of computational design approaches have been adopted in the PRIME-VR2 EU project (https://prime-vr2.eu/), mostly utilizing the Rhino-Grasshopper (https://www.grasshopper3d.com/). The project is concerned with the delivery of bespoke VR controllers to allow users to perform physical rehabilitation tailored around their specific therapy needs. Furthermore, it seeks to create an integrated environment that starts with the biomechanical scanning of a user, through the generation of bespoke CAD, to the parameterization of the virtual environment in which the user interacts.

2.2.1 Design methods in PRIME-VR2

In order to explore how new methods in computational and algorithmic design are influencing practical design work, we can unpack the methods utilized within PRIME-VR2. PRIME-VR2 partially follows the path of traditional design methodologies; relying on research, iterative conceptualisation and feedback that informs subsequent developments. Though in other ways, the methods employed are much more novel and innovative. Critically, the project takes a novel approach to the generation of product form and the workflow in which CAD is generated. As the main aim of the project is to create bespoke designs tailored around the individual user, ergonomic and other biomechanical data has been crucial in structuring the design methodology. We can summarise the key stages as follows; **1) definition of abstract spatial boundaries 2) integration of unique ergonomic data 3) algorithmic exploration of design space 4) final design decision and CAD refinement.**

This workflow, outlined in Figure 2, lends itself to the development of algorithmic design methodologies as it seeks to expand the domain by which design solutions are formed. By reformulating the process not necessarily as a linear process of finding solutions, but as a more dynamic process whereby the form-finding strategies are moved closer to the user and the spatial envelopes in which the design options explored are more focused within a bounded solution space informed directly by relevant user data, in this case ergonomics. Abstract design solutions can thus be created earlier in the process, facilitating greater comprehension of form possibilities and articulation between form and functional requirements.

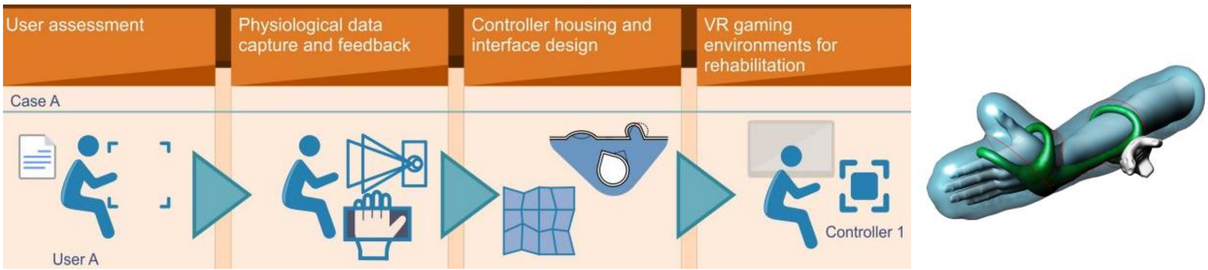


Figure 2. PRIME-VR2 workflow and abstract controller structure

In the case of PRIME-VR2 the unique anatomical profiles as derived from an ergonomic scanning procedure is combined with the abstract spatial boundary definition **(1/2).** This ergonomic data can then be utilised as the basis for algorithmic form finding **(3)**, with reference to the abstract representations that inform how the form finding processes are structured. The form finding processes will lead to a set of results that can be visualised in the CAD environment **(4)**, these can then be further refined by varying elements of the algorithm or separate editing procedures.

What this workflow highlights is how computational power can change and enhance the processes of design. Critically, PRIME-VR2 identifies creating abstract spatial classes as key to exploring design space. Focusing the computational efforts not on a very general problem but creating a more structured space in which the algorithm can explore and generate CAD forms. The outlining of this workflow as explored within PRIME-VR2 sets the scene for a deeper analysis of how these approaches may be applied within the teaching of design and related tools such as CAD, sketch work or prototyping.

3 HOLISTIC TEACHING OF CAD

3.1 Challenges in CAD pedagogy

Teaching of CAD is an essential part of product design and engineering courses as students can easily create digital models to explore, imagine and test their ideas. While this is traditionally done with standard parametric modelling, the evolvement of technology has assisted in the development of modern CAD software which can be particularly useful for teaching and learning, as their integrated advanced simulation and visualisation tools can transfer the functionality of digital models to real-world scenarios [7]. Besides the aforementioned benefits of computational and generative design in previous sections, virtual reality is also regarded as a promising teaching tool that increases motivation and enjoyment of students while keeping them highly engaged [7] and can be valuable in cases of distributed projects and online collaboration. However, integrating VR into design modules comes with challenges mainly related to accessing necessary equipment and the associated costs for educational institutes [8]. Moreover, the software complexity and often intimidating user-interface of the total of these emerging technologies, in combination with limited time resources, impedes their comprehensive teaching in single-semester classes. Still, as dynamic course content and advanced digital visualisation tools of higher-level resolution and aesthetics, which are commonly preferred by students, tend to negatively affect creativity [9], a balance must be achieved between improving the quality of students' design outcomes while adhering to the principles of the design process.

Design education curricula have to keep up with the constantly changing nature of CAD technologies which evolve into immersive 3D experiences or touch and gestured-based interfaces and are now finding application in numerous industrial fields. Therefore, educators have to ensure that teaching materials are updated accordingly as the emerging representational technologies are key to the access and sharing of knowledge in design studio learning environments [10]. Due to the huge range of different CAD software available in the market, educators tend to teach quite generalized guidelines and processes, instead of delivering in-depth tutorials of specific tools. This is also one of the reasons that CAD education should provide students with diverse tasks, forcing them to develop the ability to identify and associate the most appropriate media for specific design activities and therefore, show rationale and achieve autonomous learning [11]. In other words, students should demonstrate that kind of strategic CAD knowledge, instead of simply knowing a specific software's functions and the process of using them [12]. Research has also shown that CAD curricula should always be depending on the role CAD will play in the student's future career [12]; therefore, design education should cover a significant range of CAD technologies and let the students choose the most interesting to them. This is also related to the effectiveness of student engagement, as their intrinsic motivation tends to be increased when feeling that the teaching material is beneficial for them personally and related to their background skillset [13]. All the above challenges are even more evident in the case of postgraduate level modules, involving students of varying engineering disciplines and diverse levels of CAD experience. In these cases, educators have to ensure that CAD fundamentals are taught to a complete degree, while those already acquiring that basic knowledge can progress by improving their competence through more advanced CAD methods.

3.2 Design of a CAD module

Here, the implications for the delivery of CAD teaching are considered through the experience in redesigning a module at the University of Strathclyde ('Product Modelling and Visualisation') that has sought to move beyond basic feature creation skills towards an understanding of where and how emerging techniques can be deployed in the design process, while at the same time providing a base level of competence in the operation of a CAD system. In order to support this, concepts from the literature and instances from the PRIME-VR2 project have informed a structure that allows for an initial modelling exercise to be used as a foundation, for a more theoretical and expansive exercise in assigning and blending advanced techniques in the development process.

As a postgraduate module, this class must accommodate students from varying backgrounds and competencies in CAD. In order to provide a subject matter that allowed for the basics of solid modelling to be grasped, while at the same time providing the opportunity for more advanced forms to be explored, students were set the challenge of designing a cutlery set (knife, fork, tablespoon and teaspoon). While this seems a straightforward task, on closer inspection it provides a good range of modelling challenges. It is something familiar that students can relate to. And there are items at hand for those who wish to build it around existing designs, but there is scope for innovation for those who are more adventurous. Also, time limitations certainly exist for students who have no significant experience CAD; however, this challenge encourages reflection, analysis, research and exploration. The assignment was split into two parts (Figure 3):

- Part A is the generation of a high quality visual, a technical visual and a technical drawing set. Full documentation and rationale of the modelling process was to accompany these.
- Part B was the utilization of an advanced technique, chosen from a supplied list, and applied to one item of cutlery. Students were responsible for selecting their chosen technique and reflecting on how it could be implemented in a CAD workflow.

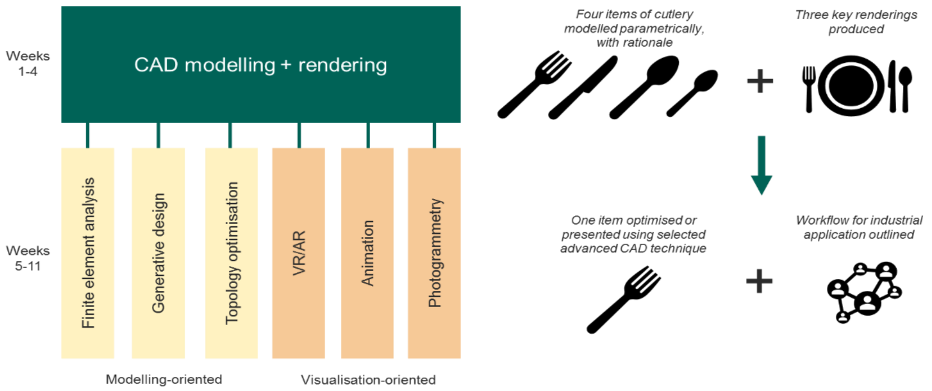


Figure 3. Structure of module (left) and expected output (right)

In overall, the required deliverables that were submitted by the students were of good standard, in their vast majority. As far as the modelling-oriented Part A is concerned, the students managed to achieve the module's learning objectives to a satisfying degree and consequently, expand their 3D modelling competences. In detail, although a relatively small percentage of them chose to proceed with unique, advanced designs (Figure 4), the ones who produced cutlery items of ordinary nature, still accomplished to go beyond the application of solid-modelling and, instead, make effective use of curves and surface-modelling techniques. While also focusing on accurately representing detailed cutlery features by using less common modelling features, the documentation and modelling rationale provided was meaningful and reflective.

However, in terms of the employment of an advanced technique in Part B, the freedom of selection offered resulted in a substantial number of students choosing to invest in the less challenging methods of Fine Element Analysis or simple exploded view Animations, instead of the more complex VR, AR, Generative Design or Photogrammetry, which all fall into the emerging CAD techniques. Although it can be argued that the technical-related challenges involved somehow discouraged students from pursuing these, the ones who attempted them had already significant experience in most CAD aspects. Therefore, due to such techniques evolving in today's industry, it is vital that their benefits are clearly communicated to students through their active integration into CAD education, in order to make them as confident as possible in their usage and establish them as competent designers in the future.

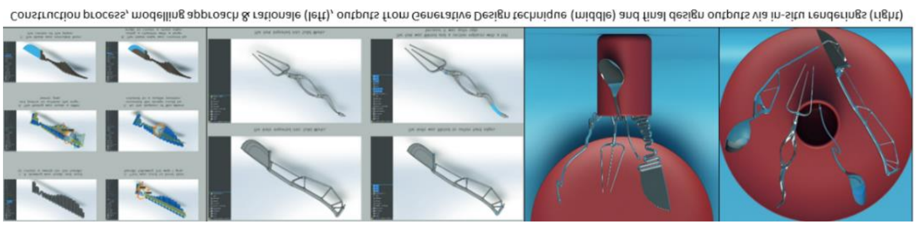


Figure 4. Example images from student's design folio in cutlery design

4 CONCLUSIONS

This paper discusses the context and history of CAD along with the two emerging techniques of computational design and advanced visualisation which are different to traditional modelling practices and have strongly contributed to its constantly changing landscape. A case study on the PRIME-V2 research project is utilised to illustrate the novel methodology and CAD workflow applied in the design of bespoke VR controllers for physical rehabilitation. Nevertheless, providing that the integration of advanced CAD teaching in design education raises a number of challenges, the paper also describes the configuration of a postgraduate module that seeks to provide not only foundational modelling skills, but scope to explore advanced CAD methods and reflect on routes to implementation. Literature findings and insights from the case study have contributed towards a novel structure of a two-part exercise which allows the graduate students to practice the basics of modelling while selecting and applying an advanced method which is suited to their design purposes, personal improvement and career ambitions. Therefore, CAD educators should ensure that technological progress is reflected in the content of teaching materials and besides providing functional knowledge of emerging methods, demonstrate the accompanying challenges, appropriate application and reasonable selection of them to design students.

This project has been funded by the European Commission as part of the H2020 program,
under the grant agreement 856998.

REFERENCES

[1] Tornincasa S. and Di Monaco F. (2010). The future and the evolution of CAD. In *Proceedings of the 14th international research/expert conference: trends in the development of machinery and associated technology* (Vol. 1, No. 1, pp. 11-18).

[2] Wilson P. (1987). A short history of CAD data transfer standards. *IEEE Computer Graphics and Applications, 7*(06), 64-67.

[3] Ye X., Peng W., Chen Z. and Cai Y. Y. (2004). Today's students, tomorrow's engineers: an industrial perspective on CAD education. *Computer-Aided Design, 36*(14), 1451-1460.

[4] Caetano I., Santos L. and Leitão A.M. (2020). Computational design in architecture: Defining parametric, generative, and algorithmic design. *Collection of Frontiers of Architectural Research,* 9, 287-300.

[5] Stasiuk D. (2018). Design Modeling Terminology, available at, https://archinate.files.wordpress.com/2018/06/dstasiuk-design-modeling-terminology1.pdf

[6] Wodehouse A., Loudon B. and Urquhart L. (2020). The configuration and experience mapping of an accessible VR environment for effective design reviews. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 34(3), 387-400. doi:10.1017/S0890060420000293.

[7] Xie C., Schimpf C., Chao J., Nourian S. and Massicotte J. Learning and teaching engineering design through modelling and simulation on a CAD platform. *Comput Appl Eng Educ*. 2018; 26: 824– 840. https://doi.org/10.1002/cae.21920.

[8] Koohgilani M. and Glithro R. "VIRTUAL REALITY AS A TEACHING TOOL IN ENGINEERING & DESIGN." *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019), University of Strathclyde, Glasgow. 12th-13th September 2019*.

[9] Ranscombe C. et al. "Which visualisation Tools and why? Comparing perceptions of student and practicing designers toward digital sketching." *DS 104: Proceedings of the 22nd International Conference on Engineering and Product Design Education (E&PDE 2020), VIA Design, VIA University in Herning, Denmark. 10th 11th September 2020*.

[10] Casakin H. and Wodehouse A. A Systematic Review of Design Creativity in the Architectural Design Studio. Buildings 2021, 11, 31. https://doi.org/10.3390/ buildings11010031.

[11] Kuna P., Hašková A., Palaj M., Skaan M. and Záhorec J. (2018). How to teach CAD/CAE systems. *International Journal of Engineering Pedagogy, 8*(1), 148–162. https://doi.org/10.3991/ijep.v8i1.8185

[12] Gracia-Ibáñez V. and Vergara M. Applying action research in CAD teaching to improve the learning experience and academic level. *Int J Educ Technol High Educ* 13**,** 9 (2016). https://doi.org/10.1186/s41239-016-0010-5

[13] Claus P. Ü. T. Z. "Teaching CAD with a pedagogical system ranging from videos to individual tutoring." *Journal of Industrial Design and Engineering Graphics* 12.1 (2017): 21-26.

SHEDDING LIGHT ON INDUSTRIAL DESIGN. EDUCATING PRODUCT DEVELOPERS FOR A SUSTAINABLE FUTURE IN DESIGN AND ENGINEERING EDUCATION

Martin LUCCARELLI
School of Textiles & Design, Reutlingen University, Germany

ABSTRACT
A premise guaranteeing the successful interdisciplinary teamwork in product design is a mutual understanding of both professional and academic communities of the different design expertise and the role they play in the process. It appears that the open compound word *industrial design* is open to interpretation in European education. This ambiguity had a negative impact on the labour policies of some European countries, which have labelled some professions with incorrect names. Therefore, this terminological inconsistency urges for clarification within the design community. This work analyses the term *industrial design*, it presents historical developments in European industrial design education, in particular in Germany and in the Netherlands, and discusses how the education to the industrial design profession was positioned towards product development. This paper suggests that the causes for the observed lack of clarity about the meaning of the term *industrial design* are of an etymological and disciplinary kind. In order to act as a bridge between the professional and academic communities, universities should create the premises for interdisciplinary collaboration between designers and engineers through standardized communication, ultimately contributing for a sustainable future in both design and engineering education.

Keywords: Industrial design education, product development process, interdisciplinary collaboration

1 INTRODUCTION
In the field of product design, the quality of the final product depends on the correct integration of the activities of each domain involved [1]. Since product development requires integrating different domains to accomplish a common goal, it is key to study product design as an interdisciplinary subject [2]. In this paper, interdisciplinarity in product design is intended as the approach focusing on how interactions among disciplines can be enhanced to share information right from the beginning throughout the process, ultimately synthesizing and harmonizing links between disciplines into a coordinated and coherent whole [3]. A premise guaranteeing the successful interdisciplinary teamwork in product design is a mutual understanding of both professional and academic communities of the different design expertise and the role they play in the process.

In today´s European universities an ambiguity in classifying industrial design can be observed. While the term *design* has risen to new levels of centrality at universities shifting from the level of departments and faculties to whole institutions [4], industrial design is both offered as art- and science-oriented degree within the same countries. In Germany, for example, the Stuttgart State Academy of Art and Design offers an MA programme in industrial design, and the Technical University of Munich offered an MSc programme with the same name until 2021. Moreover, a variety of MA curricula in European countries are labelled as product design curricula. An example may be the Royal College of Art that offers an MA programme called Design Products or the ESAD College of Art and Design that offers both a BA and an MA called Product Design. At the same time, other universities currently use open compound words containing the term *industrial design* to imply that what is been taught is different from purely industrial design. An example may be the Elisava School of Design and Engineering that offers both a bachelor’s and master's degree called Industrial Design Engineering.

The ambiguous way in which European study courses are catalogued and the recurrent habit of using the terms *product design* and *industrial design* as synonyms ultimately had a negative impact on some countries' labour policy. Being the latter unable to find cohesion on the role of industrial design from design education, professions are labelled with names that have little to do with the designated activities. In Germany, as example, the name Technical Product Designer has been coined for a profession that is actually intended to be that of a technical draftsman [5]. So, what is it then that we are all referring to when we mean industrial design in the first place?

The aim of this paper is to clarify this terminological inconsistency within the design and engineering community. To do so, the terms *design*, *industrial design* and *product design* are analysed and compared to each other. Moreover, historical developments in European industrial design education, in particular in Germany and in the Netherlands, are presented to discuss how the education to the industrial design profession was positioned towards product development.

This work is expected to shed light on industrial design, thus providing a better understanding on how industrial design relates to product design education. This contribution is relevant for all universities involved in design and engineering education, including art and engineering schools. It is meant to promote the standardization of key terms in product development to ultimately improve the communication between designers and engineers involved in this process.

The remainder of the paper is structured as follows. In the following chapter, this terminological inconsistency is explored from an etymological perspective, while chapter three explores it from an historical one. Finally, chapter four presents the conclusions along with recommendations for design and engineering education.

2 DESIGN, INDUSTRIAL DESIGN AND PRODUCT DESIGN: ETYMOLOGICAL ISSUES

The word *design* is derived from the Latin words *de*, i.e., "about" or "coming from" and *signum*, i.e., "sign", "image" or "figure". In English, *design* as a verb may refer to as the act of making or drawing plans for something, while the noun as the drawing or set of drawings showing how something is to be made, how it will work and look. As neither the process nor the output is clearly specified by the term itself, this denomination is used in different fields when referring to development actions or results. Consequently, a designer, i.e., a person who imagines how something could be made and draws plans for it, could potentially have a background of any kind. When *design* is specifically used as term referring to a particular domain, it is generally assigned to the applied arts. This designation was first used to differentiate those arts that apply to everyday objects from those that generate results with no practical use, i.e., fine arts [6]. To the applied arts does belong industrial design.

In English, the open compound word *industrial design* may refer to the process of designing the shape, features, etc. of manufactured products. The modifying adjective *industrial* clarifies two issues that are left open to interpretation when the term *design* is used alone. It stresses out the importance of the action (i.e., as a verb) rather than the topic (i.e., as a noun). Moreover, it clarifies the context in which the design action takes place. It may refer to as something related to industry or having a lot of industry and factories. However, the output of this design activity is not clearly defined since something industrial may refer to a product as well as to a landscape or even a nation. The birth of *industrial design* as term in the mid-1800s coincides with the growth of industrialisation and mechanisation, which in turn had started one century before in Great Britain with the Industrial Revolution [7]. The increase in design complexity in the eighteenth century that culminated with the Industrial Revolution meant an increasing specialisation, which in turn meant more division of labour [8]. This division of labour is linked with the term *industrial design* itself. Indeed, the difference between industrial design and the previously known craft-based approaches was the sudden separation between ideation and creation since product form was no longer determined by the creator of that product at the time of its making [9].

The open compound word *product design* may refer to as the process of creating or improving a product by learning what consumers want and examining similar products that are already available. The modifying adjective *product* clarifies one issue that is left open to interpretation when *industrial* is used as alternative term. It specifies the output of the implied action, since a *product* may refer to as something that is made to be sold, usually something that is produced by an industrial process or, less commonly, something that is grown or obtained through farming.

In literature, the perspective that the term *product design* is a synonym for *product development*, or at least refers to an embedded process in product development, is supported by a number of authors [2,10-12]. According to this view, developing a product produced by an industrial process involves several domains [10]. Mention engineering design, industrial design, ergonomics, marketing and innovation management as the domains that are nearly always involved in product design. Moreover, the required skills may be linked to the specific product typology to be designed. When taking an electro-mechanical product of modest complexity as example, [11] list industrial designers, mechanical designers, electronics designers, purchasing specialists, manufacturing engineers and marketing professionals. According to [2], product design is an arena in which two domains actively engage in design practice, while others are only involved in the process. To the former group do belong engineering design, being responsible for designing internal parts and the resulting layout design (usually related to mechanical design as products are based on mechanical components), and industrial design, being in charge of designing the outside of a product resulting in an outside form and the related user facing interfaces; to the latter group do belong marketing people that support design activity by providing market and consumer data, purchasing specialists and manufacturing engineers that mainly work in the manufacturing process to focus on the realization of already-determined product forms and functions [2]. Also [12] presents two domains as those actively engaging in design practice within the product development process named as technical design and industrial design. The former is responsible for addressing functionality (i.e., product must work, be safe and economical) and usability (i.e., product must be easy to understand and use); the latter shares the topic of product usability with technical design and addresses product personality, i.e., its appearance, to target customer satisfaction (i.e., product must be life-enhancing) [12]. Hence, while the etymology of the open compound word *industrial design* may explain why industrial design is sometimes confused with product design, industrial design does actually engage in design within product design.

3 HISTORICAL DEVELOPMENTS IN INDUSTRIAL DESIGN EDUCATION: DISCIPLINARY ISSUES

The division of labour mentioned in the previous chapter meant also separating the applied arts from the intellectual and the fine arts, leaving them without an intellectual foundation of their own [13]. With the Industrial Enlightenment, which in turn had been set by "scientific method, scientific mentality, and scientific culture" [14] of the scientific revolution of the seventeenth century, the Industrial Revolution initiated the shift from design professions to design disciplines that forged their own independent paths. In this regard, the notions of *profession* and *discipline* are of specific interest for this paper.

A *profession* refers to a vocation founded upon specialized knowledge and skills of great social value that sets it apart from other kinds of employment [15]. The linking of this term to a specialized background implies the belonging to an exclusive occupational group that acquired the abilities necessary to supply objective counsel and service for a direct and definite compensation [16]. To evolve from occupation to profession, the ability to take responsibility is needed to turn fully dependent work into a high degree of independent action. Moreover, skill and knowledge are a premise needed to become a vocation that goes beyond compensation based on production.

A *discipline* refers to the subdivision of knowledge characterised by substantive content in one academic field of study that reflects a specific social behaviour [17]. The linking of this term to an academic background implies the existence of a body of theories, concepts, methods and fundamental aims that a given discipline has to feature in order to be named as such [18]. To evolve from domain to discipline, hypotheses and theories are needed to turn mere representation into clarification of phenomena. Moreover, methodological rigor is a premise needed to become a science that goes beyond observation.

3.1 How industrial design did not become a discipline: the German influence

The emergence of industrial design as profession took place in the 20th century in Europe under the influence of the British Arts and Crafts movement first (1870-1920) and under that of the Bauhaus later (1919-1933). While the former still displayed a hard-fought relationship with machinery [19], the German movement foresaw a harmonic coexistence with them. The Staatliche Bauhaus in Weimar had been conceptualized as a state university of arts on par with other universities. Walter Gropius formulated the Bauhaus (literally "building house") programme with the goal of providing students an equal command of technology and form for the design of ornament-free, functional products intended for mass production [20]. Once closed, one attempt to continue the roots of the Bauhaus took place in Chicago in 1937 through Mohly-Nagy [21], and Germany saw the establishment of the HfG School in Ulm in 1953 through Inge Aicher-Scholl, Otl Aicher, Max Bill and others. Both schools explored the possibility to add science to art and technology, the latter two being drawn from the original Bauhaus curriculum. To do so, the HfG in Ulm included disciplines such as ergonomics, mathematical techniques, economics, physics, politics, psychology, semiotics and sociology [22]. While it is argued in literature if the attempt to articulate and legitimize designing by framing a methodology that drew from science and mathematics was successful [13,22], the impact of this school on industrial design vocabulary was immense.

In 1967 the state parliament of Baden-Württemberg demanded the affiliation of the HfG to the Ingenieurschule (literally "engineering school"), the forerunner of the German Fachhochschule (i.e., university of applied sciences) [23]. The background to this new typology of university was the German economic miracle in the 1950s and 60s, which required more well-trained, technically savvy and specialized specialists. The term *Fachhochschule* refers to a form of university that was introduced in Germany, Austria and Switzerland to provide teaching and research with an application-oriented focus on a scientific basis and that does not have the right to award doctorates [24]. Because of this orientation, teaching at universities of applied sciences is more practical than at other universities. This recategorization within German education system had a negative impact on the further evolution of HfG school typology, which lost its identity. While the term *Gestaltung* was explicitly chosen to include the whole subject area of design, thus avoiding the colloquial narrowing association of design in the sense of purely form-giving, today this term is used in Germany to name different school typologies. For instance, the HfG in Offenbach is ranked as a state university of arts on par with other universities granting doctorates, while the HfG in Schwäbisch-Gmünd is ranked as university of applied sciences focussing on design practice only. Even more importantly, this recategorization led to strengthen the industrial design profession and, at the same time, contributed to annihilate the scientific spirit that had distinguished the curriculum of the HfG Ulm and that could have fostered the definition of an industrial design discipline. Germany, a country that had historically pioneered the search for a balance between mass production and artistic individuality ever since the establishment of the German Werkbund in 1907 [22], suddenly lost its historically gained ground.

3.2 How engineering design and industrial design lost boundaries: the Dutch influence

While industrial design remained a profession, other domains managed to evolve into a discipline and explored design as research topic. [25] made an extensive historical review of design research and many disciplines out of the arena of applied arts have shown interest in it throughout history. On the engineering side, engineering design, which in turn was introduced in the sixties [26,27], approached design from the eighties as design science, i.e., a theoretical scientific approach to engineering design methods [28,29]. Engineering design became part of that design community that proved to be highly capable of consolidating the foundation of design research whilst simultaneously expanding to new disciplinary areas through integration, which in turn favoured the entry of new subdisciplines into the frame of design research [4]. This may explain how the new open compound word *industrial design engineering* came into existence.

An important role for the establishment of this term in design research and education was played by the establishment of the Faculty of Industrial Design Engineering in 1986, which had started as an industrial design programme for the Architecture Faculty at the Delft University of Technology in 1962. Literature provides no definition to clarify to what exactly *industrial design engineering* should refer to, how exactly industrial design engineering should differentiate form industrial design and why. Even considering the three most cited papers addressing this domain according to Google Scholar [30-32], the meaning of *industrial design engineering* is neither explained nor are references provided to the reader. This peculiarity is very rare in academic literature and is therefore worth mentioning. The TU Delft leaves as institution this topic open to interpretation as well, stating that the original aim of the university was to make "industrial design a broadly oriented degree programme" and to produce "integral design engineers; that is to say, engineers with an understanding of the technical, commercial, ergonomic and design-related aspects of product design" [33]. While analysing the roots or evaluating the disciplinary model behind industrial design engineering is out of the scope of this paper, its impact on the common understanding of industrial design education is undeniable. For instance, the Delft University of Technology has lately been acknowledged for being the most active institute regarding total publication in the field of industrial design [34] although no chair of industrial design is currently occupied in this institution. Currently, curricula in industrial design engineering are offered in Holland also by the University of Twente, Fontys and The Hague University of Applied Sciences. The appropriation of the term *industrial design* by the engineering domain may partly explain why papers recently published on highly ranked journals such as [4] misclassify industrial design as domain belonging to engineering.

4 CONCLUSIONS

The aim of this paper was to clarify the terminological inconsistency when referring to *industrial design* within the design and engineering community. The ambiguity in classifying industrial design by today´s European universities has been explored from an etymological and disciplinary perspective.

As far as the former is concerned, the verb *design* fails to frame a specific field in which the development action is meant to take place, while the modifying adjective *industrial* fails to specify the output of the implied process. For these reasons, the open compound word *product design* is often used as synonym when referring to industrial design. This is however incorrect, as industrial design operates within product design, which in turn refers to the whole development process.

The disciplinary perspective is far more complex, and it involves historical developments in European industrial design education. In this regard, German education developments favoured the persistence of industrial design as applied art profession. While being acknowledged for developing the educational philosophy that underpins industrial design profession since the early 1920's through the Bauhaus School, Germany is also partly responsible for cutting off the evolution of industrial design into a discipline by closing the concept of the HfG school that had started in Ulm. Consequently, this applied art did not enter the arena of design research. At the same time, Dutch education developments helped the engineering domain consolidating its foundation of design research in engineering design whilst simultaneously expanding to the area of industrial design through integration. Being acknowledged as one of the most active institutes regarding total publication in the field of industrial design, the Delft University of Technology has also contributed in creating a major confusion about it by suggesting that two types of industrial design domains may exist, i.e., industrial design and industrial design engineering. Despite the failure of industrial design to evolve into a discipline and the growing interest of engineering for this profession, industrial design belongs to the applied arts, while engineering design belongs to engineering.

4.1 Implications for design and engineering education

The following recommendations are laid out to universities offering curricula of studies in the field of product design to implement a standardized communication in design and engineering education:

- Art schools should offer study programmes in industrial design. A title different from Industrial Design is advisable only if the curriculum of study focuses on a specific typology of products, e.g., Furniture Design or Car Design. They should avoid labelling any BA or MA programmes with the term *product design*.
- Engineering schools should offer study programmes in engineering design. A title containing the term *product design* is advisable for MSc programmes addressing it as complex and multiple disciplinary subjects, e.g., Integrated Product Design or Interdisciplinary Product Design. They should avoid labelling any BEng, BSc, MEng or MSc programmes with or containing the term *industrial design*.

REFERENCES

[1] Kim K. M. and Lee K. P. Collaborative product design processes of industrial design and engineering design in consumer product companies. *Design Studies,* 2016, 46, 226-260.

[2] Kim K. M. and Lee K. P. Two types of design approaches regarding industrial design and engineering design in product design. In *11th International Design Conference, DESIGN 2010,* Dubrovnik, May 2010, pp.1795-1806 (The Design Society, Glasgow).

[3] Luccarelli M. Interdisciplinarity in product design education. Balancing disciplines to foster creativity. In *4th International Conference on Design Creativity, ICDC*, Atlanta, November 2016 (The Design Society, Glasgow).

[4] Christensen B. T. and Ball L. J. Building a discipline: indicators of expansion, integration and consolidation in design research across four decades. *Design Studies*, 2019, 65, 18-34.

[5] Bundesgesetzblatt. *Verordnung über die Berufsausbildung zum Technischen Produktdesigner und zur Technischen Produktdesignerin sowie zum Technischen Systemplaner und zur Technischen Systemplanerin*. Available:

https://www.bgbl.de/xaver/bgbl/start.xav#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl111s1215.pdf%27%5D__16442378965277 [Accessed on 2022, 7 February], (2011) 21 June.
[6] Rosenthal R. and Ratzka H. L. W. *The story of modern applied art*, 1948 (Harper & Brothers, New York).
[7] Heskett J. *Industrial design*, 1980 (Thames and Hudson, London).
[8] Smith A. *The wealth of nations*, 2007 (Harriman House Limited, Petersfield).
[9] De Noblet J. Design in progress. In *Industrial design: Reflections of a century*, 1993, pp.21-25 (Flammarion, Paris).
[10] Roozenburg N. J. M. and Eekels J. *Product design: fundamentals and methods*, 1995 (John Wiley & Sons, Chichester).
[11] Ulrich K. T. and Eppinger S. D. *Product design and development*, 1994 (Mcgraw-Hill College, New York).
[12] Ashby M. F. *Materials and product design*, 2004 (Granta Design, Cambridge).
[13] Buchanan R. and Margolin V. *Discovering design: explorations in design studies*, 1995 (University of Chicago Press, Chicago).
[14] Mokyr J. *The gifts of Athena: historical origins of the knowledge economy,* 2002, pp.36-37 (Princeton University Press, Princeton).
[15] Spencer H. *Principles of Sociology, Volume 3,* 1896 (Appleton, New York).
[16] Abbott A. *The system of professions: an essay on the division of expert labour,* 1988 (University of Chicago Press, Chicago).
[17] Price D. J. Citation measures of hard science, soft science, technology and non-science. In *Communication among scientists and engineers*, 1970 (Heath, Lexington).
[18] Toulmin S. *Human Understanding, Volume 1,* 1972 (Clarendon Press, Oxford).
[19] Crawford A. W. A. S. Benson, Machinery, and the Arts and Crafts Movement in Britain. *The Journal of Decorative and Propaganda Arts*, 2002, 24, 94-117.
[20] Weber N. F. The Bauhaus at 100: Science by design. *Nature*, 2019, 572(7768), 174-175.
[21] Findeli A. Moholy-Nagy's Design Pedagogy in Chicago (1937-46). In *The idea of design: a design issues reader*, 1995, pp. 29-43 (MIT Press, Cambridge).
[22] Bürdek B. E. *Design: history, theory, and practice of product design,* 2005 (Birkhäuser Architecture, Basel).
[23] Spitz R. *Hfg Ulm - the view behind the foreground: the political history of the Ulm School of Design 1953-1968,* 2002 (Edition Axel Menges, Stuttgart).
[24] Pahl J. P. *Fachhochschule: Von der Fachschule zur Hochschule für angewandte Wissenschaften,* 2018 (WBV Publikation, Bielefeld).
[25] Bayazit N. Investigating design: A review of forty years of design research. *Design Issues, 2004*, 20(1), 16-29.
[26] Asimow M. *Introduction to design*, 1962 (Prentice-Hall Inc, Englewood Cliffs).
[27] Woodson T. T. *Introduction to engineering design,* 1966 (McGraw-Hill, New York).
[28] Hubka V. and Eder E. A scientific approach to engineering design s. *Design Studies*, 1987, 8(3), 123-137.
[29] Hubka V. and Eder E. *Design science,* 1996 (Springer Verlag, London).
[30] Christiaans H. H. C. M. and Dorst K. H. Cognitive models in industrial design engineering: a protocol study. *Design Theory and Methodology*, 1992, 42(1), 131-140.
[31] Boks C. and Diehl J. C. Integration of sustainability in regular courses: experiences in industrial design engineering. *Journal of Cleaner Production*, 2006, 14(9-11), 932-939.
[32] Horváth I. On the differences between research in design context and design inclusive research in the domain of industrial design engineering. *Journal of Design Research*, 2008, 7(1), 61-83.
[33] TU Delft. *Delft design history: 50 years of industrial design engineering*. Available: https://www.tudelft.nl/en/ide/about-ide/delft-design-history [Accessed on 2022, 7 February].
[34] Abedini A. et al. The 100 Most Cited Papers in "Industrial Design": A Bibliometric Analysis. *Exacta – Engenharia de Produção,* 2017, 15(3), 369-374.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

DESIGNING TO ENABLE AN AGEING WORKFORCE

Ian de VERE[1], Wil DIM[2] and Jacob SHEAHAN[2]
[1]University of Lincoln, United Kingdom
[2]RMIT University, Australia

ABSTRACT
An ageing workforce and a dwindling itinerate manual labour supply have long term implications to the commercial viability of industries that require sustained physical activities. The labour recruitment challenges currently facing agricultural, construction, manufacturing and the handling and distribution industries are likely an early indicator of what other industries will face in the future. These trends are driving two significant concerns for an ageing workforce: maintaining the health of increasingly older workers and dealing with the complications of participation in the labour force for these individuals.
This paper details a teaching and research project conducted in collaboration between the *Safeness by Design* initiative and the Innovation Centre of WorkSafe Victoria, a government regulatory body that enforces health and safety policy. The project aimed at moving the sphere of influence of WorkSafe from reactive policing activities towards pre-emptive action, compelling innovation and new discourses on workplace safeness, employment longevity and the empowerment of ageing workers.
The project consisted of a research investigation of ageing and wellbeing issues, and workplace safeness, together with a taught component, a design studio that challenged students to consider physiological, behavioural and technological factors in the generation of design proposals for safe and supportive future workplaces that enable and empower an ageing workforce to continue to make a valuable contribution.

Keywords: Design education, social innovation, safeness by design, design for ageing

1 INTRODUCTION
Australians are living longer, richer, and healthier lives. As life expectancy has increased, so the complexities of an ageing population places pressure on the nation's healthcare sector, social services, and the workforce. A combination of lower fertility rates and increasing life expectancy, has seen the average age increase from 34 to 37 years over the past three decades [1]. Further, while the average intended retirement age is 65, 1 in 4 will work beyond 70: some voluntarily, however many are seeking to supplement their income or save more for retirement [2]. A diverse demographic, older workers are in demand, with many sectors reliant on their ongoing participation in the workforce. Some physically demanding industries e.g., healthcare manufacturing and agriculture are increasingly dependent on older workers remaining in employment, as their workforces age faster than most. This research, enabling an ageing workforce, recognises the issues facing the older worker across a range of different workplace contexts and asks the question, '*how can design and new technologies address the compounding factors of an ageing (working) population and enable older workers to continue to be productive and effective whilst ensuring their personal wellbeing?'*

2 AN AGEING WORKFORCE
Between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12% to 22%. As the average age of our populations increases, so too does the average age of the workforce. Driven by better than expected health, lower than expected wealth, and with industries impacted by a dwindling itinerate manual labour supply, workers will want, and may need, to work past the standard retirement age. However, as people age, they lose muscular strength, experience a decline in physical and cognitive performance, are more vulnerable to muscular-skeletal issues caused by repetitive or awkward movement patterns, and take longer to return to work after health concerns.
Consequently, ageing workers in occupations that require sustained physical activities are at increased risk of injury and exacerbated physical decline, and more likely to experience workplace discrimination, impacting their psychological wellbeing, and diminishing their confidence, self-esteem and self-worth.

2.1 Healthy ageing

In declaring 2020-2030 the ‘Decade of Healthy Ageing’, the World Health Organisation (WHO) has responded to issues resulting from a rapidly ageing global population, building global commitments in a call to action to foster longer and healthier lives [3]. Ultimately, within the context of an ageing workforce, the principles of the Decade seek to change how we think, feel and act towards age and ageing, and ensure that communities foster the abilities of older people.

While healthy ageing is targeted at developing and maintaining functional ability and wellbeing in older age, it is a concept that should be a ‘whole life’ consideration and highly relevant to all of us. Functional ability can be determined through several factors, be that our underlying physiological and psychological state, our health-related behaviours, or our environments which strongly influence our opportunities. Workers, both young and old, are affected by their social and economic equity, which is driven foremost by their working conditions. Disadvantages in health, education, employment and earning, start early and reinforce each other, and will be accumulated over a lifetime. Individuals who develop poor health will work less, earn less, and retire earlier, with working and ageing trajectories also influenced by gender, culture, and ethnicity. The Decade of Healthy Ageing provides an opportunity to address existing power relations and norms with respect to an ageing workforce and develop interventions that will influence quality of life and career longevity for workers.

2.2 Effects of ageing

As people age, they experience a decline in physicality and cognitive senses; losing muscular strength, range of movement and dexterity, and suffer impairments to vision, hearing and balance and reduced mobility. They have a higher risk of injury, being more vulnerable to falls and slips injuries and muscular/skeletal disorders, have difficulties with repetitive or awkward movement patterns, and slower rehabilitation timeframes.

In addition, ageing impacts the capacity to learn, which directly affects workers’ abilities to be valuable to their employer. While older workers have been seen to benefit from training, they are generally slower and less effective than younger people in learning new skills [4]. The speed of technological change, increasing digitisation and the unpredictability of the nature of work in the modern workplace, makes adaptation harder for older workers, increasing the likelihood of worker obsolescence. As a result, many older workers and their workplaces associate ageing with loss of usefulness, opportunities, and workplace inefficiencies [5].

Whilst older employees bring a wealth of experience and knowledge to the workplace, they are increasingly vulnerable to workplace bias and discrimination, generational stereotyping and pressure to retire [6], with two-thirds of individuals aged 45 to 74 having experienced age-related discrimination [7]. This can lead to additional stress, fatigue, and mental health issues for older individuals [8].

2.3 Impact on workplace and industry

Older workers today are healthier and more educated than ever and more willing to work, which presents unique opportunities for employers and various sectors [9]. However, the impact of ageing notably complicates their efforts in navigating the workforce and maintaining employment. Research demonstrates that older age is a competitive disadvantage, with two-thirds of companies holding this belief [7]. Typically, negative attitudes toward older workers are that they are poor long-term investments, as they may lack the ability and desire to develop or retrain themselves, cannot use new technology, or are inflexible and unwilling to change. Employees in any sector, especially older ones with lower confidence or technological competence, need continuous training to remain competitive in the workforce [10].

Alongside external opinions of them, older people also form self-perceptions in the workplace. Negative self-stereotypes have been demonstrated to affect cognitive and physical performance, exacerbating underlying conditions or worsening workplace relations [11].

It is important to note that these are all complications or risks that can be mitigated through timely and considered responses in the workplace. These measures involve employers adapting to the older work’s abilities, reducing duties and revising expectations, or changing the environment and organisational behaviours to better suit their needs and capabilities [12]. Workplaces will have to adjust to the prevalence of chronic health conditions today, to address the larger issues and barriers an ageing workforce brings tomorrow.

2.4 Designing a safer workplace for older workers

The workplace itself has evolved dramatically throughout the lives of many older workers and now needs to incorporate their needs in later life. Workplaces are complicated places, which can influence our perceptions of organisational culture and acceptance, directly impacting our motivations to leave or continue working, as well as our capacity to cope with job demands [13]. During their careers, older workers have had to utilise various strategies to adapt to such demands, and to maintain their functionality and capability in the workplace [5]. Workplaces are now becoming focused on supporting both organisational and self-development opportunities for learning, offering more support to older adults and reflecting the desires of younger workers [14].

When designing for an ageing workforce, it is essential to focus not just on those who are aged but those younger workers who, without appropriate intervention, may be forced to leave the industry early due to physical and cognitive decline, or as a result of preventable injuries.

Consequently, the approach taken in this project was to be responsive to the immediate needs of older workers, but also pre-emptive so that younger workers can enjoy good health and career longevity.

3 DESIGNING FOR SAFENESS

The need for industries to respond in a preventative and responsible way to safety in the workplace obliges consideration of a multidisciplinary and social lens of safeness, embedded throughout the design process. Safety is a challenge for designers, except where are they forced to address specific design standards and safety compliance regulations. In their focus on the fulfilment of customer wishes and the demands of commercial expectations, it can be challenging to imagine and/or prevent unintended functions or scenarios [15] and the consequences of misuse, or reckless and harmful human behaviours. Existing engineering design processes have safety retrospectively applied (as risk analysis), usually after the design phase, and analysis tools (e.g., FMEA) typically focus on component failure, and are incapable of capturing a situation which may be unsafe, but not initiated with a failure [15].

Designing with a safeness lens implies a more holistic approach, centred with a strong understanding of behaviours and cultures. It is critical for the designer to consider not just the physical hazards, but also the users and the context and environments of use, with a strong understanding and empathy for human behaviour, and awareness of the impact of rapid and disruptive socio-technical change [16]. Risk-taking behaviours, team working dynamics and interpersonal relationships (e.g., supportive, competitive, intimidatory, discriminatory or exploitive), product interactions (both planned and unanticipated), individual perceptions and expectations of safeness (whether explicit or implicit), mental health and wellbeing, and the anticipation of long-term physical and cognitive degradation caused by prolonged and repetitive activities, are key considerations in designing for safeness.

This involves interrogating how our values, attitudes, and beliefs help or hinder our engagement with daily life and safety in the workplace. The proposition of 'Safeness by Design' is to respond to the complexity of our worlds, considering the tensions of new technologies and practices while attuning to the behaviours and cultures that make us human. This holistic approach to managing and mitigating work risks sees designers align their design decision-making process with workers' perceptions of safeness. Such a strategy places the responsibilities of designers for safety beyond liability concerns, instead to actively prompt socially meaningful design initiatives within the context of safety, as 'design activists' [17].

4 SAFENESS BY DESIGN AND WORKSAFE

'Enabling an Ageing Workforce' was the first collaborative project between RMIT University's 'Safeness by Design' initiative and the Innovation Centre of WorkSafe Victoria. The collaboration provided an opportunity for Safeness by Design researchers and RMIT Industrial Design students to develop innovative design solutions aligned with WorkSafe's current areas of priority, and to demonstrate the power of design to make a positive contribution to society.

In the partnered design studio, students were challenged to investigate ageing, wellbeing and workplace safeness within specific industries, identifying areas of concern and design intervention opportunities, before responding with future-focused design proposals and recommendations to the external partners and industry stakeholders. For researchers conducting a simultaneous and comprehensive investigation into the literature on the ageing workforce in Australia, the topic offered a large scope for inquiry across multiple industries and contexts, informing the design process and building a knowledge repository.

5 PEDAGOGICAL APPROACHES

Design education should provide a supportive and challenging environment where students are provided with the opportunity to respond to increasingly complex wicked problems, rather than prescriptive project briefs. In future practice, our graduates will be required to be agile, interdisciplinary and critical thinkers who can confidently explore poorly defined problems and complex scenarios and behaviours, and then deliver innovative solutions.

Accordingly, it is important to not be overly prescriptive with design school project briefs, but instead to afford students the agency to use research and ethnographic processes to explore the context, understand the stakeholders and prevalent behaviours, identify areas of concern, and then define the problem to be addressed. This way, students are empowered to work in a more holistic manner, to develop their own project brief and take ownership of the design process and their own learning journey.

In this project, students were presented with a complex and undefined scenario, 'how to enable an ageing workforce' and encouraged to explore a range of industry contexts in search of a problem where a design intervention was appropriate. This approach, whilst initially confronting for students who are used to more defined design briefs, offers significant opportunity for student empowerment and learning, and facilitates the development of unexpected project journeys and outcomes.

6 PROJECT METHOD

The 'Enabling an Ageing Workforce' research and design collaboration between Safeness by Design initiative and WorkSafe Victoria's Innovation Centre, was conducted through two main activities, extensive exploratory research through a literature review, and a design studio project where students responded to identified issues. The collaboration aimed to (a) provoke conversation and stimulate new engagement between WorkSafe, RMIT and industry, (b) generate a new awareness of the topic, and (c) identify and examine areas of concern and propose targeted design solutions in response.

In addition to valuable student awareness and learning, the project realised several key outputs, a research report, a public exhibition, and an entrepreneurially focused stakeholder workshop.

6.1 Initial investigations

The literature review was utilised to focus and contextualise a range of subject areas, with initial research being conducted into the ageing workforce in Australia, before more directed research was conducted into specific industry contexts to support the design studio work. Whilst most of the research was conducted by Safeness by Design researchers (the authors), the initial research conducted by student groups was invaluable in identifying the specific industry issues that necessitated a design intervention, and which focused the subsequent research.

6.2 Design studio

In late 2021, Industrial Design students were engaged in the Safeness by Design/ WorkSafe Victoria collaboration through a 'Social Innovation' themed design studio. This studio enabled students working in small design teams to utilise a collaborative approach to problem solving, to construct meaning and innovate solutions to complex problems, supported with expertise from tutors and the external partner.

Integrating the literature review with the studio, students worked across multiple industry contexts including agriculture, health care, SME manufacturing, and residential and commercial construction, resolving complex problems concerning mental health, musculoskeletal disorder, workplace accident/injury prevention and the application of assistive technologies. These projects were defined by the students, emerging from problems identified during their initial research. Design projects focused on enabling the longevity and continued effectiveness of ageing workers, whilst protecting younger workers from work related health issues that may cause them to leave industries prematurely.

7 PROJECT OUTCOMES

Design outcomes were expected to be progressive, innovative and future-oriented in responding to the concerns of specific workplace contexts, and it was important that students assumed a pre-emptive and supportive approach, rather than a reactive one. Working with a 'safeness' lens for the first time, students were required to investigate and understand not just the specific workplace environments and tasks, but also the cultures and prevalent behaviours that may negatively impact worker safeness or wellbeing.

As students addressed a diverse range of occupational contexts and concerns, it was anticipated that project outcomes would be interdisciplinary, product, communication, strategic, service, and or systems design. The design intervention proposals framed the specific problem and the key design considerations and detail a design response that is supported by an implementation strategy, and an analysis of potential impact. Designs were innovative, appropriate for the specific industry context and considerate of the needs and physicality of ageing workers, supporting their longevity in employment, whilst proposing systems that aim to ensure younger workers are protected from work-related long-term deterioration

7.1 Addressing mental health in the commercial construction industry

Wags and Snags is a mobile engagement service that aims to raise awareness of mental health and connect vulnerable workers to a self-diagnostic toolkit, without shame of stigma in the workplace. It comprises two interventions; an initial on-site social engagement (using therapy dogs and social lunch), which raises awareness and facilitates access to the second part of the service, a website/app where the construction worker can undertake a self-diagnosis process, in private with spousal or family support.

7.2 Reducing injuries to healthcare workers during home visits

Airlift is a homecare patient transfer device that allows a single healthcare worker to move the patient through a range of difficult positional transfers, whilst avoiding injury and maintaining patient dignity. An inflatable slide sheet with grip handles, it actively assists patient transfer, promotes safety and corrective behaviour change, reduces grip related accidents, and enables older healthcare workers.

7.3 Enabling ageing manufacturing workers in small-medium enterprises

Two student groups took different approaches to muscular-skeletal issues in this complex workplace. PosCor is a product-service system that allows physiotherapists to move from reactive treatment to pre-emptive educational interventions, to facilitate behaviour change and reduce workplace injuries in the manufacturing sector. It uses a movement monitoring suit and data analysis software to provide the physiotherapist with a comprehensive understanding of movement patterns within the workplace, facilitating training for safer worker movements, and workplace redesign. Lift+ is a mechanical knee brace for ageing manufacturing workers that provides not only physical reinforcement and knee stability, but also supports older workers in manual tasks by providing active load bearing assistance.

7.4 Reducing ladder injuries in the residential construction industry

BreakFall aims to prevent ladder falls through a ladder and user position monitoring system with feedback warning, and personal protection for users in the event of a fall. This two-part solution consists of a ladder mounted sensor unit and an interconnected safety vest with an integrated airbag protection system to reduce injury severity. It not only protects the user from life changing injury in the event of a ladder fall, but actively prevents falls by alerting the user to potential safety issues in real time. This capability should help heighten awareness, educating workers and developing safer work practices.

7.5 Reducing the impact of vibration on ageing agricultural workers

The SPIDER vibration dampening tractor seat system specifically targets the dampening of machinery and activity-based vibrations that negatively impact farmers' health, whilst allowing rotation to reduce twisting forces on the upper body, positively impacting health and wellbeing in farming communities.

8 REFLECTIONS

It was hoped that students and researchers would be able to engage directly with target users in their workplace to gain a deeper understanding of the nuances of specific industries. Unfortunately, the extended lockdown enforced on Melbourne by the Covid-19 pandemic made ethnographic research less feasible, and it is a credit to all contributors that they were able to not only conduct insightful research, but to respond with well-considered design proposals, despite the enforced isolation. The outcomes have potential to deliver tangible and achievable benefits to all stakeholders in response to the problems and issues identified, empowering end users and adding value to their communities and industries.

Students delivered solutions attuned to both the physiological and psychological needs of workers, but also effectively imagining and anticipating the future behavioural, environmental, and technical challenges. The external partner was surprised by both the range and quality of the design proposals, noting that some of the concepts were 'accelerator ready' with clear line-of-sight to tangible impact and benefit pools. In this regard, the project partners are exploring opportunities for entrepreneurial ventures and further development of these projects that may lead to solution implementation in industry.

9 CONCLUSIONS

This project has demonstrated how a 'Safeness by Design' lens can enable an ageing workforce and deliver tangible benefits to industries, workers, economies and communities. In line with Manzini's [17] positioning of designers as facilitators who act as 'design activists proactively launching socially meaning design initiatives', this work evidences a new approach to design where safeness is not merely risk assessment or compliance but reflects a more nuanced understanding of human behaviours.

The pedagogical model of a partnered studio collaboration, supported by independent research has proved effective. Students were challenged by an ambiguous brief, whilst empowered to take ownership of the investigation and outcome, and their learning journeys. This process has enabled student-led problem identification/framing, stimulated interdisciplinary working, to deliver well considered and potentially impactful design responses. Importantly it has demonstrated to students the power of design to make a positive contribution to society, and delivered a new design consideration, the lens of safeness.

ACKNOWLEDGMENTS

The authors acknowledge the contribution of the project partner, the Innovation Centre of WorkSafe Victoria for their industry insights and expertise in workplace health and safety and pay tribute to the extraordinary efforts of the students who, during a prolonged pandemic lockdown, responded to the project brief with enthusiasm and dedication, achieving insightful and impactful outcomes.

REFERENCES

[1] Radford K., Chapman G., Bainbridge H. T. J. and Halvorsen B. The ageing population in Australia: Implications for the workforce. In S. Werth, & C. Brownlow (Eds.), *Work and Identity: Contemporary Perspectives on Workplace Diversity*, 2018, pp.39-54. (Edward Elgar).

[2] Ikin H., Thorning P., Heraghty M., Vitale M. and Turner B. *Ageing Workforce Report*, 2019.

[3] World Health Organisation (WHO). *Decade of Healthy Ageing*, 2020, pp.1-24.

[4] Picchio M. Is training effective for older workers?, 2021, *IZA World of Labor*, January 2015, pp1–11. https://doi.org/10.15185/izawol.121.v2

[5] Ng E. S. W. and Law A. Keeping up! older workers' adaptation in the workplace after age 55, 2014, *Canadian Journal on Aging*, 33(1), pp.1-14. https://doi.org/10.1017/S0714980813000639

[6] Wegman D. H. and McGee J. P. Health and Safety Needs of Older Workers, 2004, In *Health and Safety Needs of Older Workers*. https://doi.org/10.17226/10884

[7] Bersin J. and Chamorro-Premuzic T. *The Case for Hiring Older Workers*, 2019, https://hbr.org/2019/09/the-case-for-hiring-older-workers

[8] Harncharoen K., Isahak M., Kaewboonchoo O., Low W. Y. and Ratanasiripong P. Workplace Environment and Quality of Life of SME Workers: A Systematic Review, 2016, *Asia Journal of Public Health*, 7(2), pp.64–81.

[9] CEPAR. Tapping into Australia's ageing workforce: Insights from recent research, 2021.

[10] Lee C. C., Czaja S. J. and Sharit J. Training older workers for technology-based employment, 2009, *Educational Gerontology*, 35(1), pp.15-31. https://doi.org/10.1080/03601270802300091

[11] Truxillo D. M., Mccune E. A., Bertolino M. and Fraccaroli F. Perceptions of Older Versus Younger Workers in Terms of Big Five Facets, Proactive Personality, Cognitive Ability, and Job Performance, 2012, *Journal of Applied Social Psychology*, 42(11), pp.2607–2639.

[12] UNISON. The ageing workforce: Health and safety implications, 2017, In *Work Study*. https://doi.org/10.1108/ws.1999.07948daf.006

[13] Buckle P., Woods V., Oztug O. and Stubbs D. Understanding workplace design for older workers: A case study, 2009, *Contemporary Ergonomics 1984-2008: Selected Papers and an Overview of the Ergonomics Society Annual Conference*, pp.647–651.

[14] Bingham D. Learning and development of older workers, 2019, Older Workforces, pp. 15–34. https://doi.org/10.4324/9781315598789-2

[15] Rajabalinejad M. Paradigm of Safety by Design, 2019, *MATEC Web of Conferences*, 273(April 2010), 01006. https://doi.org/10.1051/matecconf/201927301006

[16] de Vere I., Mcleod R. and Wagenfeld M. (2021). Safeness By Design: A New Design Paradigm? 2021, In *International Conference of Engineering and Product Design Education (E&PDE21)*, Herning, Denmark, September 2021. https://doi.org/10.35199/epde.2021.63

[17] Manzini E. Making things happen: Social Innovation and Design, 2014, *Design Issues*, 30(1). https://doi.org/10.7748/ldp.6.3.36.s20

EMBEDDING SUSTAINABILITY IN THE ENGINEERING CURRICULUM: A COMPLIMENTARY APPROACH TO PERFORMANCE ENGINEERING AND SUSTAINABLE DESIGN

Ahmed Tamkin BUTT, Edward William Thomas CAUSTON and Matthew Alan WATKINS
Department of Engineering, Nottingham Trent University, United Kingdom

ABSTRACT

To address the UN Sustainable Development Goals, future engineers must effectively integrate sustainability into multiple areas of engineering throughout the lifecycle encompassing the design of products, development for manufacturing and end of life considerations. The impact of the quality of manufactured goods on product performance and sustainability is well documented. Furthermore, statistical methods commonly used to monitor and control product quality may be adapted to evaluate environmental performance. This paper details how sustainability is considered within the curriculum of two 3rd year modules of the Engineering courses at Nottingham Trent University, UK. The modules presented here are Performance Engineering and Sustainability in Engineering Design. Through a systematic analysis of the content, the authors have identified synergies in approaches to sustainability in the modules. It is anticipated that, through careful scaffolding and reinforcement of learning, budding engineers will be encouraged to adopt a holistic approach, in which sustainability is embedded throughout their practice.

Keywords: Performance engineering, quality management, sustainable design, inter-disciplinary engineering education

1 BACKGROUND

The exponential growth of the global economy and production has had an irreparable social and environmental impact [1, 2]. Indeed, sustainability is considered one of the greatest challenges for humanity in this century [3, 4]. In 2015, the UN General Assembly put forth “the agenda for sustainable development” which is constituted by 17 sustainable development goals (SDGs) [5, 6]. Engineering is expected to play a crucial role in achieving at least 12 of these 17 SDGs [7]. In light of this, future engineers need to be well equipped to understand, evaluate, and apply knowledge and skills from a range of inter-disciplinary fields [8] to ensure they consider a myriad of environmental and social factors when addressing current engineering problems [9].

Education for sustainable development (ESD) aims to equip individuals with necessary skills and knowledge to aid them in addressing sustainability [10]. It is essential that ESD is embedded in the engineering curriculum, providing students with opportunities to learn, practice and apply systemic thinking to real-world scenarios, enhancing their professional practice and responsible decision making [3]. ESD can be defined as an educational approach for creating awareness of issues related to sustainability [11], inculcating skills such as collaboration skills, critical and reflective thinking, entrepreneurship, and creativity. However, such skills cannot simply be taught by introducing new modules or adding content to a pre-existing curriculum, but they must be embedded throughout the degree programme [12].

A significant barrier to the adoption of a holistic approach toward sustainability is the use of modular curricula and the consequent tendency for students to compartmentalize knowledge and skills, failing to apply these outside of the context in which they were introduced [2, 13]. This raises an interesting question: to what extent can ESD be integrated into the curriculum *outside* of specific ESD modules. It is the contention of the authors that this is feasible for the educational practitioner even within the confines of the curriculum in which they are operating and without the need for radical revisions to content. This paper considers two apparently divergent modules, one for which ESD is the explicit focus and one for which it is not. Through a systematic analysis, the authors propose means by which both may be adapted to support each other in pursuit of a more holistic approach toward ESD. In this way it is hoped that new engineers may be encouraged to embed sustainability throughout their practice.

2 MODULES – CONTENT, CONTEXT & ASSESSMENT

2.1 Performance Engineering

Performance Engineering is a 3rd year core undergraduate module taught across a single term to a mix of students from mechanical, electrical & electronic, biomedical and sport engineering. The aim of the module is to introduce students to a range of statistical and other techniques in the context of measuring, monitoring, and improving engineering performance to ensure quality and efficiency.

The module is taught across 10 weeks through a mixture of lectures, seminars, and online resources, comprising short video lectures, MCQs and problem sets to be completed asynchronously. Given the range of engineering disciplines and students represented, the focus is on laying a foundation from which students may subsequently build their knowledge within their own specialism as opposed to providing a comprehensive review of the topics considered.

Due to the limited statistical knowledge of many students, early lectures are used to introduce and review standard statistical techniques including measures of average and of spread, probability distributions, sampling and estimators, the central limit theorem, correlation, regression, and hypothesis testing. Emphasis is placed on a conceptual understanding and engineering applications from across disciplines are used as examples. Simultaneously, students are encouraged to analyse engineering processes in relation to ensuring product quality.

Attention then shifts to common methods used within engineering to analyse processes. These include capability indices used to determine the ability of a process to operate within specified limits, the analysis of variance to determine the statistical significance of differences between populations, and statistical process control, especially Shewhart control charts, used to monitor and control processes. Factorial experiments, including factor and interaction effects, are considered in the context of improving process performance.

Finally, students are introduced to reliability engineering methods. These include lifetime distributions, failure rates, exponential, and Weibull distributions, the 'bathtub curve,' accelerated testing and reliability block diagrams.

Students are assessed through a 2-hour online examination and coursework assignment. The exam consists of short answer and calculation questions requiring students to select and apply methods from the module to analyse data provided. Students must also demonstrate an understanding of the practical implications and the limitations of their analysis. The coursework takes the form of a case study where students are presented with data related to a hypothetical manufacturing context for which they must apply techniques from the module to produce a management report detailing and justifying their recommendations.

2.2 Sustainability in Engineering Design

Sustainability in Engineering Design is an optional 3rd year module open to all four engineering disciplines at NTU. The module runs in term 2 and is informed by CDIO standards [14, 15]. The module aims to bring together and consolidate sustainable development within the domain of engineering design and product development. The module builds upon year 1 and year 2 core modules, Innovation and Engineering Solutions [16, 17] & Industrial Design and Product Case Studies [18] yet is still an introductory course and does not require any prerequisites. Due to the disciplinary diversity of the students enrolled in the module, the content is fairly broad. Students are equipped with the necessary tools and knowledge to tackle engineering design problems from a sustainable perspective, addressing the Triple Bottom Line [19] and Design for Total Control [20] philosophy. The objective is to move away from focusing solely on the end-of-life disposal to integrating sustainability considerations throughout the product lifecycle, being mindful of the resources consumed during the process but also considering disposal, maintenance, and various other socio-economic factors.

The module is taught across 11 weeks, through lectures, seminars, and drop-in sessions. Lectures cover the theory and principles of engineering design and sustainable engineering. Including product concept generation and development tools such as TILMAG, morphological analysis and detail the processes of product development such as phases of the product lifecycle (concept, detailed and final design specification). Students are given industrial examples of the progression of a product's life cycle detailing each of the stages, material sourcing, design, manufacturing, maintenance, usage, and disposal. At each stage of the product's life, environmental impact is discussed in terms of energy expenditure and resource consumption.

Following the product development lifecycle, sustainable engineering lectures lay the groundwork for the application of the Triple Bottom Line and Design for Total control by defining the environmental impact at each stage of the product's life calculating the embodied energy. This is performed using the Eco-audit facility in Ansys Granta EduPack software [21], which is introduced in the module with instruction on how to define these values and strategies are discussed on how to reduce the environmental impact at each stage. The drivers for sustainability in design such as legislation, social factors and financial incentives are also discussed within lectures before students are introduced to strategic sustainable design whereby consumer perspectives and sustainability certifications are considered.

The students are assessed via a 50% group coursework and a 50% individual product design project. The group coursework asks students to identify a key issue facing sustainability in engineering and propose a solution. In their groups, students are also expected to disassemble and document an engineered device to conduct a comprehensive eco-audit and propose methods of reducing the environmental impact of the device at different stages of its lifecycle. The individual design project requires students to and document the entire product lifecycle, whilst adhering to a set specification for a product given to them. The final submission is a technical report that details the development of the product from a technical and strategic standpoint, to maximize profit as well as reduce environmental impact.

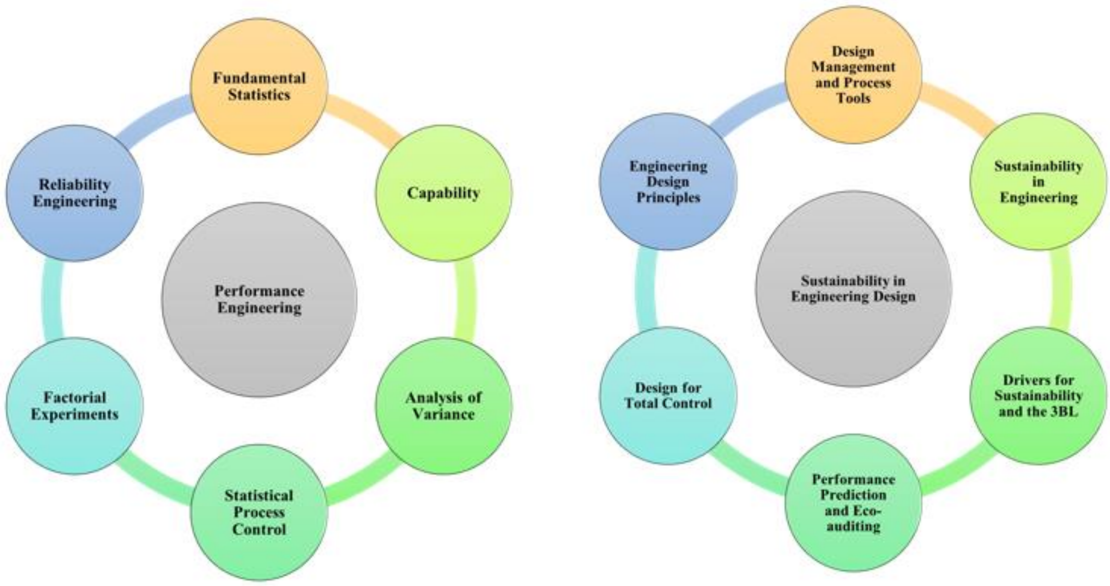


Figure 1. Comparison of the content covered in the modules in focus

3 DISCUSSIONS

It is evident that the content of these two modules *(Figure 1)* has significant differences in terms of learning and skills gained. At first glance, using these as a starting point for embedding sustainability in the engineering curriculum might seem counterintuitive. However, it is argued that the challenge of identifying synergies in these modules and finding opportunities for inter-disciplinary education despite these differences make this an excellent exercise, illustrating how educational practitioners may achieve this even while operating within the confines of an existing curriculum.

Potential synergies may relate to content, pedagogy, placement within the course curriculum or a mixture of these. While there is little explicit overlap in the content of the two modules as currently delivered, the broad learning outcomes do afford the possibility of reinterpretation. In doing so, it is critical that core content is not neglected. Perhaps the simplest way to achieve this is during student application of knowledge and skills from each module both through summative assessments and formative standalone tasks. These may require students to explore for themselves the possibilities for applying techniques drawn from Performance Engineering to Sustainability in Engineering Design. Both modules emphasize the importance of effective and efficient manufacturing processes and many of the methods used to enhance product quality and reliability may equally be applied in the pursuit of sustainability goals. Such tasks may also expand the range of learning methodologies applied within the modules, introducing more discursive opportunities into Performance Engineering while emphasizing the applicability of mathematical methods within Sustainability in Engineering Design.

Opportunities may also be present in the sequential ordering of the two modules, in that Performance Engineering is delivered to students immediately before Sustainability in Engineering Design. By embedding sustainability within the former and drawing upon methods from Performance Engineering in the latter, a sense of continuity may be achieved. The focus thus shifts toward a student-centred curriculum emphasizing the student's journey and how they are equipped with the necessary skills that encourage a pragmatic engineering practice.

Given the focus in Performance Engineering is on improving product quality and reliability, it is appropriate to open a debate as to how these characteristics relate to the integration of sustainability into design and manufacturing processes. Reliable products do not require replacing as frequently, reducing demand on resources and the impact of manufacturing and transport; efficient manufacturing means less waste and lower energy demands; higher quality products may be more energy efficient in operation. Simultaneously, we must acknowledge that the need for sustainable processes and products imposes additional restrictions that may sometimes conflict with quality requirements and increase costs. In this context, it may be informative to introduce ISO 9000 and ISO 14000 [22] to highlight the overlap between quality and environmental management systems.

The possibility of adapting statistical process control and capability techniques to emissions data [23] provides an opportunity for students to apply mathematical methods in the pursuit of environmental goals, countering initial perceptions students may have that sustainability is a purely qualitative philosophy. Case studies introducing these techniques in the context of enhancing sustainability may encourage awareness of the possibilities for utilizing methods drawn from outside traditional sustainability education.

Finally, while the emphasis of Performance Engineering is on the application of statistical techniques to enhance quality and efficiency, there is scope to expand the concept of performance to encompass sustainability as an explicit objective while maintaining the specified learning outcomes. To avoid sacrificing existing content, this may be best achieved through the coursework assignment. Moving the assignment away from an exercise in data analysis and toward a research-based task on a given scenario could allow students to integrate sustainable development within the analysis of a manufacturing process, avoiding perceptions that this has been artificially added into the assessment.

As Performance Engineering is a core module, by the time students start Sustainability in Engineering Design, they are already well versed in the design of experiments and reliability engineering. Within their individual product design projects for Sustainability in Engineering Design, students need to integrate sustainability in manufacturing by assessing and selecting the most appropriate manufacturing techniques. Indeed, the quality of production processes has been defined in terms of reliability and sustainability [24] and it is understood that efficient manufacturing leads to better product quality and reduces production losses, in turn increasing the sustainability of the entire process. A task could then be added to the individual product design project, to ask students to use techniques learnt from Performance Engineering to design experiments to determine optimum manufacturing conditions. Additionally, proposing a quantitative method to assess whether their chosen manufacturing methods meet the desired specifications.

As noted, reliable products do not need to be replaced very often. Product longevity ensures we can move away from the "use and throw" mindset to encourage a more sustainable "use and maintain" mindset. Developing efficient reliability assessment techniques ensures the performance is not compromised under unprecedented or demanding conditions [25]. Reliability analysis learnt in Performance Engineering can be used by students during the individual product design project to

propose a methodology for assessing product reliability. This will encourage students to embed reliability throughout the product development cycle.
Under the proposed modifications, students will have already been introduced to ISO 9000 and ISO 14000, and therefore will appreciate the rigorous processes and requirements of quality management certifications. Consequently, the introduction of strategic sustainable design via certifications and eco-labelling will be more easily understood and implemented in their individual projects.

4 CONCLUSIONS

This paper has illustrated how educational practitioners might work together to embed ESD more fully within the curriculum. Despite operating within curriculum constraints, synergies have been identified even in divergent engineering modules. Through this, interventions have been proposed to encourage future engineers to adopt a holistic approach toward embedding sustainability throughout their practice. The authors suggest that a crucial component of embedding ESD is for educators to consider the student journey and how sustainability themes run between modules. The focus should be upon how students are engaging with these themes and not merely upon introducing sustainability as an add-on component to be taught. To achieve this, educators working with the same cohort of students should be encouraged to enter a dynamic discourse, sharing both their interpretation of learning outcomes and their approach to achieving and assessing these. In this way they may be able to step beyond an analysis of specifications and reimagine their approach toward achieving learning outcomes concurrently with embedding sustainability. By pairing ESD practitioners with other educators, the latter may be supported in bringing sustainability themes into their modules while the former may better contextualize their teaching within the curriculum.

REFERENCES

[1] Chams N. and García-Blandón J. (2019). On the importance of sustainable human resource management for the adoption of sustainable development goals. *Resources, Conservation and Recycling*, *141*, 109-122.
[2] Watkins M., Casamayor J. L., Ramirez M., Moreno M., Faludi J. and Pigosso D. C. (2021). Sustainable product design education: current practice. She Ji: The Journal of Design, Economics, and Innovation, 7(4), 611-637.
[3] Guerra A. (2017). Integration of sustainability in engineering education: why is PBL an answer? International Journal of Sustainability in Higher Education.
[4] Mintz K. and Tal T. (2014). Sustainability in higher education courses: Multiple learning outcomes. Studies in Educational Evaluation, 41, 113-123.
[5] UNESCO. (2017). Sustainable Development Goals. Retrieved from http://en.unesco.org/sdgs
[6] UN General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1, available at: https://www.refworld.org/docid/57b6e3e44.html [accessed 21 February 2022]
[7] Hadgraft R. G. and Kolmos A. (2020). Emerging learning environments in engineering education. Australasian Journal of Engineering Education, 25(1), 3-16.
[8] Czerniak C. M. and Johnson C. C. (2014). Interdisciplinary science teaching. In Handbook of Research on Science Education, Volume II (pp. 409-425). Routledge.
[9] Lattuca L. R., Knight D. and Bergom I. (2013). Developing a measure of interdisciplinary competence. The International journal of engineering education, 29(3), 726-739.
[10] Quelhas O. L. G., Lima G. B. A., Ludolf N. V. E., Meiriño M. J., Abreu C., Anholon R. and Rodrigues L. S. G. (2019). Engineering education and the development of competencies for sustainability. International Journal of Sustainability in Higher Education.
[11] Paulauskaite-Taraseviciene A., Lagzdinyte-Budnike I., Gaiziuniene L., Sukacke V. and Daniuseviciute-Brazaite L. (2022). Assessing Education for Sustainable Development in Engineering Study Programs: A Case of AI Ecosystem Creation. Sustainability, 14(3), 1702.
[12] Takala A. and Korhonen-Yrjänheikki K. (2019). A decade of Finnish engineering education for sustainable development. International Journal of Sustainability in Higher Education.
[13] Ramirez M. (2006). Sustainability in the education of industrial designers: the case for Australia. International Journal of Sustainability in Higher Education, 7(2), 189-202.

[14] Butt A. T. (2022). Sustainable Design & Product Death. In Proceedings of the 18th International CDIO Conference, hosted by Reykjavik University, Reykjavik Iceland, June 13-15, 2022 (In Press)
[15] Malmqvist J., Edström K. and Rosén A. (2020b). CDIO Standards 3.0 – Updates to the Core CDIO Standards. In Proceedings of the 16th International CDIO Conference (pp. 60–76), hosted on-line by Chalmers University of Technology. Gothenburg, Sweden: Chalmers University of Technology (online).
[16] Butt A.T. and Siegkas P. (2021). Integrated CAD and Reverse Engineering to Enhance Conception and Design. In Proceedings of the 17th International CDIO Conference, hosted online by Chulalongkorn University & Rajamangala University of Technology Thanyaburi, Bangkok, Thailand, June 21-23, 2021.
[17] Siegkas P. (2020). Reverse Engineering and Introduction to Engineering. In Proceedings of the 16th International CDIO Conference, hosted on-line by Chalmers University of Technology, Gothenburg, Sweden, 8-10 June 2020
[18] Siegkas P. (2021). Introduction to Industrial Design and Product Case Studies. In Proceedings of the 17th International CDIO Conference, hosted online by Chulalongkorn University & Rajamangala University of Technology Thanyaburi, Bangkok, Thailand, June 21-23, 2021.
[19] Elkington - Cannibals with Forks: Elkington, J. (1998). Cannibals with forks: the triple bottom line of 21st century business. New Society Publishers
[20] Johnson A. and Gibson A. (2014). Sustainability in engineering design. Academic Press.
[21] Ansys. (2021). Ansys Granta EduPack. https://www.ansys.com/en-gb/products/materials/granta-edupack
[22] International Organization for Standardization. Management System Standards, available at: https://www.iso.org/management-system-standards.html [accessed 5 March 2022].
[23] Corbett C. J. and Pan J. N. (2002). Evaluating environmental performance using statistical process control techniques. European Journal of Operational Research, 139(1), 68-83.
[24] Kostina M., Karaulova T., Sahno J. and Maleki M. (2012). Reliability estimation for manufacturing processes. Journal of Achievements in Materials and Manufacturing Engineering, 51(1), 7-13.
[25] Leangsuksun C., Song H. and Shen L. (2003). Reliability Modelling Using UML. Software Engineering Research and Practice, 2003, 259-262.

EXPLORING SENSUOUS QUALITIES OF TEXTILES

Monica Louise HARTVIGSEN and Karen Marie HASLING
Design School Kolding, Denmark

ABSTRACT
As designers we engage with materials in various ways throughout the design process. Especially textile designers who are met with a demand to be able to describe and communicate textiles – in words as well as in physical materials. In this paper we propose a tool consisting of a sensorial wheel and a visual wheel aiming at textile design students at a foundational level.
The tool is meant to develop textile designers' awareness and language by evaluating existing textiles, but at the same time providing the students with an open tool to readjust and combine with other methods and include in their existing design process.
The tool has been tested in a workshop at BA level and showed that students were able to evaluate and vocalise their chosen textiles and the sensorial qualities the textiles expressed by using the two wheels. In the reflection session afterwards, we have focused on the outcome of the sensorial wheel for the students to reflect on the use of the tool and how they experience sensorial qualities differently, thus developing their individual design language and process.

Keywords: Design education, textile design, textile expression, sensuous qualities, learning tool

1 INTRODUCTION
Making, describing and selecting material is something design students are engaged with throughout their education. In this paper we look closer at the textile as material of investigation. We find it relevant to explore textiles specifically, as textile designers are highly engaged with the development of textile materials, including choices on fibre, yarn, construction and after-treatment level. Here students are met with a need to explain their material choices in relation to technical, aesthetic and functional aspects. Furthermore, since textiles are applied to a certain context, it is essential that the embedded sensuous qualities expressed in the textile match the context of use.
With this paper we want to develop and explore a tool mainly for textile design students to engage with the sensuous qualities of textile materials. This is done as a support for students to further develop a vocabulary to enrich their decision making and communication of design choices, when developing textile materials or selecting them for certain applications.
In design education different scholars have contributed with tools and methods aimed for design student to explore the sensorial dimension of materials. Examples of these are *The Experience Map* [1,2], *The Comparative Scale of Materials Attributes* [3], *The Repertory Grid* [4], *The Tripod Approach* [5], *The Atlas of Materials* [6], *The Meaning of Materials Tool* [7], *The Materials in Product Selection tool* [8]. The proposed tool is not meant to be used instead of these, but in addition to, together with or before these, as we wanted to develop a tool for design students on a foundational level. Consequently, the tool provides the student with an uncomplex approach to work with sensorial qualities using the tool as an entry point for further and more complex exploration of materials and their attributes.
To develop our tool, we used *The Experience Map* (ExpMap) as a primary inspiration source and build on parts of the framework it presents. The ExpMap presents a procedure of five steps that takes the user from an existing product and a vision statement ending with a sensorial analysis [2].

1.1 Why create another learning tool?
In our tool we wanted to have emphasis on the textile itself and less on the context of use, here being an existing and envisioned product or vision statement. Furthermore, since the tool is aiming for mainly textile design students at a foundational level, these can be regarded as novice designers, we have wanted to develop a tool consisting of two activities that can be used together but also independently. Moreover, representing an institution with strong focus om design methods and processes, we have wanted to

propose ways to approach and understand textile materials that can add to students' existing tools introduced in the programme rather than a defined framework. In our tool, emphasis can be put on the reflection and discussion session after comparing the sensorial wheels, building on the work of Schön's theory of reflection-on-action [9,10].
The tool proposed in this paper is also a part of a larger pedagogical frame and teaching methods, for instance we have asked the students to build a repository of materials, a material library, which the students collect and produce themselves, which they afterwards can use in different exercises, taught at the school, and as a part of their design projects. This means that the tool can be presented in class as a brief exercise and then be modified and combined with other tools in multiple ways.
Finally, we found it crucial to develop a tool that encourages students to actively engage with – and sense - physical material samples (e.g., collected materials or materials produced as course work) using a hands-on and analogue tool that can be printed and worked with by students individually, in smaller groups as well as in class settings.
In the paper we first introduce the tool, we then explore and test the tool in a workshop with design students and we present the findings and discuss the insights from the workshop and present future work.

2 SENSORIAL AND VISUAL WHEEL

The developed tool consists of two wheels: a sensorial wheel and a visual wheel. In Figure 1, the templates for the two wheels are shown. For the wheels, we have worked with six categories: *Colour, Shape, Sound, Odour, Tactility and Texture.* Some of these categories relate to a certain sense while others are a combination of senses e.g., *Colour* relates to our visual sense, while *Texture* combines both the visual and touch senses. This approach forces the user of the wheel to focus on all the sensorial qualities of a textile simultaneously.

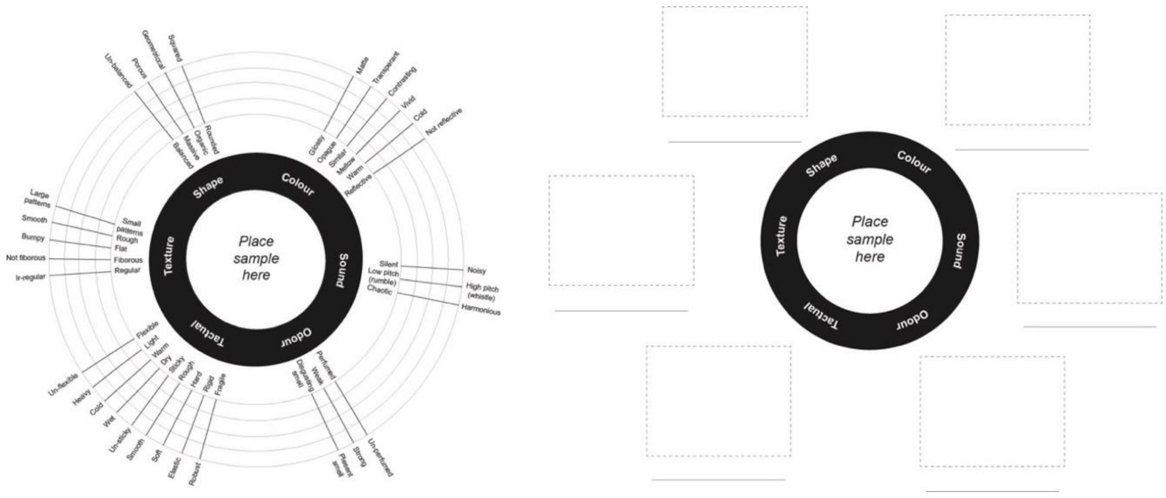


Figure 1. The sensorial wheel (left) and the visual wheel (right)

Inspired by the ExpMap, in the sensorial wheel we use multiple contrasting word pairs to create scales to assess each category. In the *Colour* category the word pair *Mellow-Vivid* is contrasting each other as a scale to subjectively evaluate the colour from. Contrasting word pairs continue around the wheel and gives a visual representation of the sensorial qualities of the textile. In the sensorial wheel new word pairs can be added to allow the user to personalise and thus describe the textile of sensorial investigation as thoroughly as possible, an example can be seen in Figure 2 visualised by a dashed line.
The visual wheel is a continuation of the sensorial wheel. The user chooses one word from each of the six categories and writes the word under the square assigned to each category. The chosen words are used as inspiration to find a visual material representation that describes the word of interest, thus adding a visual 'layer' to describe the textile.
The tools are meant to be worked with in a physical form, providing the user a hands-on approach to evaluating sensorial qualities of textiles, thus allowing easy reflection and discussion, since the wheels can be placed next to each other and shuffled around to allow multiple configurations. Configurations could be e.g., comparison of multiple material samples by individual students as a means to understand contrasts in materials or comparison of material samples amongst a group of students to understand contrasts in students' understanding and interpretation of the samples.

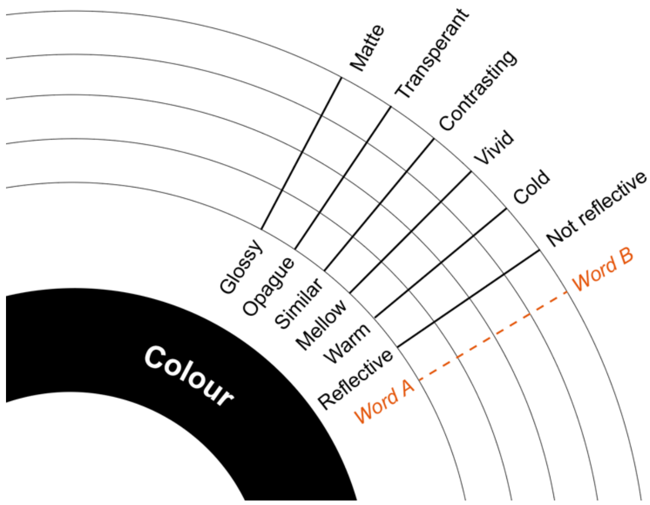


Figure 2. A section of the sensorial wheel showing how a word pair could be added

3 THE WORKSHOP - CONTEXT

The workshop was carried out as a part of a BA course at our institution on material strategies during the sixth semester. The workshop was attended by four textile design students, two accessory design students and six industrial design students. In the workshop, we wanted to introduce the wheels as a learning tool to understand expressions of already existing textile samples. For the workshop, we prepared 5x5cm textile samples of various compositions, differentiating in fibre, construction, colour and texture to provide the students with samples holding contrasting sensorial qualities.

We also provided the two wheels on A3 size paper to emphasise the physical interaction with the textiles and to allow for a physical, hands-on discussion. In Figure 3, the two wheels with the same sample made by one of the students is shown.

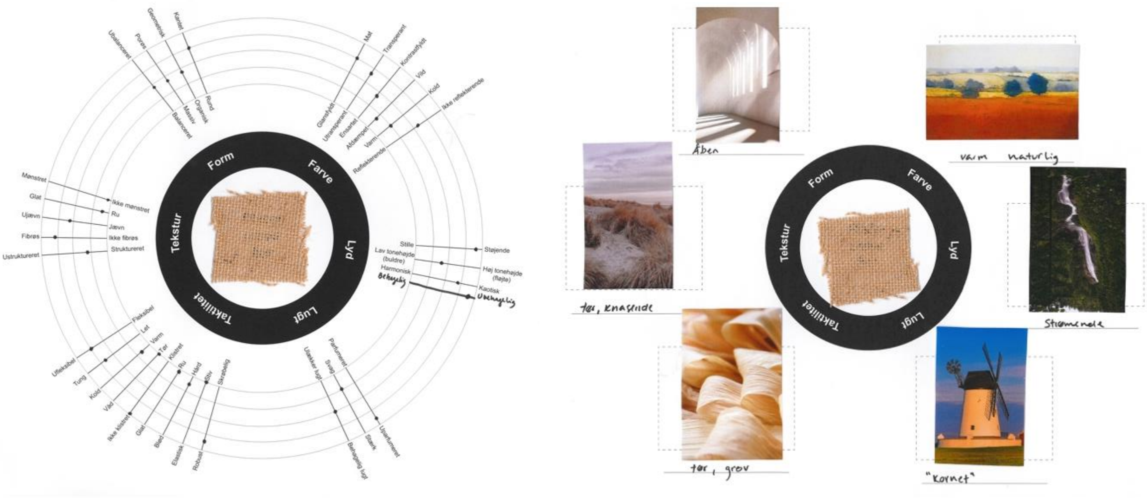


Figure 3. An example of one of the students filling in the two wheels

The students were asked to choose two textiles and evaluate these based on both wheels. Some students chose to work individually while others worked together. After students had evaluated their chosen textiles, all wheels were placed next to each other, shown in Figure 4, to provide a visual overview and allow for direct comparison between wheels and to support reflection and discussion among students on their evaluations and how the use of the tool was experienced. To evaluate the tool and the workshop, notes and insights from the students were written down, while the students were working with the wheels as well as in the discussions afterwards.

Figure 4. Students discussing their wheels in groups comparing how they have analysed the sensorial attributes of the chosen textile

4 FINDINGS

During the workshop, some students found it easy to work with the wheels, while others were a bit more apprehensive until they got started. After a few initial questions, the students worked concentrated on the two wheels. It seemed to help the students working in groups, being able to discuss together on how they would evaluate the sensorial qualities of the chosen textiles, already reflecting on the sensorial qualities and vocalising their understanding with each other, while filling out the wheels.

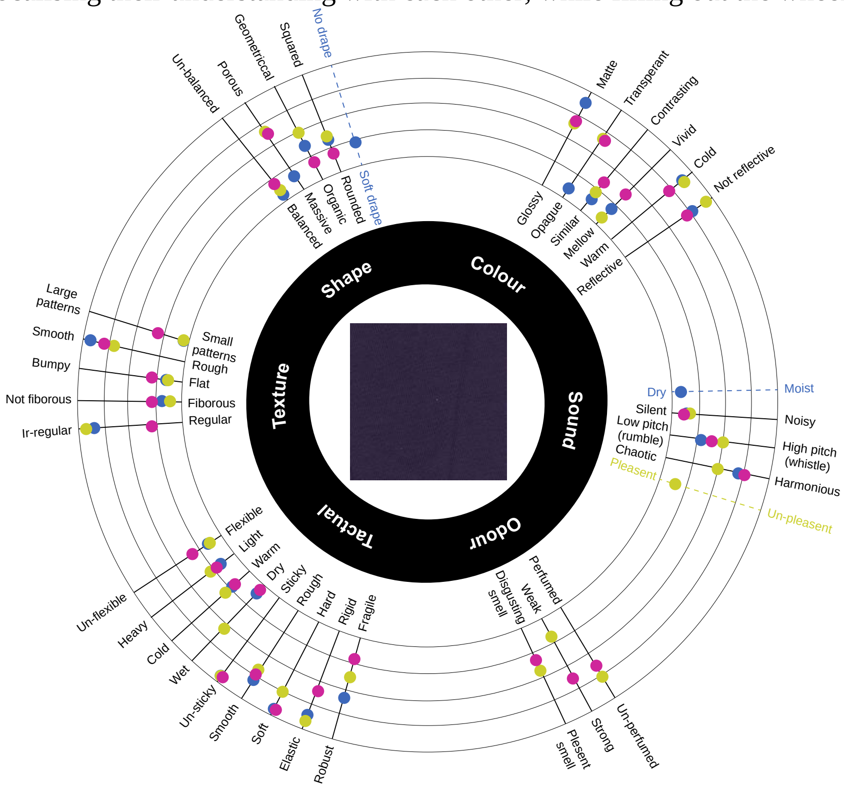


Figure 5. Examples of how students have filled in the sensorial wheel for one of the samples. Sensorial wheels for three students have been placed on top of each other

In Figure 5 the three sensorial wheels from students having chosen the dark blue knitted cotton textile are shown. Each of the students is indicated with a colour. This represents differences as well as similarities between the different sensorial wheels, thus visualising how students evaluate sensorial expressions in different ways.

In the following session where the wheels were compared, students mentioned that they found it useful to work with textile materials, which are easier to compare, because they are in "family." It was evident, that students compared the two textile samples with each other, which was not initially something we asked them to do. Here they evaluated the sensorial qualities by contrasting the two textiles they had chosen and, in some cases, using the same wheel templates. In addition, some also personalised their sensorial wheels and added contrasting word pairs, mainly in the sound category. On this, one student expressed that it could be a challenge to compare contrasting materials e.g., metal and textiles as their sensorial qualities would differ extremely. Overall, the students found the wheels useful and expressed an interest in using this approach in future design projects, also adjusting the tool to fit into their own design process.
Since different design disciplines were participating in the workshop, it was interesting to observe how these worked differently and thus evaluated the sensorial qualities differently. E.g., in one group, with an accessory and a textile design student, they discussed that the textile design student was biased, because he was trained in working with textiles and thus had a larger vocabulary and already existing knowledge of textile materials.

5 DISCUSSIONS

With this tool we wanted to create a way for the students to explore sensorial qualities of already existing textiles and to further develop a language around textiles, expanding their vocabulary on textile qualities and to train the student in nuancing their reflections with the textile material itself and about textiles qualities with others.
We chose to develop an easy to use and open tool to allow the design students to modify and integrate it into their own design process.
Based on feedback, it was important for the students to realise, that there were no 'right' answers and that we as educators are not to describe differences, but for students themselves to discover and acknowledge that they experience textile samples in different ways; subjectively as 'users' and objectively as 'design professionals,' thus training their ability to distance themselves from the experiment afterwards.
We have chosen to aim the tool for textile design students, since they are occupied with physical materials as their primary focus and are trained throughout their education to develop a language around sensorial quality. Textile designers deal with sensorial qualities as a core part of their design practice and providing them with this tool, we wanted to communicate in a tangible way, how they can explain and visualise, how they evaluate textiles and thus how they make decisions in their design process and being able to argue for those decisions.
It was a big advantage to test the tool with third year bachelor students, since they are almost graduated designers, they could very well articulate their evaluations and reflect on the tool, which provided valuable feedback. In future work we are planning to test the tool with more novice design students in earlier semesters, thus seeing if students in their early education can use the tool and how they evaluate sensorial qualities of textiles, also allowing us to follow how they incorporate and iterate on the tools in their own projects. One example, was a group of students in the BA course, where we introduced the tool. They used the tool as a part of the evaluation of their own material samples, thus applying the tool in another contexts than textiles, shown in Figure 6.

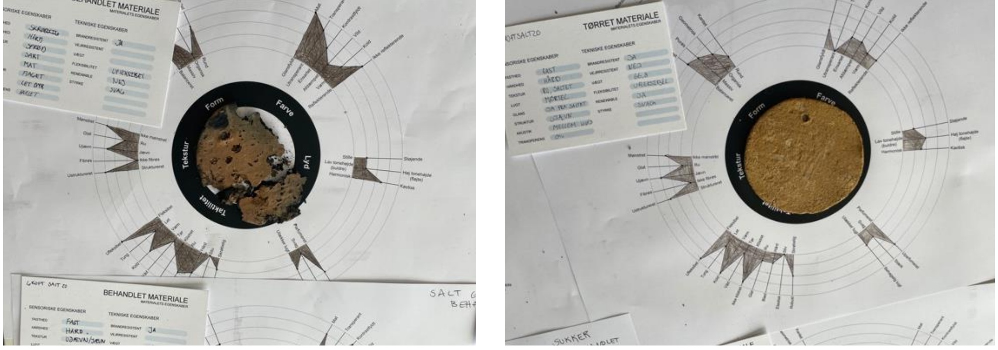


Figure 6. Examples of how students have worked with their own design project using the tool on DIY material samples

6 CONCLUSIONS

In this paper we introduced a tool inspired by the ExpMap as further development to use for foundational design education for primarily textile design students to develop the design student's language about textiles by evaluating already existing textile samples. The tool consists of a sensorial wheel and visual wheel, where the sensorial wheel describes contrasting word pairs based on sensorial qualities and the visual wheel shows chosen words from the sensorial wheel as pictures. We tested the tool in a workshop with third year bachelor design students, of which some were textile designers. Findings indicated that students overall found the tool useful and were able to reflect on the tools afterwards both in comparing their sensorial evaluations of the textile samples with each other, but also reflecting on whether they thought they could apply it in their own design process and how.

REFERENCES

[1] Camere S., Schifferstein R. and Bordegoni M. (2015). The Experience Map. A tool to support Experience-driven Multi Sensory design. In the conference on the *Design and Semantics of Form and Movement*, DeSFoRM October 2015, pp. 147-155.

[2] Camere S., Schifferstein H. N. J. and Bordegoni M. (2018). From abstract to tangible: Supporting the materialization of experiential visions with the Experience Map. *International Journal of Design*, vol. 12(2), 51-73.

[3] Hasling K. M. and Bang A. L. (2015). How associative material characteristics create textile reflection in design education, *Journal of Textile Design Research and Practice*, 3:1-2, pp. 27-46.

[4] Bang A. L. (2013). The Repertory Grid as a Tool for Dialog about Emotional Value of Textiles, *Journal of Textile Design Research and Practice*, 1:1, pp. 9-25.

[5] Bang A. L. (2012). The Tripod Approach: A Systematic and Structured Framework to Designing Applied Textiles. I J. Brasset, P. Hekkert, G. Ludden, M. Malpass, & J. McDonnell (red.), *Out of Control: Proceedings of 8th International Design and Emotion Conference 2012*

[6] Rognoli V. (2010). A Broad Survey on Expressive-sensorial Characterization of Materials for Design Education. Middle East Technical University *Journal of the Faculty of Architecture* METU JFA 2010/2 (27:2), pp. 287-300.

[7] Karana E., Hekkert P. and Kandachar P. (2010). A tool for meaning driven materials selection. *Materials and Design* vol. 31(6), pp. 2932-294.

[8] van Kesteren I. E. H., Stappers P. J. and de Bruijn J. C. M. (2007). Materials in product selection: Tools for including user-interaction aspects in materials selection. *International Journal of Design, vol. 1*(3), pp. 41-55.

[9] Schön D. A. *The reflective practitioner: How professionals think in action.* 1983. (Ashgate Publishing Limited. U.K).

[10] Schön D. A. Designing as reflective conversation with the materials of a design situation. *Knowledge-Based Systems*. 5(1), 1992, pp. 3-14.

DESIGN SPRINT METHODOLOGIES TRANSFORMED IN A DIGITAL ENVIRONMENT

Karen WINFIELD[1], Nicolette Dullesco SIZER[2] and Francesco Luke SIENA[1]
[1]Product Design Department, Nottingham Trent University, United Kingdom
[2]Engineering Department, Nottingham Trent University, United Kingdom

ABSTRACT
How can you deliver innovative teaching to over 150 students to propel their learning, connect them with leading industry experts, solve real world problems, and offer students the chance to learn from their peers across year groups? This paper presents the Design Sprint project; an intense five-day event delivered in 2020/21. This project engaged product design students from Nottingham Trent University (NTU), a team of over ten academics, clients from an industrial design team (Futura Nova), a large healthcare institution (UCL Partners), in addition to partnering with Anglia Ruskin University, to engage with focus groups within healthcare. This paper outlines the preparation and facilitation of the design sprint, identifying why we chose this methodology despite the challenges of remote/online working. The preparation/pre-sprint sessions and the key components of the sprint are discussed, highlighting how we adapted the traditional design sprint model into a hybrid methodology. The activity plan shares the key activities undertaken with examples of the Miro workbooks. Our approach was to build a programme that we could utilise going forward in online or in-person settings, to further develop the product design curriculum at NTU. Our main aim in delivering this methodology was for different year groups to work together in a live collaborative project whilst sharing/learning knowledge from a professional industrial network when utilising a methodology which could be applied in their future professional practice.

Keywords: Blended learning, collaborative/cooperative learning, design sprint, product design, transformation, pandemic, education, digital inclusion, hybrid learning

1 INTRODUCTION
A design sprint is a flexible product design framework that is used to maximise the chances of producing an outcome that people will want; the design sprint process is conducted by a team whereby a product or service is designed [1]. Usually, a design sprint utilises and wraps elements from the design process whereby scientific methods are combined with design activities in combination with philosophical viewpoints and perspectives. Design sprints are often used to solve big problems and test new ideas. Jake Knapp presents a structure/framework and a variety of focussed activities to allow a successful design sprint to be completed within just five days [2]. Integrating design sprints into the classroom or a design studio however is a significant challenge. This is complicated further when integrating this into higher education setting, especially within product design education where cohort sizes can vary from 50–150 students. Integrating design sprints into the classroom as a way of exploring new active learning tools for project-based learning approach has been utilised by academics in various sectors ranging from human computing, UX/UI design, engineering, industrial design, amongst others [3-5]. However, many researchers note that it is important that design sprint activities are run in a timely manner in order to rapidly focus product innovation to drive more valuable outcomes for the user [5].
Design sprints have considerable benefits towards teaching and disciplining students to work in ways that they will experience in industry. This approach has proven to compliment action design research, especially within the design of healthcare products [6]. This paper presents the design/delivery of an intense design sprint for 150 BSc Product Design students at NTU. This design sprint, originally planned for in-person delivery within a large design studio, was conducted within the confines of an online environment due to the UK COVID-19 pandemic national lockdown. The design sprint project presented an opportunity to engage students in an interactive way that they would not otherwise have experienced due to the limitations of working remotely. Initially planned as a 2nd year project, this soon

became an opportunity to unite 1st and 2nd year groups, to encompass a more holistic experience where both year groups would meet for the first time online and share a collaborative learning experience.

2 DEVELOPING A HYBRID DESIGN SPRINT MODEL

The design sprint methodology is often used in business communities to rapidly test ideas to see if they have potential for further investment of time thus identifying the right opportunities to progress. Companies adopt this methodology to seek quick feedback on ideas so that they can save time and money. Adopting this methodology compresses potentially months of work into just five days. Originated out of Google, design sprints have become a benchmark for companies to adopt and expediate their development process. Working with experts, an intense five-day activity starts with the problem statement and progresses through a plan of Mapping, Ideation, Prototyping and Testing to achieve a desired outcome. The length of the design sprint allowed us to plan a five consecutive day event that reached an outcome that the 2nd year cohort would subsequently further refine/develop to conclude a second stage summative assessment. In addition, the design sprint methodology is a business tool that we wanted to utilize considering the topic of focus i.e., the healthcare sector. The project brief statement below was created in collaboration with one of our professional partners Future Nova:

"How might we find a better way for healthcare professionals to capture and share information in a clinical environment"

Developing the design sprint alongside Future Nova allowed skills that resided outside of the academic team to be leveraged, in this case their network at Anglia Ruskin University and the Academic Health Science Network. The development of the online/hybrid design sprint was significantly more effective when engaging a wider group of collaborators. When setting up our hybrid design sprint model, there were three distinct differences compared to a traditional sprint. Firstly, the challenge environment would typically exist within a business organisation; ours existed outside of the business organization and in an academic framework. Secondly, the challenge would be set and solved within the framework of a business, relying on the internal experts to solve the issues; ours was set by an external professional partner and we had to draw on the diverse external expertise to inform the design sprint process. Third, a typical delivery of a methodology would be face to face; our delivery was fully online. The biggest challenge we faced was how could we translate an intense in person experience and deliver this as an immersive online experience across two-year groups with differing abilities and expectations. The digital environment needed to become a portal for all activities for our cohorts.

Our schedule of delivery utilised MS Teams supported by the use of Miro. However, unlike lectures, tutorials etc., that may last up to an hour, the sprint programme was an intense five-day event whereby each day provided up to six hours of contact time. The challenge we faced was how could we maintain the momentum and interest of the students throughout the full five days to ensure progress through the projects and avoid fatigue. We faced a number of challenges working online due to the intense nature of this methodology. The biggest challenge of note was empowering students to interact and find their own social groups. Engagement in sessions was challenging with not all students turning their cameras on or contributing to group activities. The use of technology itself was a challenge including lack of internet, poor/intermittent connections for both for staff and students. Setting up MS Teams calls with 150+ participants across the globe was challenging. As the event required full time engagement over 5 consecutive days, avoiding mental fatigue was also a concern. We also needed to ensure that the methodology was inclusive and not isolating with a number of students having various statements of access ranging from learning difficulties to registered disabilities.

After conducting a gap analysis of the current sprint, we found that elements of a traditional design sprint were either not required or had to be adapted for online delivery. Furthermore, due to the student's familiarity working through taught design processes, we adapted the design sprint methodology to align to the knowledge base of our students and removed steps which were repetitive to allow quicker progress. This adaption compensated for the fact we were working online rather than face to face. Working online also meant our transition to activities would be slower due to moving students and staff through Miro board links and in/out of MS Teams channels. The lack of physical movement which would be otherwise presented in a traditional sprint model was compensated by immediate access to prerequisite resources. The success of this was having a core localized sprint team who had definitive roles to support the event and were a key part of the planning ahead of the events. The roles followed a

"RACI" profiling where the core team took roles to be either be Responsible (R), Accountable (A), Consulted (C) and Informed (I). Roles may have spanned the RACI with roles varying from macro planners, micro planners, developers, and facilitators.

2.1 Professional engagement

A key measure of success was based on drawing on professional expertise to fill gaps of knowledge and understanding of the problem area. The challenge area was focused on acute care in a healthcare setting. We relied on our partnership with Future Nova to provide support as experts in the field and to further help secure the support of two other key partners for the project; Anglia Ruskin University supported the formation of the user focus group. In addition, UCL was introduced as they could advise students on what they would be looking for as buyers within the NHS. All parties were part of the expert panel on day five whereby they represented the client, the clinical users, and the buyer. This level of input needed a high level of coordination and flexibility from each of the parties to be aligned to the master plan. Being online provided an enhanced opportunity for engagement which may otherwise not be afforded with a traditional schedule. Our engagement with our partners was supported through collaboration with Future Nova; their historical relationships proved invaluable for us to be able to engage with the UCL and Anglia Ruskin University.

2.2 Preparing and planning the Design Sprint

Planning the roadmap for the design sprint started months in advance to engage the core industry partners and further to embed their knowledge/expertise. The roadmap of engagement for the students and staff started ahead of the core design sprint with a small number of icebreaker/team bonding events, followed by the pre-sprint day. The pre-sprint session was delivered a month in advance where a number of outcomes were tested. Firstly, we needed to test the engagement of the students and how they connected within their cohort and across year groups. Secondly, the timing/sequencing of the activities, including the transitions between Miro and MS Teams. Finally, student fatigue rates needed to be established by testing the activities and pace to retain engagement throughout the day.

Whilst the pre-sprint activity was all delivered in one day, the sprint was to be delivered over five days. The content that we created to support the five-day sprint was released in a methodical/controlled way to prevent students getting ahead of themselves. Each day was revealed at the end of the subsequent session enabling the students to gain awareness of what was planned next. The master plan for the sprint included the planning of day-to-day activities in the sprint and pre sprint sessions and further planning of the student groups. As we were integrating year groups that had otherwise never met or worked together before, we had to curate balanced groups considering ability/skill set, ethnicity, location, interest, friendship groups etc. We allowed each of the 1st and 2nd years to choose their peer groups within their respective year groups which we then matched together appropriately. The challenge for 1st years was that their social contact had been minimized. As such, 1st year selection was also supported through tutor discretion, where we could see peer support groups had formed.

As in all cohorts, there were students of low engagement which we spread across the groups to provide the best opportunity to work with their peers but also minimise groups with negative outputs. We curated teams of 10 students which included four to five second years and four to five first years. Balancing of groups with additional students was conducted where we felt that attendance of some may be an issue due to historical performance or the inclusion of weaker students. These groups would stay together throughout the project. The groups were assigned their own pre-built Miro board and MS Teams room for the whole event which they owned, and this provided a collaborative and engaging working space.

3 THE PRE-SPRINT

To engage the students effectively prior to the five-day design sprint, pre-sprint lead in activities were delivered online to engage the students across the cohorts. This also allowed the academic team to understand the student's capability/resilience to stay within a programme for an extended length of time. Furthermore, we used these events to ensure that any specialist knowledge or student contacts/network could be harnessed prior to the five-day sprint. The two main tasks of the pre sprint day were to identify the roles within each of the student groups and map out student knowledge in the challenge area whilst identifying what they didn't know. The pre sprint activities allowed the groups to practice working as an active group for the first time, this gave them time to figure out how they would stay connected using social media channels offline. Among the key activities developed was the profiling of each group member. A profiling matrix helped define roles and responsibilities of each team member identifying current levels of core skills and creativity. This profiling helped each group understand how each other's approaches may be biased and how to address this ahead of the remaining activities (Figure 1). The shaping of the teams involved a number of activities to be completed within a 30-minute timescale. These timed activities related to the brief were core to the pace through the pre sprint and sprint. Short bursts of energizing activities were also balanced with regular breaks to rest and refresh. This pattern was typical of a traditional sprint and proved even more important to relieve fatigue experienced in intense online sessions. By the end of the day each group presented their chosen project direction.

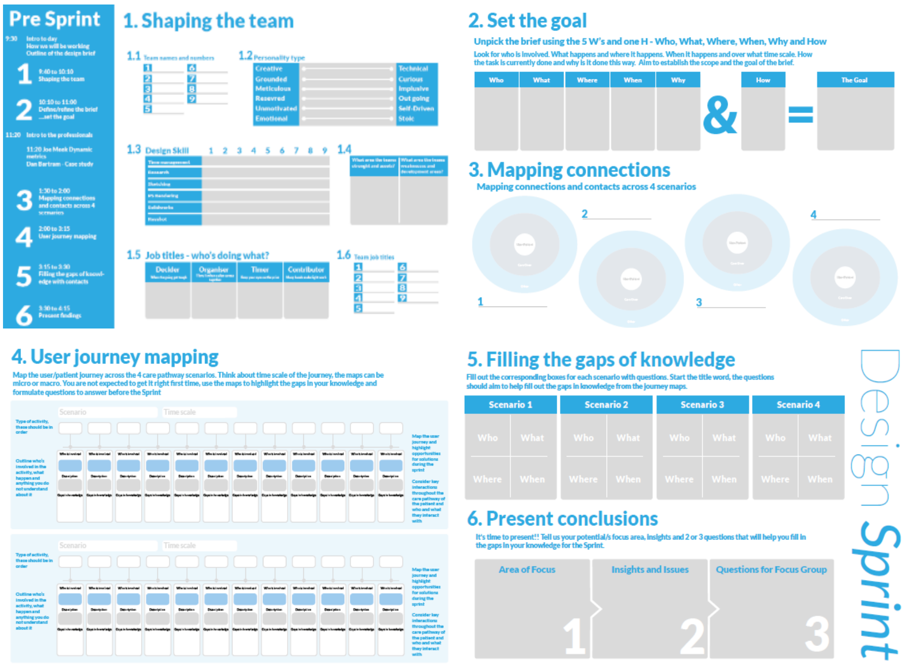


Figure 1. Pre-Sprint Activities & Workspace

4 THE 5 DAY DESIGN SPRINT

The five-day sprint delivery aligned to the structure of the pre-sprint sessions allowing progress throughout each day. The supervision of the tasks allowed the gradual unlocking of the Miro boards. The launch events visibility to activities in a controlled manner ensured the students did not feel overwhelmed, but also ensured groups didn't jump ahead/skip parts of the process. Each activity was facilitated by the core academic team and supported by the collaborators at appropriate times. Each activity had set expectations and defined time limit with expected outputs. The exercises were supported through examples described by the facilitator and supported further with real life case studies to ensure realism/connection. MS Teams channels were set up for each of the groups to meet outside of the main MS Teams channel. Whilst this ensured students worked amongst their group, the academic team could join any group at any point to encourage collaboration/facilitate discussion. The ability of the tutors to move around the activities/groups on MS Teams and view student work through the Miro links provided transparency to enable intervention if groups were not progressing. The Miro boards were laid out with structured day to day activities (Figure 2). This approach formed the backbone of the sprint allowing engagement within each team; the Miro boards also formed part of the group's formative assessment alongside their pitch to the clients on day five. Whilst work was being developed across the five days, progress could be tracked remotely and further monitored across group activities.

The core tutor team monitored the workflow in each session and adjusted the subsequent sessions, accordingly, thus building on the knowledge of how well students had engaged and rate of completion. Without doubt, working online provided the benefit of constantly connecting with professional teams across the breadth of the UK. These touchpoints with individuals may not have been as easily available if we had not adopted the platform of remote communication through MS Teams. The focus group that helped contribute to the student's primary research was also organized remotely and had to be timed to the availability of the key healthcare professionals across multiple sectors and healthcare providers.

Engagement of the students was challenging at times; some students did not switch their cameras on at all and some never responded in the live meetings when prompted. Engagement could be monitored through the work produced in the virtual space which was name/time stamped upon creation. In an attempt to reengage students we managed this with one-to one follow ups.

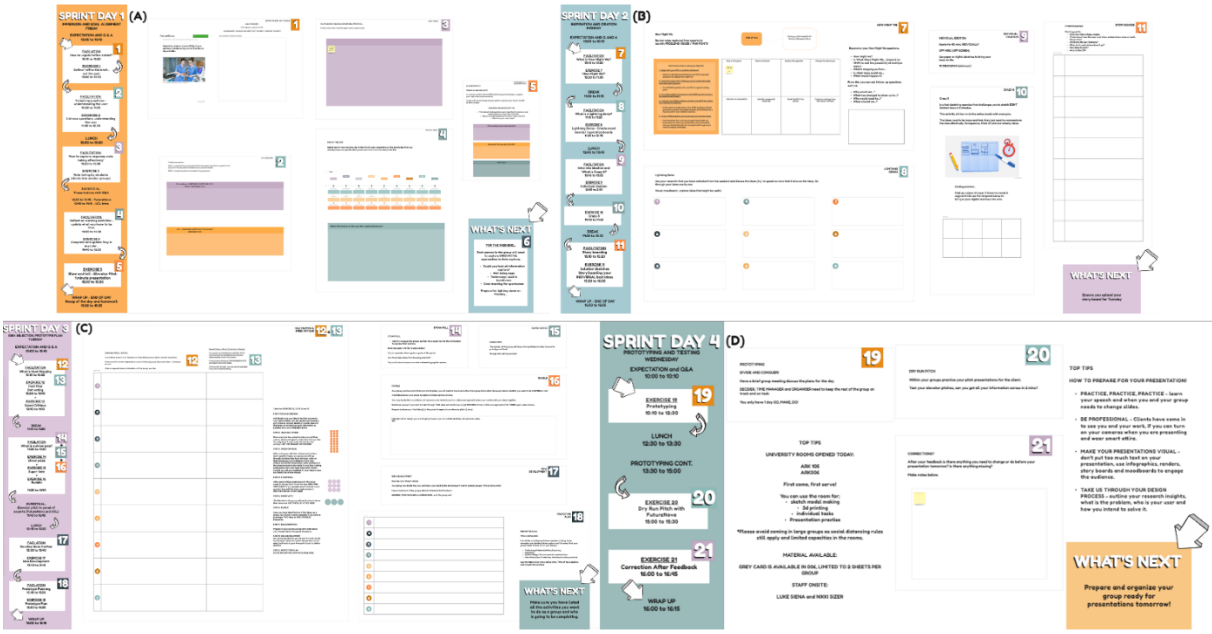


Figure 2. Design Sprint Miro Boards:
a) Day 1: Map, b) Day 2: Sketch, c) Day 3: Decide, d) Day 4: Prototype

To further reassure the remaining group members, peer assessment was used to confirm the contribution or not of students. Students that had disengaged were encouraged to return to the group as they needed to show evidence of the project as it contributed to their assessments. For first years this was part of their summative portfolio and for second years the project outcomes would develop into a CAD summative assessment. In addition to the direct curriculum learning for both year groups, there was an expectation from the second years to demonstrate skills and knowledge gained through collaborative working i.e., taking on leadership roles which could support their own personal development leading to their placement year. The experience of delivering this methodology online will allow us to introduce tools and methods into the future delivery of hybrid sprints which may take place in a face-to-face environment in future academic years. Tools such as Miro/MS Teams continue to provide access to invaluable expertise and potentially open up opportunities to enrich the experience of face-to-face teaching and learning whilst also providing a level of flexibility to engage with external professionals.

4.1 Student outcomes

The design sprint connected two-year groups in a vertical learning experience. The aim was to develop their professional skills whilst working in a team of mixed abilities thus creating opportunities to find their own space within a team and identify themselves. The tasks were diverse to allow the strengths of everyone to be used and provide a sense of self-worth and accomplishment within their group. This forced most students to engage and see where they could contribute to the tasks within their assigned role to ensure success for the team. The group dynamic would help propel the teams through the stages and this was even more critical due to the remote nature of the activity. Whilst building the challenge area and the activities of the sprint, we worked alongside the requirements of the curriculum both for first and second years. We also were aware that whilst building the collective plan we were working with differing outcomes. As this was designed to be a group activity the shared responsibility was across both years. Second year students would take the lead in the tasks and further develop the outcomes in conclusion of the sprint contributing to their individual summative CAD submission. Whilst the first years played a valued supportive and contributory role, their work would be part of their summative portfolio demonstrated through their personal research and design development. Overall, the learning outcomes for both year groups focussed on building their professionalism, practice and understanding of design/business methodologies whilst aligning the learning outcomes to the relevant IED framework.

5 CONCLUSION & RECOMMENDATIONS

The conclusions drawn from the evaluation and reflection of the design sprint have helped inform future delivery of this project in future years. Key insights highlighted have identified that planning needs to include all external/internal partners and commence months in advance. A pre sprint activity is vital to inform the main sprint event; to establish the working model for students, but also to trial the event for academics and external partners. A core sprint team that is clear on their responsibilities needs to be in place. Miro and MS Teams should be integrated into any future plans to build in flexibility and transparency whilst connecting with external collaborators regardless of the setting. The Design Sprint project has provided an interactive methodology that is now integrated into the BSc Product Design curriculum at NTU. Although typically undertaken in person, the COVID-19 pandemic created a disruptive influence on collaborative learning and the design sprint presented an opportunity to encourage collaborative/interactive learning in a different way. Instead of delaying the delivery of this project, the team at NTU utilised the design sprint thinking by adapting it into an online programme through digitisation and collaborative/cooperative learning.

Despite using an online format, this project created greater collaboration between year groups that ordinarily would not have been realised. Our structure allowed less confident students to engage equally within an active collaborative space through the use of digital tools i.e., Microsoft Teams and Miro. The immediate success of the design sprint was realised through the delivery of several pre-sprint activities that engaged key stakeholders and embedded knowledge prior to the event. The challenge for this project was to not only to provide continuity of engagement over five consecutive days but to further encourage students who had never met to work together to work collaboratively. Student feedback highlighted:

> *'The design sprint was a fun yet challenging experience. We were able to develop our skills working collaboratively through digital platforms ensuring we met deadlines, considered the users environment, and solve the problem at hand. Our team thoroughly enjoyed working with Future Nova.' [7]*

One of biggest challenges faced was the mixing year groups/peer groups. It was key for groups to become self-supportive before the start of the design sprint. The curation of the digital space was key to the success of the adoption of the methodology. This project has unlocked further potential for adoption of hybrid design sprints. The sprint has demonstrated the benefits for academics, students, and industry partners to work collaboratively regardless of the setting. Finally, we strongly recommend the cross-cohort delivery of design sprint projects due to the promotion of peer-to-peer support across cohorts which to date now continues beyond the design sprint project.

REFERENCES

[1] Banfield R., Lombardo C. T. and Wax T. *Design sprint: A practical guidebook for building great digital products*. O'Reilly Media, Inc, 2015 Sep 28.

[2] Knapp J., Zeratsky J. and Kowitz B. *Sprint: How to solve big problems and test new ideas in just five days.* Simon and Schuster; 2016 Mar 8.

[3] Ferreira V.G. and Canedo E. D. *Design sprint in classroom: exploring new active learning tools for project-based learning approach*. Journal of Ambient Intelligence and Humanized Computing, 2020;11(3):1191-212.

[4] Ferreira V. G. and Canedo E. D. *Using design sprint as a facilitator in active learning for students in the requirements engineering course: an experience report*. In Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing, April 2019 (pp. 1852-1859).

[5] Thomas J. and Strickfaden M. *From industrial design education to practice: creating discipline through design sprints.* In International Conference on Applied Human Factors and Ergonomics, July 2018, pp. 111-121. Springer, Cham.

[6] Keijzer-Broers W. J and Reuver M. D. *Applying agile design sprint methods in action design research: prototyping a health and wellbeing platform.* In International Conference on Design Science Research in Information System and Technology, May 2016 (pp. 68-80). Springer, Cham.

[7] Broughton-Shaw J. *Future Nova and Nottingham Trent University Design Sprint.* Future Nova. Available: https://www.futurenova.com/futurenova-and-nottingham-trent-university-design-sprint/ [Accessed on 2022, 6 March] (2021) 18 May.

PERFECTION VS IMPERFECTION - EVOLVING PERCEPTUAL QUALITIES OF CONCRETE

Tara HARB and Tatjana LEBLANC
University of Montreal, Canada

ABSTRACT
This paper talks about material aging and quality perception of concrete artifacts and discusses how both can affect the user experience. It explains how innovative concrete recipes and manufacturing techniques gave rise to alternate uses while referring to critical milestones that triggered change throughout the material's history. The authors observe changing attitudes towards perfection and imperfection and discuss sustainable and emotionally-durable trends that embrace material ageing. The research reveals significant progress in concrete technologies. It will remain the most prescribed building material for the expansion of the urban world. Learning to better compose with material ageing is therefore necessary and of high relevance to design education and all disciplines concerned.

Keywords: Industrial design, sustainable design, quality perception, product and material experiences, concrete artifacts

1 INTRODUCTION
In a world where city centres continue to expand, concrete is under great scrutiny. Over the years, it has considerably shaped the urban landscape and affected urban users' quality of life. The environmental, sociocultural, and economic effects of urban densification are of great concern and have caught attention of various disciplines which recognise the urgent need to address these issues [1], [2], [3].
Engineers, architects and industrial designers are thus searching for more durable solutions all while favouring eco-friendly materials and diminishing wasteful practices. Trending activities include life cycle analysis, recycling of materials, and reduction of waste.
We were interested in looking into possibilities to prolong the use of a product and making material aging acceptable. Our research was more specifically investigating the appraisal and user experiences of concrete artifacts [4], [5] to better understand the complex cultural and social phenomena that affect quality perception of concrete. Since perceptions are idiosyncratic and highly context dependent, it was necessary to immerse ourselves in the subject by both observing and actively participating in the experience of the material in its contexts [4] by studying the material's appraisal through a naturalistic approach [5], [6], [7].
Literature reviews helped us amass data from historical and technical documents, scientific studies, and mediatic sources providing us with insights into concrete's development throughout history and identify the milestones that triggered change. Empirical observations and photographic content helped us document physical and contextual characteristics of concrete artifacts and extract varying perceptual qualities [9]. The gathered data was subsequently mapped out, categorised and interpreted using the material's experience frameworks [13] [14]. In addition, gathered statements and testimonies revealed people's varying perception of the material. The following sections explain the key findings and how they influence the perception of concrete.

2 WHAT CAN BE LEARNED FROM THE EVOLUTION OF CONCRETE
History teaches us how technological progress and socioeconomic needs have shaped societies. Our historic overview of concrete's evolution revealed to us which critical milestones have affected the industry.
The research showed that a wide variety of concrete-like materials and mixes can be traced back to ancient Neolithic, Greco-Romanic, and Middle Eastern civilisations [15]. The categorisation of concrete, as seen below, shows that concrete-like materials can be either naturally found or manufactured from various compounds (Figure 1).

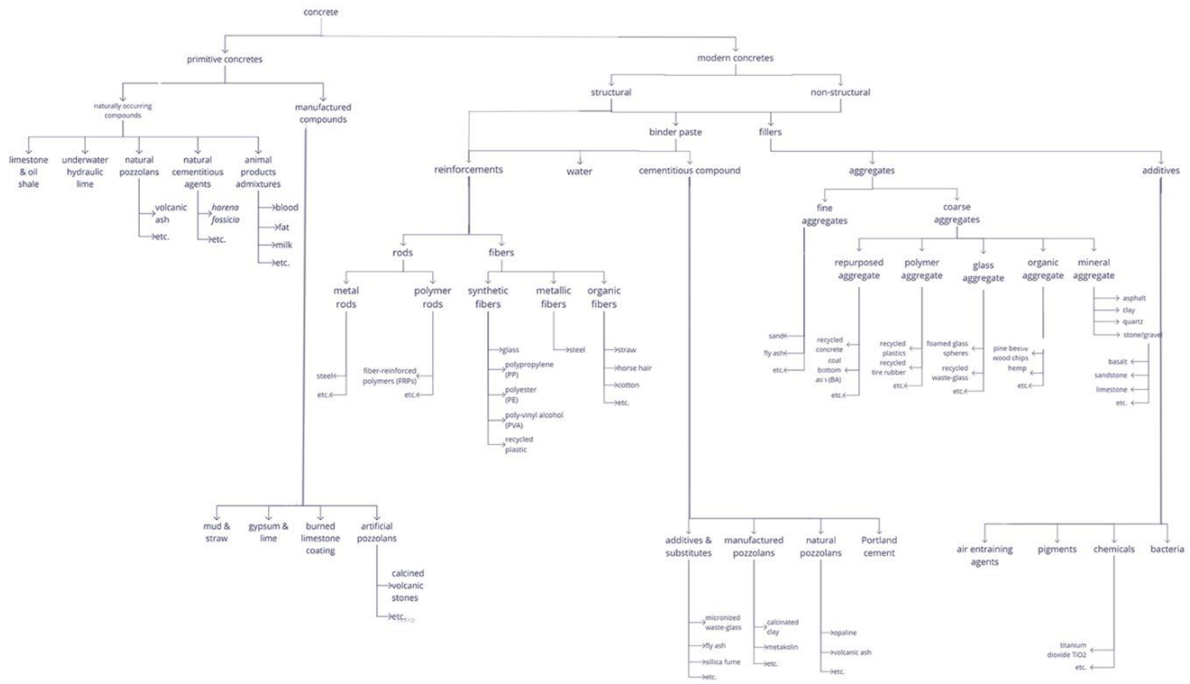


Figure 1. Primitive and Modern Concretes, T. Harb (2022)

2.1 Changing recipes

Although, recipes have been significantly improved, steel reinforced concrete and Portland cement remain to date two of the most relevant discoveries which have revolutionised the industry [15], [16], [17]. However, in the late 20th century, the material's environmental impact had become cause for great concern [18], notably due to the astonishing quantities of natural resources required to manufacture it and the effects it has on our ecosystem [19]. Driven by the sustainability movement, researchers continue to develop new mixes in order to improve concrete's physical properties, including its ecological footprint, durability, and aesthetics.

New mixes, such as the Ultra-High-Performance Concretes (UHPC), offer better compressive strength, ductility, tensile strength, heat-deflection, auto-repair capabilities, and freeze-thaw cycle resistance [21]. Other eco-friendly recipes also enhance the ecological performance of traditional MCs by incorporating recycled materials as fillers [19].

Current studies are looking into optimising the natural resources by reusing wastewater, replacing ingredients with non-biodegradable waste materials [20], or by using by-products of other industries (e.g., fly ash) [21]. Other experts explore other additives to improve concrete's performances and quality such as self-cleaning 'smog eating' concrete with photocatalytic additives [22], photoluminescent concrete absorbing UV radiation [23], and even bio-concretes which facilitate the growth of microalgae, moss, fungi, and lichens on its surface [24], to only name a few.

2.2 Changing manufacturing techniques

Furthermore, the introduction of on-site recycling and modern production techniques has considerably changed the construction industry in terms of efficiency, cost saving, and speed.

Traditionally casted in wooden formworks leading to *rigid* and *robust geometrical* shapes, alternative manufacturing techniques began using flexible formworks that produce *softer* volumes and more *delicate* finishes, as seen below (Figure 2) [25]. The introduction of 3D printing or CNC-milled moulds using fluid-dynamics algorithms, are pushing the limits even further [26], [27] (Figure 3). The need for formwork has been eliminated, all while optimising the production process, reducing waste, and increasing the precision of complex artifacts in which material is strategically placed when structural support is required [26].

Figure 2. (left) Concrete Pavilion by ZHA & ETH Zurich – image by Philippe Block via ZHA from ArchDaily.com (2018)
Figure 3. (right) Concrete Choreograph by ETH Zurich – image from Dezeen.com (2019)

2.3 Changing applications

The emergence of high-performance recipes as well as alternative manufacturing techniques is providing designers, architects, and engineers with unprecedented opportunities. They allow them to create once unthinkable shapes and textures with concrete [9]. The material, once mainly featured in large-scale architectural and structural applications, is now also being used on a smaller scale to produce indoor furniture, lampshades, sinks, or tableware.

In recent years, architects and interior designers are exposing the qualities of *béton brut* in artifacts of remembrance or spirituality (memorials, mosques, temples, churches, etc.), and more recently in residential environments, thus highlighting a *rough, strong, industrial* look, which is often associated with “brutalism”. These perceptual qualities of the material are also exploited in cinematography, photography, and sculptural artwork, drawing attention to concrete’s *rhetoric*, *poetic,* and *symbolic* values [9].

2.4 Changing perceptions

Although concrete is usually highly appreciated for its pragmatic qualities (e.g., *availability, performance, cost, adaptability to wide spectrum of applications*, etc.), it remains a *controversial* material which some learned to love, and others reject [9].

Our research was trying to elucidate the causes of this apparent dualism by analysing mediatic and historical documents and by extracting experts and public appraisals and testimonies. The results were organised using bi-polar semantic scales [28] (*ugly* vs. *beautiful, durable vs. non-durable, cheap vs. rich)* and subsequently analysed according to Desmet & Hekkert’s *product and material experience framework* [14] by assessing the described aesthetic pleasure (or displeasure) produced while interacting with the product, the associated meanings, and the resulting emotional responses.

The study [9] revealed that design professionals, insiders, and early-adopters consider concrete artifacts as *impressive, practical, durable, richly textured*, *(denotative meaning)*, as well as *beautiful*, *modern*, *masculine, sexy (connotative meaning)* [29]. According to statements, the product and material experience of some concrete artifacts generate strong feelings of *fascination*, *attraction*, and *desire*.

On the other hand, others associate concrete with *social housings, prisons,* or *bunkers*, thus resulting in a certain degree of adversity towards the material. They tend to link the material with (connotation) *war*, *social housing*, and *concrete jungle* while denoting its physical qualities: *heavy*, *grey*, *cold*, *rough*, *etc*. Concrete thus comes off as *uninviting, cold, oppressing,* and *cheap* which generates feelings of *repulsion*, *hate,* or *boredom* [9].

To appreciate a product or a material, people draw from past experiences (positive or negative). They consciously or subconsciously make associations that are meaningful or memorable to them.

Therefore, some older generations, for example, tend to associate concrete with *wars, ghettos and crumbling infrastructures*, whereas the younger generations, which may rather associate concrete with *social housing* and *vandalism.* Their experiences and appraisals affect their attitude towards the material.

2.5 Quality perception of concrete

In general, experts see concrete as a *synthetic* material which behaves like any other *natural* one as it ages [15], [16], [17]. During the casting process, as the mix cures, it spontaneously exhibits superficial *"imperfections"* that manifest themselves in form of stains, air bubbles, crumbles, and cracks (see Figures 4, 5 & 6). However, these 'signs of life' [30] are *inevitable* and *harmless* as they do not diminish the structural performance of the material [15]. Others, however, perceive them as *unattractive imperfections*, similar to blemishes, scars, or stains on skin.

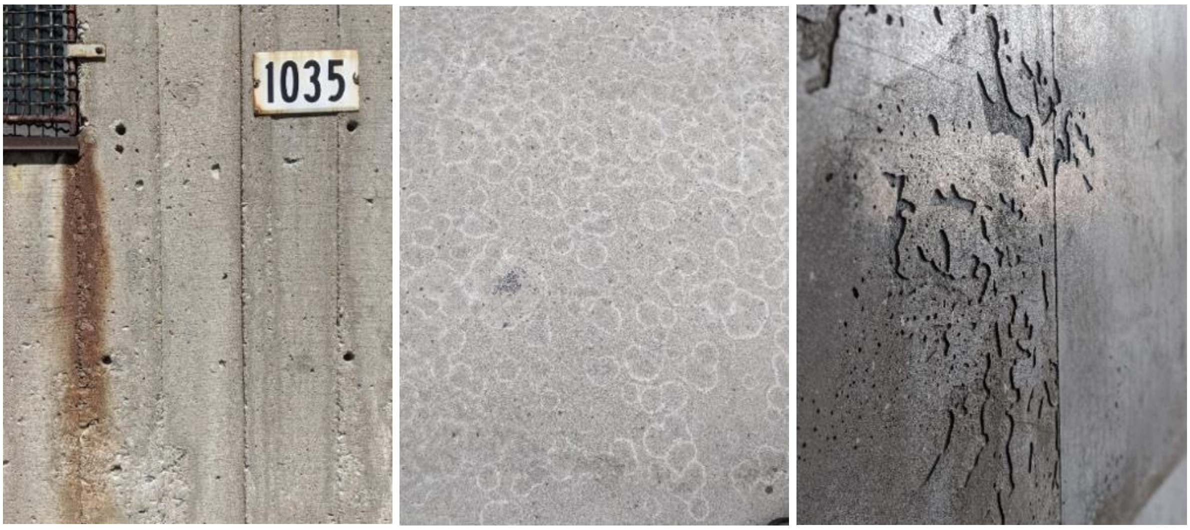


Figure 4 & 5. (left, middle) Concrete imperfections – image by T. Harb, Montreal, CA (2020)
Figure 6. (right) Concrete imperfections – image by T. Harb, Tokyo, Japan (2019)

Indeed, quality perception can be linked to modern trends in economy-driven consumer societies which easily discard *worn* artifacts rather than *preserving* or *repairing* them [30]. However, different cultures can have varied attitude towards imperfections and material ageing in general. In fact, some like to compare surface stains and scratches to wrinkles and scars on a human skin while others tend to accept these 'imperfections' as traces of life, which add a sense of *wisdom* to the artifact, making it more *valuable* and *worthy of preservation.* It mirrors the *respect* of a culture for their elders, or the appreciation of the patina on materials such as oxidised copper, old leather, seasoned wood, and other natural materials [31], [32].

Yet, while *naturally-behaving* materials and their imperfections are seen to acquire *pleasing sensorial characteristics* as they age [33], most *synthetic* materials – and concrete in particular – do not benefit from such considerations of their imperfection. This begs the question: What does it take to embrace *imperfection in* concrete and to find *beauty* in its *unpredictability* and *uniqueness*?

3 A CHANGING PARADIGM

The evolution of the material and the (re)discovery of old and new recipes contributes to a multitude of uses that are of contradicting values and meanings and which vary from one generation, culture, and society to the other [9]. Some are universally shared and pragmatic (*affordable, accessible, imperfect, etc.),* while others are far more subjective (*unique, meaningful, expressive, repulsive, intimidating, cold, etc.*) [20]. Our research shows, that these perceptions can change. Technological progress brought along new unexpected and useful features (e.g., self-repairing, CO2-absorbing, etc.) and surprising applications in new fields which affect the quality perception of concrete artifacts. The younger generations tend to embrace progress more easily by celebrating the re-discovery of the material [34].

Furthermore, modern societies are witnessing a shifting collective consciousness which call for more responsible lifestyles and sustainable practices [34]. Instead of discarding artifacts which bear signs of use, more and more users are finding value in imperfections and are learning to fix and preserve. Human centred design can contribute positively to this shift by composing with the material's natural ageing through its different uses. This paradigm shift is in part the result of our climate change awareness, a crisis that requires the world's attention.

However, aesthetic appreciations are also cultural ones. Society is learning to reject premature obsolescence by respecting, and sometimes embracing, a materials' natural behaviour as it ages. For example, to remedy concrete defects, which may occur with the passage of time, multiple repair techniques are available (e.g., epoxy injections, overlay, stitching, routing & sealing, patching, etc.) which would prolong its use.

Yet, we may need to learn to accept such signs of material aging. Designers can play a role in this equation by considering from the beginning of the design process the different stages of the material aging across its lifecycle, knowing that some materials will degrade with time, while others mature and improve (e.g., by gaining a patina, etc.). The social values affixed to such material ageing are indeed contradictory [30] as signs of wear are seen to greatly influence the user experience thus sometimes adding value and charm through the discovery and appreciation of these manifestations (e.g., scratched old wooden surfaces), while other times rather devaluing the artifacts (e.g., stains on concrete floors)

4 RELEVANCE TO DESIGN EDUCATION

Some cultures began adopting a new material aesthetics which embraces imperfections and graceful aging and deterioration. With this rising interest in sustainability, concepts such as the aesthetic of sustainability have emerged, proving to be of high interest for design disciplines and can be seen as an effective way to influence the behaviours and actions within a society [33].

Design educators may need to do more to address questions of how to promote sustainable lifestyle, how to embrace material aging, and how to assess a material's lifecycle.

Despite its multiple advantages, concrete maintains a bad reputation. It is seen to deteriorate poorly, and mass urbanisation contributes to the depletion of our natural resources worldwide. Although, a significant progress has been made in the field, design curriculums do not always showcase it adequately and requires more attention.

5 CONCLUSIONS

To conclude, concrete can be perceived in contradicting ways as the material can hold opposing meanings: while some apprehend the material and associate it with *premature deterioration* and *environmental concerns*, others appreciate it and *admire* its *bold and unique qualities*.

The research has shown that technological progress and novel applications offer design opportunities that can also support sustainable design practices. It is our belief that design disciplines can play a significant part in helping promote a sustainable material culture and change user perception of typically neglected materials. In that sense, human-centred and sustainability-driven design teachings have the ability and responsibility to contribute positively to the shift in paradigm. Although we solely focused on the case of concrete, our observations are also relevant to other materials and artefacts.

The human centred design approach needs to better represent people's individuality and to promote emotional attachment, specifically relating to product and material experiences. Design education can thus put more emphasis on material behaviour over time and encourage designers to compose *with* – as opposed to *against* – materials' natural aging process by envisioning alternatives which extend life expectancy and embrace signs of use.

REFERENCES

[1] Mulder K. F. "Urban Symbiosis as a Strategy for Sustainabilising Cities: An Overview of Options and Their Potential, Pitfalls and Solutions." *Civil Engineering Research Journal* 2, no. 3 (2017).

[2] Jacobs J. *The Death and Life of Great American Cities*. Vintage Books, 1992.

[3] "The World Bank Annual Report 2010 : Year in Review. World Bank Annual Report." Washington, DC. ": © World Bank., 2010.

[4] Cross N. "Science and Design Methodology: A Review." *Research in Engineering Design* 5, no. 2 (June 1, 1993): 63–69.

[5] Creswell J. W. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4 edition. Thousand Oaks: Sage Publications, 2013.

[6] Hodder I. "The Interpretation of Documents and Material Culture. I." In *N. K. Denzin, & Y. S. Lincoln (Eds.), Handbook of Qualitative Research*, 673–715. Thousand Oaks, CA: Sage, 1994.

[7] Denzin N. K. and Lincoln Y. S. *The Landscape of Qualitative Research*. SAGE, 2008.

[8] Schön D. A. *The Reflective Practitioner : How Professionals Think in Action*. Routledge, 1983.

[9] Harb T. "The Perceptual Qualities of Concrete : A Change in Paradigm." Université de Montréal, 2021

[10] Desmet P. and Hekkert P. "Framework of Product Experience." *International Journal of Design* 1 (April 1, 2007): 57–66.
[11] Forty A. *Concrete and Culture: A Material History*. Reaktion Books, 2013.
[12] Simonnet C. *Le beton, histoire d'un materiau*. First edition. Marseille: Editions Parenthèses, 2005.
[13] Veenendaal D., West M. and Block P. "History and Overview of Fabric Formwork: Using Fabrics for Concrete Casting." *Structural Concrete* 12, no. 3 (2011): 164–77.
[14] Sherwin C. "Design and Sustainability." *The Journal of Sustainable Product Design* 4, no. 1 (January 1, 2004): 21–31.
[15] Meyer C. "Concrete as a Green Building Material." *Journal of Materials in Civil Engineering*, 2000, 10.
[16] Ganiron Jr T. "Recycling Concrete Debris from Construction and Demolition Waste." *International Journal of Advanced Science and Technology* 77 (April 30, 2015): 7–24.
[17] Tagnit-Hamou A., Soliman N. and Omran A. "Green Ultra-High Performance Glass Concrete," 2016.
[18] Dezeen. "Researchers Develop 'Biological Concrete' That Grows Moss and Fungi," 2013.
[19] Mujkanović A., Bečirhodžić D. and Merdić N. "Self-cleaning Concrete – A Construction Material for Building Cleaner World," Trends in the Development of Machinery and Associated Technology, 2016, 4.
[20] Luo Y., Zhang L., Liu Z., Wang Y., Meng F. and Wu J. "Thermal Performance Evaluation of an Active Building Integrated Photovoltaic Thermoelectric Wall System." *Applied Energy* 177 (September 1, 2016): 25–39.
[21] West M. "Fabric-Formed Concrete Structures." *First International Conference on Concrete*, 2001.
[22] Wangler T., Lloret E., Reiter L., Hack N., Gramazio F., Kohler M., Berhard M. et al. "Digital Concrete: Opportunities and Challenges." *RILEM Technical Letters* 1 (October 31, 2016): 67–75.
[23] antistatics. "The MaoHaus, Digital Fabrication." Accessed March 18, 2021.
[24] Osgood C. E., Suci G. J. and Tannenbaum P. *The Measurement of Meaning*. 1st Edition. Urbana-Champaign: University of Illinois Press, 1967.
[25] Barthes R. *Mythologies*. Les lettres nouvelles, 1972.
[26] Chapman J. *Emotionally Durable Design: Objects, Experiences and Empathy*. 2 edition. London ; New York, NY: Routledge, 2015.
[27] Karana E., Pedgley O. and Rognoli V., eds. *Materials Experience: Fundamentals of Materials and Design*. 1 edition. Amsterdam: Butterworth-Heinemann, 2013.
[28] Ashby M. F. and Johnson K. *Materials and Design: The Art and Science of Material Selection in Product Design*. 3 edition. Oxford: Butterworth-Heinemann, 2014.
[29] Saito Y. *Everyday Aesthetics*. Oxford, New York: Oxford University Press, 2008
[30] Gidley J. "Evolving Education: A Postformal-Integral-Planetary Gaze at the Evolution of Consciousness and the Educational Imperatives | Semantic Scholar." School of Education Southern Cross University, 2008.
[31] Scott J. and Marshall G. *A Dictionary of Sociology*. *A Dictionary of Sociology*. Oxford University Press, 2009.

REDUCING AIR POLLUTION IN CITIES: EVALUATE THE GAP IN POPULATION ENGAGEMENT AND POLICY STRATEGIES

Minh NGHIEM
Oslo Metropolitan University, Norway

ABSTRACT
Improving outdoor air pollution is a global emerging concern that can be explored in product design education. Polluted air causes not only severe health risks but also negative effects on economics of countries. Urban planning design is a crucial part of the improvement process. However, this process often involves many different interdisciplinary factors. This master's project study focuses mainly on two different approaches to improve air quality: *reduction* of *pollutant emissions* by traffic management strategy and enhances *pollutant dispersion* by *urban planning*. A review highlights the current research on the two approaches, their limitations, and future consideration. To gain richer information through a user-oriented design approach to better understand participants' attitude, a qualitative approach with deep-in digital interviews was used in this study. This study reveals a gap of information between policymakers and users, which decreases the effectiveness of air quality improvement policies.

Keywords: Air pollution, urban design, street canyons, local traffic policies, product design education

1 INTRODUCTION: POLLUTION IS VERY EXPENSIVE

Air pollution is considered as a primary environmental concern worldwide. This issue is especially more serious in cities because of pollutant emissions released from vehicle transportations. As a result, exposure to polluted air can affect negatively to people's health. A recent study estimated that 4.1 million people died associated with poor air quality in 2016 [1]. Another research from O'Donoghue, R.T. (2007) [2] and Quiros, D.C. (2013) [3] further revealed that breathing during walking increases significantly the health risks of pedestrians when compared to other road users. Health risks of air pollution consequently make countries sustain considerable economic costs, including direct medical costs, health care costs, and opportunity costs from diminished productivity of pollution-damaged populations [1]. Therefore, improving outdoor air pollution and harm reduction solutions in city centres are essential to encourage people to switch to sustainable transports such as walking, cycling, or public transport.

To get an overview of air pollution in urban environments, in 2021, the municipalities of Oslo, Bergen, Bærum, Drammen, and Kristiansand, as well as NILU, OsloMet, Telenor, Telia, and Vicotee, collaborate in the URBANITY. This research project includes master's students in product design education and the overall aim is to provide an opportunity to continuously monitor air quality with a low-cost sensors network in the cities. The project will create high-quality real-time air quality maps, providing residents and stakeholders with better information and reliability. The stakeholders hope that upon completion of the project, they will create a platform to improve services to residents, such as personalized air quality information, meanwhile encourage citizen participation in making traffic policies and urban planning.

2 BACKGROUND AND LITERATURE REVIEW: A MATTER OF POLICIES

Numerous studies on reducing air pollution have been conducted on various aspects, including traffic management strategies and urban design strategies. However, this information remains fragmented, mainly focused on specific parts and somewhat technical, which reduces its applicability to local policy or urban development and management plan [4]. A broad literature review reveals a more comprehensive picture, indicating potentials for ongoing research. Meanwhile provides the evidence base for decision-makers in the implementation strategy of clean air policies.

Over the last few decades, the EU has developed clean air policies focus on reducing pollutant emissions. Most local policies have steady attention on air quality improvement by using traffic management strategies (TMS). A review by Bigazzi, A.Y. [5] indicates their policies focused mainly on two primary mechanisms:

The total amount of vehicle kilometres travelled: primarily affected through travel activity and mode choice modifications such as using public transportation, reducing private car usage, increasing parking fees, shared-ride programmes, telework, etc.

Average emissions rates: affected through vehicle and fuel characteristics and driver behaviour modifications like ring road utilization, odd-even driving, speed limit reduction.

Bigazzi has reviewed numerous identified studies to evaluate the state of evidence that TMS can improve urban air quality for exposed populations. Only 7 of the 22 studied strategies have limited evidence of effects on air quality. While other TMS strategies do not have sufficient evidence of its impact [5]. Besides, some TMS strategies are also associated with the risk of negative effects or opportunities for spill over and indirect effects.

On the other hand, recent air quality mappings in several cities in Europe such as Paris [6], London [7], and Antwerp [8] indicated city street canyons have levels of air pollution (NO_2) nearly as high as highways and ring roads, despite lower traffic intensity. Therefore, more attention has been driven towards passive methods in using natural ventilation to enhance pollutant dispersion and reduce pedestrian exposure to air pollutants among researchers, urban planners, and policymakers.

These studies spread from city-wide scale [9] to local scale such as street canyons in the city centre [4]. Many studies have demonstrated that urban morphology on a large scale affects atmospheric pollution dispersion. Although this phenomenon is still underexplored, significant progress has been recently made in the field.

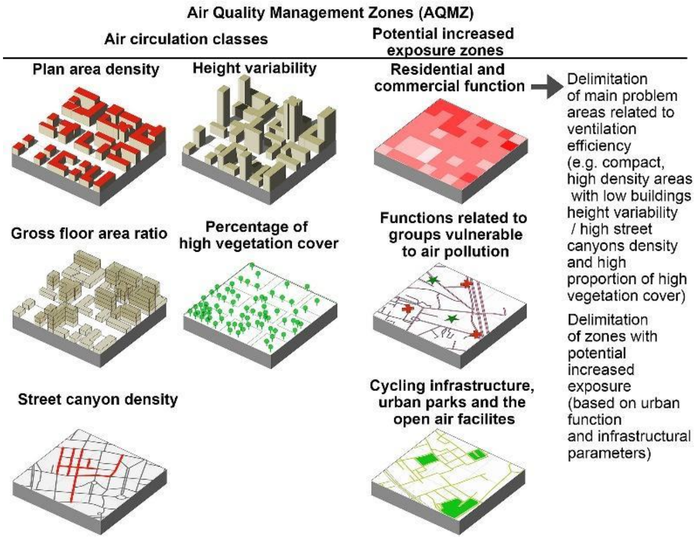


Figure 1. The set of indicators for the Air Quality Management Zones [9]

The gain is the same as studies on a local scale in the city centre. In most urban environments, the city centre area is defined by street canyon configuration, building configuration, the in-canyon configuration [4]. This study aims to describe the general effects of urban morphology on the dilution and dispersion of airflow and pollution. Researchers could have a visual diagram of these different parameters.

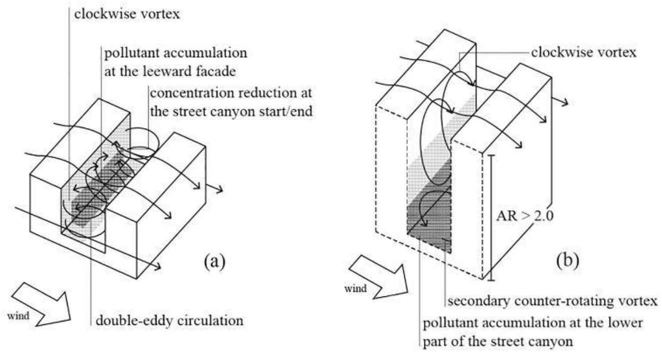


Figure 2. Estimated airflow and pollutant distribution [4]

3 RESEARCH QUESTION: NEW PARADIGM IN THE WAY MAKING POLICIES

Studies on the efficiency of LEZs [10] [11] [12] in the last couple of years have all concluded that results are uncertain. Moreover, research by Boogaard, H. et al. (2012) [13] and Ku, D. et al. (2011) [14] shows that local transport policies, including LEZs, only achieve low results in reducing traffic-related air pollution. In other words, the effects might be possible, but the evidence of benefits is insufficient [5]. Therefore, a different approach is needed. It is essential to planning urban which allowing the wind to flow around the building and disperse traffic air pollution. Those street canyons restrict vehicle emissions diffusion and aggravate roadside air quality. However, this issue is often unnoticed by stakeholders, architects, designers, and the public in city planning due to lack of information. This matter leads to the research question in this study: *How to evaluate gap in population engagement and policy of clean air development strategies in traffic management and urban planning?* The scope of this topic concerns a wide range of interrelated disciplines. In particular, the design process demands both understanding of core urban morphology features (e.g., gross floor area ratio, plan area density, and frontal area density) and the involvement of stakeholders in urban planning. Stakeholders can be categorized into regulators, producers, and users. An analysis of stakeholders can gain a different perspective in improving urban air quality. Due to limited time and resources, this pilot master project focused on only analysing public awareness about local policy examination.

4 METHODS: LITERATURE REVIEW AND QUALITATIVE APPROACH

The research methods used in this review were introduced in the book Research Design by Leavy, P. [15].

4.1 Qualitative approach

This review applies the qualitative method through deep-in digital interviews. The interview consisted of a set of questions about the participants' interest and engagement in urban air quality, then determined the level of willingness to participate in city air pollution reduction programmes. This approach allows having back-and-forth dialogue with respondents, which results in collecting richer information and better understanding the respondents' opinions. Based on the largest age group in Oslo, the participants were chosen from 19 to 44 years old with higher education.

4.2 Design of interview

The interview was designed to follow three main categories and variables associated with each category. Table 1 shows an overview of categories and their variables.

Potential exposure to air pollution: This category determines the targeting of respondents. The respondents should involve in outdoor activities in order to move forward to other questions in the other two categories.

Engagement of population to air quality issue: This category can reveal a better understanding of the respondents' perception and their attitude towards air quality and improving air quality.

Willingness to participate in measures for air pollution reduction: This category provides behavioural patterns that may affect urban policies in improving air pollution in city centres.

Table 1. Category of analysis

Category	Variable
Potential exposure to air pollution	Exposure time
	Activity types during exposure
Engagement of population to air quality issue	Perceptions of air pollution
	Perceptions of air quality information
	Engagement in improving air quality
Willingness to participate in measures for air pollution reduction	Measures in traffic management strategies (TMS)
	Measures in urban planning

All participants were selected based on their outside time and their variety of outdoor activities in the city centre. The majority of members spend more than 6 hours per week outside, high potential of exposure to air pollution.

Activity type results in a wide range of outdoor activities such as walking, cycling, or staying outside. More than a half ratio related to high breathing rate activities. The average inhales weight of pollutants of pedestrians and bicyclists having high breathing activities is higher than the average value observed from commuters [2]. That indicates that interviewed group is a potential due to the increased risk inhale weight of pollutants.

5 RESULTS AND DISCUSSION

5.1 Engagement of population to air quality issue

Perceptions of air pollution: All positive feedback on the need to have air quality information available. The results of the in-depth interviews showed similarities in their perceptions of air pollution. The majority of the students rated the air quality as good. It may be due to the similarity of the group of students in terms of age and living environment. However, that similarity also reflects the monotony of information about air pollution. At the same time, their definition of bad or polluted air is very vague and general.

Perceptions of air quality information: The majority will consider changing their behaviour based on air quality information. In that, air quality has a substantial impact on half of them. However, information about air quality is hard to find in instant smartphone apps or PC desktops. People need to access a specific website (https://www.iqair.com/) or smartphone apps (Air visual) to look for information. This inconvenience also prevents the dissemination of information about air quality. Therefore, people tend to use their senses to judge air quality without using any factual information.

Air quality impacts people's daily activities, especially for vulnerable people such as children, the elderly, and people with a history of respiratory disease. There is a need for citizens to have air quality information available.

In 2018, a pilot project from Castell, N. had deployed low-cost sensors to monitor air quality in kindergartens in the Oslo area to help parents and kindergarten staff change practices accordingly. Although some promising results have been achieved from that, the quality of the data is still questionable [16]. The real-time environmental data at high spatial and temporal resolution need more time to develop.

Similarly, most of the current local activities are heavily related to transport management evaluation and still lack of area morphology consideration, both in terms of city wide-scale and local scale. Each city has a different morphology, such as gross floor area ratio, plan area density, and frontal area density that will strongly impact on air circulation level. At the same street canyon, placing the sensor in an area with good ventilation will give false-positive results. Conversely, when setting sensors at points of accumulation, the data will give false negative feedback. Evaluating studies on a smaller scale help identify sensor locations that fully reflect the air quality in that area, avoiding inaccurate sensor information from local interference.

5.2 Willingness to participate in measures for air pollution reduction

Measures in traffic management strategies: the result shows that all interviewees are willing to cooperate in air quality improvement policies from moderate to high levels.

However, agreement levels with increasing fees in using private vehicles are not supported by interviewees at most measures, especially compared with increasing public transport. Despite the high level of willingness from participating in policies and a high impact of air quality in behaviour, people still do not want to pay extra money for toll fees or convert to greener vehicles. The reason for it may generate from the fact that insufficient evidence of effectiveness for convincing citizens to accept that policy.

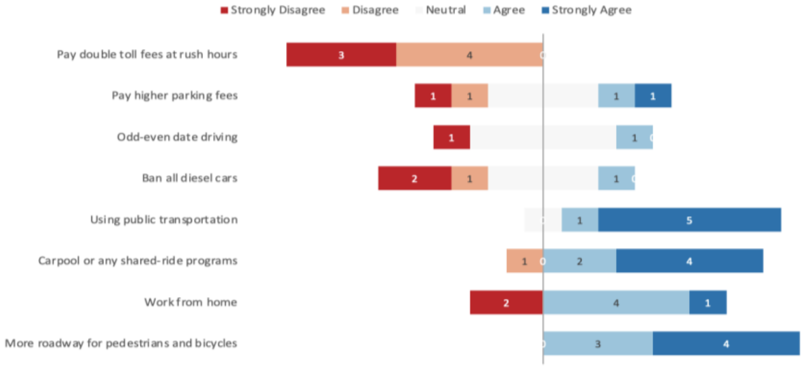


Figure 3. Respondents' opinions about solutions for improving outdoor air quality-TMS policies

However, the assessment from the target in these measures is still based on subjective experiences and not on objective research results. Such ambiguity can explain the lack of air quality improvement reports with solid evidence for each measure, including TMS and urban design. effective evidence-based measures based on Bigazzi's research can be cost-based measures, including increased toll fees and parking, especially for diesel vehicles [5].

Figure 4 shows a high agreement level; however, the low awareness level of the interview group regarding the effect of urban design on air pollution reduction despite the group background.

For example, the solution of planting tall trees in polluted areas is chosen by most students. Still, that measure is not recommended because tall trees will obstruct the wind in diffusing pollution, and the green wall on the building façade does not have a noticeable result in dispersion air pollution [4].

Such misunderstandings can show a lack of sufficient information to raise public awareness of effective measures to improve air quality.

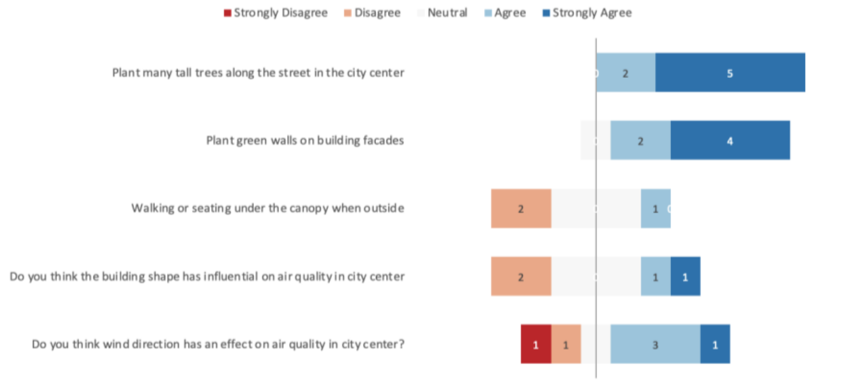


Figure 4. Respondents' opinions about improving outdoor air quality – Urban Design policies

6 CONCLUSIONS

There is a massive gap between the policymakers on improving air pollution and the citizens. The lack of information on air quality will reduce the level of cooperation with policymakers on these issues. In addition, decision-makers themselves need tools to measure the effectiveness of their policies. Creating a platform is absolutely essential. On that platform, the policymakers can adjust their decisions based on quick and timely information, and the people also benefit from this information. This information will strengthen people's support for measures to reduce air pollution emissions to the government.

However, as this pilot master study has shown, measures of the effectiveness of TMS are either completely unproven or very weak. The reason is that there are too many external factors affecting the measurement process. Especially in the complex urban context, it is easy to be biased. The information that can be received may be too local or to spread to reflect the data accurately.

Frameworks and guideline diagrams for ventilation to reduce pollution have been studied on an urban scale, and the smaller central scale is a big step forward. It contributes to standardize data collection for the system to evaluate the measures applied, the synchronization platform between different strategies. In addition, it provides stakeholders with more parametric tools to deploy strategic studies to measure air indicators and have more foundation for implementing further studies. These strategic studies eventually enable stakeholders such as architects, designers, policymakers, and citizens to have a better foundation to promote the contribution of ideas to develop measures to improve air quality.

However, the studies on transport strategy and urban design still have technical limitations that need further investigation. The improvement of the cheap sensor is necessary. In addition, further studies on the parameters of meteorology and the natural urban environment are required to increase the reliability of the data.

It is worth noting that efforts from the policymakers are not enough. Citizens need to be more active in looking for information and increasing their attention to air quality. That will promote citizen's contribution to the development of improving air quality policies.

ACKNOWLEDGEMENTS

This study was part of the Design Research course in Master Programme Product Design. I want to acknowledge my Professor in the Product Design Department, for guiding me through this course. I would also like to thank my fellow students for their support.

REFERENCES

[1] *The Cost of Air Pollution*. Other Environmental Study. 2016: World Bank. -1.

[2] O'Donoghue R. T. et al. *Exposure to hydrocarbon concentrations while commuting or exercising in Dublin.* Environment International, 2007. 33(1): p. 1-8.

[3] Quiros D. C. et al. *Ultrafine particle exposures while walking, cycling, and driving along an urban residential roadway.* Atmospheric Environment, 2013. 73: p. 185-194.

[4] Voordeckers D. et al. *Guidelines for passive control of traffic-related air pollution in street canyons: An overview for urban planning.* Landscape and Urban Planning, 2021. 207: p. 103980.

[5] Bigazzi A.Y. and Rouleau M. *Can traffic management strategies improve urban air quality? A review of the evidence.* Journal of Transport & Health, 2017. 7: p. 111-124.

[6] Cariolet J.-M. et al. *Assessing the resilience of urban areas to traffic-related air pollution: Application in Greater Paris.* Science of The Total Environment, 2018. 615: p. 588-596.

[7] Network L. A. Q. *Environmental Research Group of King's College, London.* Web page: http://www.londonair.org.uk/london/asp/default. asp, 2017.

[8] Meysman F. et al. *Citizen science reveals the population exposure to air pollution.* 2020.

[9] Badach J. et al. *A framework for Air Quality Management Zones - Useful GIS-based tool for urban planning: Case studies in Antwerp and Gdańsk.* Building and Environment, 2020. 174: p. 106743.

[10] Panteliadis P. et al. *Implementation of a low emission zone and evaluation of effects on air quality by long-term monitoring.* Atmospheric Environment, 2014. 86: p. 113-119.

[11] Holman C., Harrison R. and Querol X. *Review of the efficacy of low emission zones to improve urban air quality in European cities.* Atmospheric Environment, 2015. 111: p. 161-169.

[12] Ezeah C., Finney K. and Nnajide C. *A Critical Review of the Effectiveness of Low Emission Zones (LEZ) As A Strategy for the Management of Air Quality in Major European Cities.* Journal of Multidisciplinary Engineering Science and Technology, 2015. 2(7): p. 1860-1868.

[13] Boogaard H. et al. *Impact of low emission zones and local traffic policies on ambient air pollution concentrations.* Science of The Total Environment, 2012. 435-436: p. 132-140.

[14] Ku D. et al. *Review of European low emission zone policy.* Chemical Engineering Transactions, 2020. 78: p. 241-246.

[15] Leavy P. *Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches*. 2017: Guilford Publications.

[16] Castell N. et al. *Localized real-time information on outdoor air quality at kindergartens in Oslo, Norway using low-cost sensor nodes.* Environmental Research, 2018. 165: p. 410-419.

CRITIQUE: A WORKSHOP TO ESTABLISH SHARED UNDERSTANDING AND CLEAR RESPONSIBILITIES BETWEEN DESIGN STUDENTS AND THEIR LECTURERS

Lore BROSENS[1,3], Ellen DE VOS[1,2,3] and Marina EMMANOUIL[1,3]
[1]Design.Nexus research group Ghent University, Belgium
[2]imec-mict-UGent, Belgium
[3]Department of Industrial Systems Engineering and Product Design, Ghent University, Belgium

ABSTRACT

With the new industries on the horizon, where design engineers will become facilitators of innovation that need to keep up with an array of new technologies, it is essential that our students are equipped with skills in line with this new role. From literature describing emerging paradigms (Skills for Industry 4.0, and 21st century skills) it becomes clear that students need life-long learning skills, which have been linked to reflective thinking and learning during critique. However, at our university we noticed that students needed to be assisted in this. Students seem unable to translate the discussion points during critique sessions to design actions or challenge teachers' feedback with counter arguments. Therefore, it is important to establish clear goals and consistency of actions between teachers. This paper will report on the development of such goals through a critique workshop with lecturers and focus groups with students. The outcome of the development is a template with responsibilities for both the feedback-giver (lecturer) and recipient (student). These responsibilities are categorized in actions before, during, and after the critique is given in an effort to trigger reflection at various moments. With this template we hope to provide different anchors for both student and lecturer to have insightful critique moments. By sharing our experiences, we wish to inspire other design engineering lecturer teams to try to come to their own shared understanding of what critique should entail and how responsibilities between lecturers and students are divided.

Keywords: Critique, feedback, life-long learning skills, reflection, template

1 INTRODUCTION – THE IMPORTANCE OF CRITIQUE FOR LIFE-LONG LEARNING SKILL DEVELOPMENT

One of the greatest challenges for design engineering are the current changes in industry triggered by new technologies that are rapidly evolving. Correspondingly, the roles of design engineers are also changing to become facilitators of innovation within multidisciplinary teams [1]. In order to take up these roles, design engineers need to be equipped with the skills to update their knowledge during their career on new emerging technologies. Schneorson and her colleagues [2] confirm this by stating that design engineers must adapt to an open-minded approach of life-long learning. So, in order to prepare current students for a successful career, even when future technologies are largely unknown, we must prepare them to keep updating their knowledge and skillset as they go. Furthermore, this rationale is not only found in literature, but is also highlighted in the discussion at this conference on the professional and pedagogic roles of design and engineering.

As researchers [3–5], and the design engineering community as a whole, come to an understanding that design curricula should change and we inquire what these changes should encompass, the question remains how design engineering education should actually support students in developing these skills. Paulsen [6] shares some findings in his book and states that life-long learning skills have been linked to personal mastery, design engineer identity development, and an open-mind towards new ideas and challenges. Tracey and her colleagues [7] add to this by stating that the aforementioned competences are better acquired when students engage with reflection during critique or feedback sessions. The importance of these critique sessions in cognitive competence development is again stressed by Scagnetti [8], who finds that critique is where independent thinking is developed and reflection is grasped. Building on these arguments it could be said that supporting students in learning during feedback sessions or critique is very important for their designer identity development and their ability to continue to learn during their career.

2 BACKGROUNDS

Zooming in on these highly important critique moments, previous research points out that this is a very complex way of transferring knowledge [9]. This is mainly due to the fact that critique needs to be adapted for every student for maximum student benefit. So, educators have to be creative in order to personalise their means of educating [10]. This is in-line with recent developments of looking at critique as a consulting, tutoring, feedback, or even coaching moment. However, these new ways of looking at critique also opened the discussion within our field of what the specific role of critique is.

A first perspective is that of critique as an assessment moment where the student and teacher gain an insight into the level of quality of the work [11-12]. However, recently some curricula and teachers have started moving away from this view on critique towards more informal critique. When not communicated clearly, this shift leads to confusion on the students-side [13]. Students are unaware of the level of formality of the critique, which relates to their level of preparedness. Also, a lecturer in year one might have a very informal approach, which confuses students later in their studies if they encounter more formal critiques. Therefore, it is important to establish clear goals and consistency between teachers.

A second view is that of critique as a learning moment where the focus should be more on feedback giving. Usually, this means that students present their in-progress work and they receive input to continue their design processes [8], [10]. The goal is that the feedback-giver and feedback-receiver come to a shared understanding [13]. Additionally looking at critique as feedback can benefit students on multiple other levels. Students have the opportunity to learn new skills [10] and refine their way of thinking about design [15-16]. However, many instructors did not realize that looking at critiques as a learning moment can have all these impacts. They seem unaware and it seems unclear as to how they can make sure students benefit the most from the time spend on critiquing [14]. This accentuates the need for lecturer support in order to deliver a high-quality level of feedback to every student.

Third, many design lecturers refer to their critique moments as open-ended discussions [9] or a dialogue between an experienced designer and a less experienced designer [18]. Clearly, seeing critique as a discussion is a perspective that is moving away from the more formal ways of looking at critiquing, beyond feedback, towards an informal discussion. Strikingly, when critique becomes less formal, so does the term evolve to a 'crit' [10]. Although the setting is less formal, researchers have found that the goal is still to come to a shared understanding of what is and what could be [16], and initiating reflection [13]. However, the same issues occur here as well. Prompting students to reflect in order to develop problem solving skills requires a personal approach to critique and teachers are in need of support [17].

Fourth, by looking at critique as a moment to develop designer identity, teachers tend to focus on the end goals of the design engineering curriculum. These include: development of design expertise, communication skills [12,10], independent thinking [8-9], decision making, and finding your voice as a designer [10,18]. These outcomes are important to instructors as they are aiming to transfer these capabilities to students. By focussing so much on the end goal, teachers tend to neglect students immediate needs in order to continue their creative process [9]. Additionally, the capabilities listed above need to be trained over time, and moreover trained through a scaffolding process. Therefore, teachers should first assist students a lot, and then, gradually, support them less. If every student is on a different learning path, that requires a very flexible approach to critiquing.

Lastly, critique moments are also seen as reflection triggering moments. Researchers state that when students are encouraged to take part in critique, they stop for a few minutes and think about what they know, do not know, did, did not do, and which choices they made [17]. But, reflection can also be generated after the critique [13], by thinking about the judgements and disagreements. Researchers add that students can benefit from listening to recordings, away from the moment and pressure, in order to start developing this skill.

3 TOWARDS A SHARED UNDERSTANDING OF CRITIQUE

Building on the above-stated rationale, and our own experiences within the Industrial Design Engineering programme at Ghent University, we see a two-fold deficiency in the way critique is currently approached. First, it is important to come to an agreement of how curricula, courses, or even individual lecturers implement critique in their classes. Students are easily confused on the level of formality of a critique and consequentially might not prepare it adequately. Students would benefit from a consistent approach in critiques from all lecturing staff. Second, both lecturers and students need to be supported in the roles they have during a critique. Lecturers need to be assisted in delivering high quality, personalised, and scaffolded critiques. Students need to be assisted in reflections prompts both before, during, and after the critique. Our students are taught through weekly critiques from the first year. However, we noticed that students do not succeed in processing the given critique towards an answer, neither in words, nor in (design) actions. Engaging with reflection will benefit students' actions, designer identity development, communication, problem solving, and decision-making skills. Surely, this focus on reflective thinking and learning during critique should be introduced in a scaffolding way.

This paper shares our experiences on filling both gaps. Although everyone sees the importance of critique, the requirements concerning these critique-sessions are not consistent among different lecturers. There is no coherence in the shared expectations, which are often not properly communicated and leave the students uncertain about the goal and type of critique. Therefore, we set out to create a workshop for a team of design engineering lecturers to come to such a shared understanding. Additionally, we also hope to develop a template that can distinguish the different roles of a lecturer and student, and assist students in reflection before, during, and after a critique. With this template we hope to provide different anchors for both student and lecturer to have insightful critique moments.

4 TEMPLATE DEVELOPMENT METHOD

4.1 Critique workshop

All team-members (n=15) of the Industrial Design Engineering programme at Ghent University were invited to a workshop on critique during a dedicated education-team day (30th June 2021). A coherent group of fifteen Industrial Design Engineering lecturers, a mixture of professors, (post-)doctoral researchers, and practical instructors gathered physically. No specifications were given before the workshop, however, there was a prior agreement to tackle this subject on the allocated time. Hence, all participants were motivated to engage. English was chosen as the workshop language due to participants from different nationalities.

4.2 Procedure

A pedagogic developer at the faculty of Engineering and Architecture was consulted before the workshop. His team had created a general guideline for lecturers on the topic of feedback to stimulate active learning. They distinguished between feed-back, feed-forward or feed-up. The researchers copied this insight into their workshop preparations. Additionally, the researchers also looked into the state-of-the-art research findings on critique (a synthesis can be found in the background section of this paper). The fifteen participants were divided in five groups with mixed teaching experience based on seniority and type of courses (some courses in the programme are more technically orientated and others more focused on entrepreneurship).

At first, the lecturers were asked to share an anecdote on the subject matter. Most shared something they already had implemented in their course and considered best-practice, others shared problems or struggles they encountered related to critique. Second, a first template, created by the researchers, was given as a starting point for the main exercise. A paper was divided in six parts: vertically, three different times were indicated (before, during and after) and, horizontally, the template distinguished between the student and lecturer (teacher). The teams were asked to select the most relevant excerpts provided by the researchers and locate these on that field of the template where it fits most, according to them. These excerpts were selected by the researchers and originated from the previously developed guideline on feed-back, feed-forward, and feed-up combined with statements from our literature review. Participants could then add post-it notes, arrows, text, or highlights to further elaborate on the excerpts. Subsequently, the participants were asked to indicate (with coloured dots) whether the action mentioned was a basic element of a critique session and should be introduced to the freshmen, or if it was appropriate, for more experienced students. An example of such a filled-out template can be seen in

Figure 1. Lastly, all groups presented their completed templated to the other teams. At this point, questions could be asked. Most participants filled each field of the template. It was, striking to see that some lecturers (two groups) find their responsibility is limited to before and during a critique. They did not indicate any lecturer responsibilities for after the critique is finished.

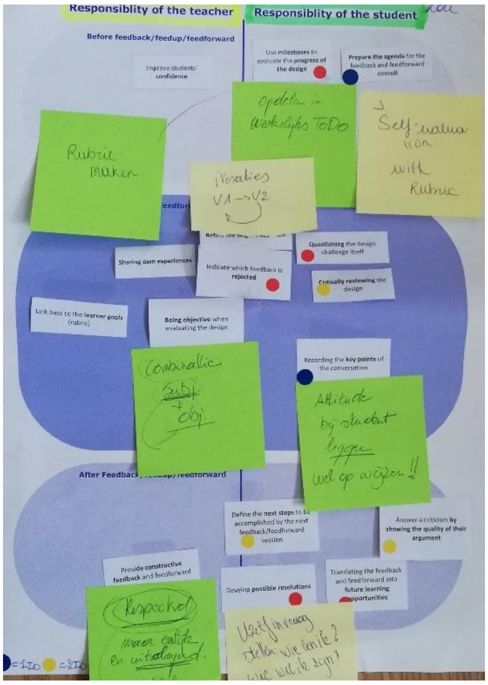


Figure 1. Example of filled out template during workshop

4.3 Incorporating stakeholder insights

After the workshop, the researchers summarized the templates and processed these. During this synthesising, the researchers deliberately looked for similarities across the templates so that we could come to this team-shared understanding on critique. Our synthesis was sent anew to the participants. Due to the close link between the researchers and the participants -they are colleagues- a quick and efficient communication characterized this project. No further comments were made, and several participants agreed to implement the created tool in their course the following year.

Complementary, also the opinion of two external experts was requested. A first expert is the pedagogic developer already mentioned above. He accentuated the cyclical shape of a critique session and suggested to rethink the graphics of the template. Content-wise this loop was already implemented. The second consulted expert, a student psychologist, is evidently more familiar with the interpretation and perception of students. She illustrated among other elements that too much openness makes students feel insecure and can obstruct them in taking action. A particular focus on the preparation and the post-session could help the students.

Lastly, in order to incorporate insights from all relevant stakeholders we organised a focus group with students. The focus group consisted of eight students, two from each year of our three-year bachelor’s programme and two students from our one-year master’s programme. What was found during this focus group is that students found the language used in the template hard to understand. They suggested to either rephrase the statements to be more ‘hands-on’ and to introduce the template together with an explanation of what everything means. Most students in the focus group found that the practical tips in the template were the most valuable (e.g., if a student struggles with taking notes during a critique, a solution could be to bring a peer to take notes or ask if you can record the session). Lastly, students stated that if they had to commit to every single aspect of the template for every critique they have, it would overload them with a lot of extra tasks. Therefore, it would be best for teachers to indicate which aspects of the template they find most important within their course context. Additionally, students are prepared to put in the extra work, but then expect a prepared lecturer as well.

4.4 Dissemination

After synthesising and incorporating all the comments of stakeholders (team-members, experts, students), the template was presented to all Industrial Design Engineering students during a kick-off event at the start of the academic year 2021-2022. The template can easily be found by this target group on the university's online platform. In addition, the students can find a visualization of the tool as a poster on the campus walls. At any moment, the researchers can be contacted for further information both by teachers and students. Furthermore, a pilot-study is currently in progress in several courses of the programme: freshmen, sophomores, graduating bachelor and master's students are at least in one course employing the template. The responsible teachers accentuate some of its topics to match with their study content and approach. Also, the use of the template is adjusted to the expected maturity of the students.

5 OUTCOMES AND DISCUSSION

In this paper we presented our strategies and experiences of coming to a team-shared understanding of critique and to develop a template that could clarify the different expectations between a lecturer and student. By engaging with this workshop our team agreed that we see critique as a feedback moment, where students and lecturers have a discussion. By introducing a common critique session template, we merge the most relevant aspects of such a discussion without narrowing down the options lecturers have to emphasize certain parts. However, the template itself is only a means in order to create routines where, if successful, the use of the template will eventually become redundant.

Multiple stakeholders involved, saw benefits of structuring the responsibilities of critique. Especially because students are now also encouraged to express expectations towards the lecturer instead of being subjected to a one-sided information stream. Our aim was to develop a template that can bring clarification and objectivity in the discussion without ignoring that critique can impact one's feelings and unavoidably containing some subjectivity. Therefore, we included prompts for lecturers like: *"Check whether the student interpreted the comments as you intended. You can validate how the feedback was reformulated and if it was rejected or not. Maybe if the student is not comfortable yet, they will share this in the consult documentation."* But also, towards students: *"Show your uncertainties by explicitly stating the challenges and difficulties you are experiencing. It is important to show unfinished work and dare to fail. You do not have to prove yourself, instead an honest and transparent communication about your work will stimulate useful dialogue*."

The pedagogical developer found it inspirational that the template did not only state how critiques should be tackled, but also what attitudes we expect both parties to bring to the conversation (e.g., students taking ownership, lecturers being supportive and formulating constructive critique). In order to create space for reflection and the designer's interpretation of the given project and its context we added prompts like: *"How will you adjust your approach? Define the next steps, judge what is good to bring forward, and prioritise. Reformulate the assignment by the next critique and refine your design approach.."* In order to avoid vagueness, we included calls-to action to pronounce different interpretations like: *"Judge what is good to bring forward and prioritise. Reformulate, in your own words the critique."* Lecturers pointed out this would increase their confidence that their message had been understood.

5.1 In-progress and future work

Besides implementing the template in multiple courses and testing it out, we are also sharing our experiences thus far. One of those sharing platforms is this conference and also as part of a university-wide workgroup on feedback. We hope to inspire other courses that might not be as familiar with teaching through critique. In parallel to implementing the template in multiple courses, the students, who took part in the focus group were approached again and were keen to organise a student event dedicated to training on critique sessions. Our template could be showcased and act as the start of a debate.

ACKNOWLEDGEMENTS

We would like to thank the Industrial Design team (our colleagues) for their input into developing this template, and their willingness to test it in their courses. We would like to thank Lander Cnudde (pedagogical developer) and Annick Eelbode (student psychologist) for sharing their expertise. Lastly,

we would like to stress that this template is a discussion between lecturers and students, so we, without their insights, would not have been able to develop it.

REFERENCES

[1] Augsten A. and Gekeler M. *From a master of crafts to a facilitator of innovation. How the increasing importance of creative collaboration requires new ways of teaching design*. The Design Journal, vol. 20, no. sup1, pp. S1058–S1071, 2017, doi: 10.1080/14606925.2017.1353049.

[2] Schneorson D., Persov E. and Bigger R. *Designing Your Future - 21st Century Skill-Set for Industrial Designers: The case study of Israel Design Field.* Design Journal, vol. 22, no. sup1, pp. 243–259, 2019, doi: 10.1080/14606925.2019.1595862.

[3] Norman D. A. *When You Come to a Fork in the Road, Take It: The Future of Design.* She Ji, vol. 2, no. 4, pp. 343–348, 2016, doi: 10.1016/j.sheji.2017.07.003.

[4] Findeli A. *Rethinking Design Education for the 21st Century: Theoretical, Methodological, and Ethical Discussion.* Design Issues, vol. 17, no. 1, pp. 5–17, 2001, doi: 10.1162/07479360152103796.

[5] Meyer M. W. *Changing Design Education for the 21st Century*. She Ji: The Journal of Design, Economics, and Innovation, no. February, pp. 13–49, 2020.

[6] Paulsen M. B. Higher Ed Book, vol. 31.

[7] Tracey M. W., Hutchinson A. and Grzebyk T. Q. *Instructional designers as reflective practitioners: Developing professional identity through reflection.* Educational Technology Research and Development, vol. 62, no. 3, pp. 315–334, 2014, doi: 10.1007/s11423-014-9334-9.

[8] Scagnetti G. *A dialogical model for studio critiques in Design Education*. The Design Journal, vol. 20, no. sup1, pp. S781–S791, 2017, doi: 10.1080/14606925.2017.1353024.

[9] McDonald J. K. and Michela E. *The design critique and the moral goods of studio pedagogy*. Design Studies, vol. 62, pp. 1–35, 2019, doi: 10.1016/j.destud.2019.02.001.

[10] McDonald J. K., Rich P. J. and Gubler N. B. *The Perceived Value of Informal, Peer Critique in the Instructional Design Studio*. TechTrends, vol. 63, pp. 149–159, 2019, doi: 10.1007/s11528-018-0302-9.

[11] Christensen K. S., Hjorth M., Iversen O. S. and Blikstein P. *Towards a formal assessment of design literacy: Analysing K-12 students' stance towards inquiry*. Design Studies, vol. 46, pp. 125–151, 2016, doi: 10.1016/j.destud.2016.05.002.

[12] Gray C. M. *Democratizing assessment practices through multimodal critique in the design classroom.* International Journal of Technology and Design Education, vol. 29, no. 4, pp. 929–946, Sep. 2019, doi: 10.1007/s10798-018-9471-2.

[13] Oak A. *It's a nice idea, but it's not actually real: Assessing the objects and activities of design*. International Journal of Art and Design Education, vol. 19, no. 1, pp. 86–95, 2000, doi: 10.1111/1468-5949.00205.

[14] Yilmaz S. and Daly S. R. *Feedback in concept development: Comparing design disciplines*. Design Studies, vol. 45, pp. 137–158, 2016, doi: 10.1016/j.destud.2015.12.008.

[15] Miceli L. and Zeeng L. *Reconstructing the critique. Using inclusive formative feedback in face-to-face and online communities of practice to improve knowledge acquisition in design education*. The Design Journal, vol. 20, no. sup1, pp. S1250–S1259, 2017, doi: 10.1080/14606925.2017.1352654.

[16] Rodgers P. A., Innella G. and Bremner C. *Paradoxes in Design Thinking*. The Design Journal, vol. 20, no. sup1, pp. S4444–S4458, 2017, doi: 10.1080/14606925.2017.1352941.

[17] Welsh A. A. and Dehler G. E. *Combining Critical Reflection and Design Thinking to Develop Integrative Learners*. Journal of Management Education, vol. 37, no. 6, pp. 771–802, 2013, doi: 10.1177/1052562912470107.

[18] Christensen B. T. and Ball L. J. *Dimensions of creative evaluation: Distinct design and reasoning strategies for aesthetic, functional and originality judgements.* Design Studies, vol. 45, pp. 116–136, 2016, doi: 10.1016/j.destud.2015.12.005.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

INTRODUCING PEER-ASSISTED LEARNING CONCEPT IN A DESIGN COURSE

Sagar CHIRANKAR, Shyam Kumar Singh MUNDA, Aasmita DAS, Arnab PATRA, Elishan JAMI, Kanika MEENA, Sonu SONU and Supradip DAS
Department of Design, Indian Institute of Technology Guwahati, India

ABSTRACT
Design education is based on interactive discussions between students and their facilitators. Deeper engaging interactions can generate a range of concepts in the initial design phase. However, from the student's perspective, the discussions with the course facilitator may turn formal and pose a restriction on free-flowing ideas. Despite applying different student engaging methods, there still seems to be an invisible barrier that holds them back from freely expressing their design thoughts. The concept of Peer-Assisted Learning (PAL) was introduced in a design course in the Department of Design at the Indian Institute of Technology, Guwahati (DoD, IITG), to solve this issue. This paper discusses the observations and findings of the experimental study with PAL in an industrial design course for concept generation. Conceptual solutions were developed for different design problems as part of the design charrette planned within the course. The final year Masters in Design students mentored junior students from third-year Bachelors in Design in the design charrette under the course instructors' guidance. This exercise helped the junior design students quickly open up with their mentors and share their ideas smoothly. The senior students acted as a catalyst in generating a range of possible outcomes in a short period. A survey conducted at the end of this course with the junior students showed that the students accepted PAL well and would like it to be part of other courses in the future. Therefore, this paper recommends introducing PAL in design education as it effectively develops professionalism in senior students and helps the junior students use their seniors' experiences. Additionally, it imbibes a sense of community learning in the student group.

Keywords: Peer Assisted Learning in design education, community learning, concept generation

1 INTRODUCTION
The many concepts generated in the early design phase are crucial for any design innovation [1]. However, design students usually struggle to explore the problem space and fix the concept in the initial stages. Furthermore, it is observed that junior design students have apprehension in expressing their ideas to senior faculty members within the formal structure of design education. Thus, to overcome this hurdle, Peer Assisted Learning (PAL) was introduced in an industrial design course on an experimental basis. In this experiment, final-year Masters in Design students (peer tutors) engaged with third-year Bachelors in Design students (peer tutees) to guide them in their concept generation process. PAL has a vital conceptual share of most medical education [2]. However, no known evidence of it being implemented in a formal design course is found. This paper discusses the influence of PAL as an innovative method for concept generation in junior grade students.

2 AIM AND OBJECTIVE
Since PAL was borrowed from a different domain of practice, it is thus necessary to assess the impact and perception of the developed method in practice. Furthermore, the research aims to inspect PAL's performance during the concept generation stage and understand students' perceptions of implementing it as a formal teaching method. Therefore, under the supervision of the course instructor, PAL was introduced in a 5-day online product design elective course at the DoD IITG. A quantitative survey was conducted with peer tutees to record their experiences at the end of the course.

3 PEER ASSISTED LEARNING (PAL)

Peer-assisted learning acquires information and ability through active helping and supporting others [2]. The participants are not professional tutors but are committed to helping each other learn & grow. PAL is beyond teaching and learning, and the students involved imbibe the role of facilitators and develop a sense of concern [2]. Boud and Cohen (2014) defined peer learning as *"the use of teaching and learning strategies in which students learn with and from each other without the immediate intervention of a teacher"* (p.2). The following factors can be considered critical for a successful PAL session - 1) educational distance between peer tutor and peer tutee, 2) form of teaching and setting, and 3) size of learner group [2]. Despite peer tutors being more senior, they behave more like facilitators & mediators, creating an environment of cooperative learning and guiding the peer tutees through active learning [2]. The peer tutors assist new students in making the transition from school to university and help them adjust to the new lifestyle as they have a go-to person to ask any questions. PAL is mutually beneficial for student tutors and student learners [7]. They guide the peer tutees in resolving issues through dialogue, boosting self-esteem, encouraging the use of Helpdesks or other resources, and advising them on contacting programme directors or careers counsellors if the course was not fit for them [4]. PAL allows students to explore new concepts comfortably in a less formal academic environment. It helps students develop self-awareness, critical reflection, and openness to feedback. The peer tutors aided them by providing problem-solving tactics, encouraging them to support each other, recommending time management strategies, and simply being another face on campus to recognize. They are helpful and more easily approachable and offer straightforward explanations and practical examples, which further aided in developing a "deeper understanding." They further encourage group interaction and discussions. As per a previous study, students who did not participate in PAL accounted for the majority of course withdrawals. The students who were a part of PAL showed relatively high attendance [4].

4 EXPERIMENTAL APPROACHES

4.1 Research Questions

This study seeks to understand the effect of the PAL method in Design Education on generating novel concepts by peer tutees in a tangible product design course and aims to answer the following research questions:

1) Does using the PAL method result in more innovative concept generation?
2) How do peer tutees perceive PAL in use?

4.2 Participants

Eighteen third-year Bachelors in Design students participated in the experiment under the elective Industrial Design course. In addition, a group of 6 final-year Masters in Design students mentored the peer tutees under the supervision of one course instructor in an online method of teaching. The peer tutees were divided into teams of 6 with three members each.

4.3 Method

This experimental study was conducted under the supervision of the course instructor in a longitudinal research approach and spread over four phases. This approach helped establish a comparison in the results and affirm the positive effect of the treatment. The four phases were concept generation without the PAL method, planning phase (within peer tutors), execution phase (with PAL method), and the last phase was the survey phase, as illustrated in Figure 1. Phase I began by asking the students to generate novel concepts without the PAL method. In phase II, the peer tutees were given a short presentation by the peer tutors explaining the broader scope of 6 different topics. The peer tutees were then divided into six groups of 3 students, each based on their 1) Preferences of topics, 2) 3D modelling & presentation skills, and 3) Physical prototyping skills to form a balanced team. At the beginning of phase III, each team met online. The peer tutees initiated an informal onboarding session and explained the sequence of activities planned for the course. Each team followed a different modus operandi for conducting the design charrette. Some shared resource materials with students, others started by asking curious questions, and a few other teams began with group activities. Based on the design brief, the scope of the project and final deliverables were mutually decided by the tutees and the tutors. After identifying the problem areas, the students dived into ideation and concept generation. After multiple rapid brainstorming sessions, each team developed novel concepts ranging from 5 to 20 ideas, depending on the complexity of the topic. The peer tutors periodically updated the progress of each team to the course instructor and gathered feedback. To shortlist the final concept, each team decided to vote based on the following parameters – 1) Effectiveness, 2) Quantity, 3) Quality, and 4) Novelty [5][6]. The final concept was further developed based on the inputs shared by the tutors and presented towards the end of the 5th day. At the end of the presentations in phase IV, an online survey was conducted with the tutees to understand their learning experience and acceptance of the PAL method.

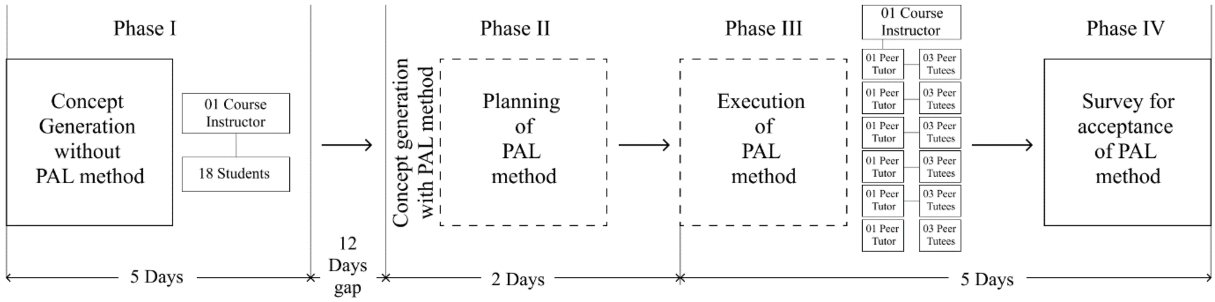


Figure 1. Experiment execution diagram

4.4 Sequence of activities

In phase III of the execution phase, each of the six peer tutors had their process of mentoring the tutee, which is explained below:

Team A- Topic: Design for Playful Furniture, Design brief: Find ways to design playful furniture and create playful furniture using them. On day one, the students were asked to define and understand playfulness as an ice-breaker activity. The next task was broken into three actions - making task lists, documenting playful activities, and grouping them. Day two comprised changing the context of products by adding playfulness to them. With the obtained data on day three, brainstorming sessions were conducted to generate multiple concepts. The concepts were shortlisted for further detailing. The last two days included developing a CAD model, scaled prototypes, and the final presentation.

Team B- Topic: Design for Traditional Toys, Design brief: To design traditional toys for imparting knowledge to kids. As an ice-breaker session, the team was engaged in casual conversation on day one. The tutees and the tutor then moved to identify comparable products in the market. Tutees were asked to brainstorm to generate multiple concepts based on days two and three data. In the last two days, the concept detailing and development of CAD models was concluded with the final presentation.

Team C- Topic: Construction Toys, Design brief: To design and develop construction toys for kids. On day one, the tutees were engaged in social games of finding answers with relevant keywords. The second day was dedicated to extracting the keywords deduced from the previous day. The third day’s activity was to design a unit with the Kaizen technique*. On day four, the tutees were asked to develop multiple units using a similar method before the final refinement and detailing. On the last day, the tutees presented two of their best concepts.

Team D- Topic: Tech-induced learning toys, Design brief: To develop technology-induced design learning toys for kids. On day one, the tutees were engaged in an informal question-and-answer session to define the topic briefly. Later the same day, activities such as gathering ideas from the surroundings and making a list of comparable tech products were conducted. The ideation stage spanned over two days, generated multiple novel ideas, and filtered them. The final concept was further detailed for CAD modelling on the fourth day. The concepts were presented on the last day.

Team E- Topic: Musical instruments for Kids, Design brief: To design self-intuitive musical instruments for kids. The tutor conducted a small question-and-answer session as an ice-breaker on the first day. The next day’s activities included creating and identifying conventional sound generation techniques. Tutees were asked to develop their concepts and combine them to form a final concept on the third day based on the data. The fourth and fifth days were assigned for product detailing, prototyping and presentation.

Team F- Topic: Future of Wearables, Design brief: To design healthcare wearable devices for kids. The topic was introduced to the tutees on day one, and resource materials were shared. This was followed by different mapping and understanding activities. Multiple brainstorming sessions were conducted on days two and three to define design parameters and generate novel concepts. Concept detailing was done on the fourth and fifth days, then CAD modelling and a final presentation.

In phase IV, the tutees were asked to respond to the following questions to understand their overall experience and perception of the PAL method.

Table 1. Questions submitted to the students

Q#	Text of Questions	Scale
Q1	Rate your experience of learning with peer tutors.	(Average to Excellent)
Q2	Rate your experience of the following [Discussion with senior mates]	(Average to Excellent)
Q3	Rate your experience of the following [Design thinking]	(Average to Excellent)
Q4	Rate your experience of the following [Task flow]	(Average to Excellent)
Q5	Rate your experience of the following [Overall outcome]	(Average to Excellent)
Q6	Would you like to opt for the PAL in the future in other courses?	(Yes/No)

5 RESULT & DISCUSSIONS

5.1 Major Findings from Phase I

In phase I, the peer tutors had to generate novel concepts with the conventional pedagogy without the PAL method. The concepts generated without any mentorship of senior students have the following issues: 1) low count of concepts generated, 2) lack of novelty, 3) deficiency in technical skills, and 4) lack of clarity. The peer tutees lacked practical exposure and a holistic approach to problem-solving. Such a situation necessitates a scaffolding system to facilitate novice students' creative concept generation. Some of the examples of concept generation are shown in Figure 2.

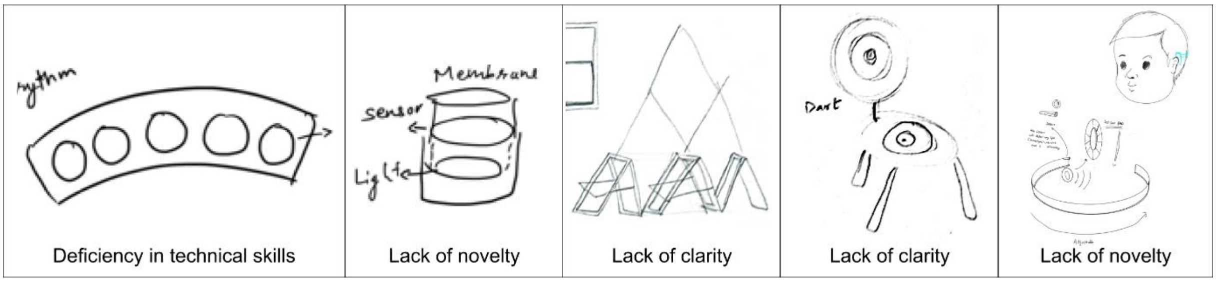


Figure 2. Concept sketches from phase I

5.2 Major Findings from Phase II

Based on the response from the peer tutees, it was observed that a few topics were more preferred over others.

5.3 Major Findings from Phase III

An important finding from the execution phase was that the number of concepts generated increased instead of phase I. The concepts in phase III were substantially improved as they showed a better understanding of problem-solving and enhanced cognizance of technology. It was also found that the preferences of topics solely did not influence the performance of the tutees. The mentorship from phase III also helped in the overall concept presentation—a few examples of concepts generated with the PAL method, as shown in Figure 3.

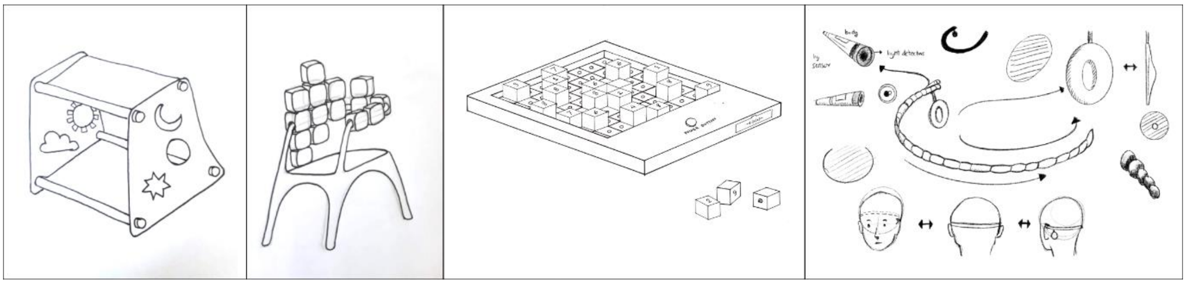


Figure 3. Concept sketches from phase III

5.4 Major Findings from Phase IV
The survey response shows a positive outlook from the tutees towards PAL with senior peer tutors as it helped in boosting their confidence. The survey shows that the overall course could have been more structured and detailed. However, it was observed that the online mode of conduct and shorter course timeframe proved to be detrimental to the overall experience of a few students as the scope for tangible explorations was limited. The responses to the survey are visually summarized in Figure 4.

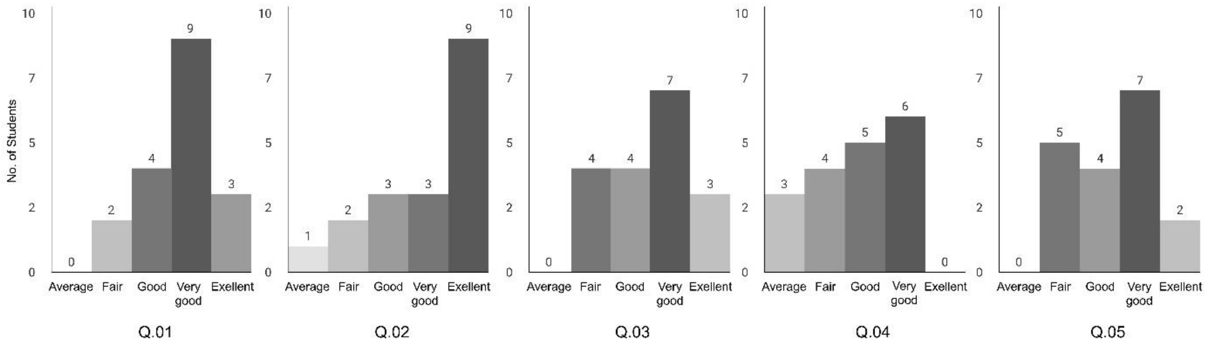


Figure 4. Responses of the participants

Based on the response to Q6 in Table 1, it was found that 100% of the students would like to opt for the PAL method in other courses. They also appreciated the experimental and unconventional approach to the study. It was also observed that novice designers lack the exposure and capacity to absorb complex theoretical concepts. Thus, technology-based or complex concept-driven projects need more time and interactions for better explorations of solutions.

6 RECOMMENDATIONS
This experiment of introducing PAL to third-year design students shows that this method helps to generate diverse and novel design concepts. This study shows a strong inclination of tutees toward interacting with their senior students and using their experience to develop a holistic understanding of the design process. Thus, this paper recommends conducting further research in a more extensive setup for formally introducing PAL in a product design course. A similar study should be conducted offline with a larger sample group to assert the positive impacts of the method further.

7 CONCLUSIONS
This paper discusses the impact of the PAL method on novice designers while introducing it in an elective course setting. Observations from phase I indicate the necessity of a guidance system to stimulate the creative output of design students to generate novel and diverse concepts. The survey phase shows a positive perception of this method. Seniors' expertise aids peer tutees in rapid exploration and novel concept generation. It was observed that the PAL method mitigates the inhibitions towards senior faculties, which could hamper the innovation process. Although this experiment was carried out for an industrial design course, it might be replicated in other design domains to see if the outcomes are comparable. Such research could contribute to the PAL method's formal recognition in design education.

REFERENCES

[1] Yang M. C. Concept generation and sketching: correlations with positive design outcome. In *Proceedings of the ASME Design Engineering Technical & Computers in Engineering Conferences*, New York, 2003.

[2] Herrmann-Werner A. et al. “Peer-Assisted Learning (PAL) im medizinischen Grundstudium: eine Übersicht,” *Z. Evid. Fortbild. Qual. Gesundhwes.*, vol. 121, pp. 74–81, 2017, doi: 10.1016/j.zefq.2017.01.001.

[3] Boud D., Cohen R. and Sampson J.(. OTUOT (Eds.). (2001). Peer Learning in Higher Education: Learning from and with Each Other (1st ed.). Routledge. https://doi.org/10.4324/9781315042565

[4] Nafalski A., Berk M. and Cropley A “Peer Assisted Learning for Electrical Engineering students.” Ph.D. diss., 1998.

[5] Santosh J., Andreas L., Viktor H., Elin O. and Anders W. “Interdependency between average novelty, individual average novelty, and variety,” *International Journal of Design Creativity and Innovation*, vol. 3, no. 1. Taylor & Francis, pp. 43–60, 2015, DOI: 10.1080/21650349.2014.887987.

[6] Hertenstein J. H., Platt M. B. and Veryzer R. W. “The impact of industrial design effectiveness on corporate financial performance,” *J. Prod. Innov. Manag.*, vol. 22, no. 1, pp. 3–21, 2005, DOI: 10.1111/j.0737-6782.2005.00100.x.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

SYSTEMS THINKING AND INTERDISCIPLINARITY IN DISCIPLINARY DESIGN EDUCATION

Malene Pilgaard HARSAAE[1], Thomas ØSTERGAARD[1] and Anne Louise BANG[2]
[1]VIA Design + Business, VIA University College, Denmark
[2]Center for Creative Industries and Professions, VIA University College, Denmark

ABSTRACT

The field of education is highlighted as an essential area for sustainable development. With the aim of developing a positive attitude to addressing global changes, the lifelong learning of the individual is emphasized. UNESCO promotes eight key sustainable competencies to be included in education to ensure that future agents contribute to the necessary green transition and the work towards achieving the 17 UN Sustainable Development Goals. The first one of these key sustainable competencies is 'systems thinking competency.' Many of the systems which surround us and make up our current paradigm on the one hand contribute to keeping the status quo, despite numerous initiatives towards a green transition, and on the other hand the systems entail a complexity that is challenging for students to comprehend and thus change, alter or disrupt. Generally, there is a lack of systemic understanding among students at VIA Design & Business, which, from an environmental perspective; affects their ability to contribute to the radical change needed.

The paper explores how students can obtain a deeper understanding and knowledge of the system and sub-systems constituting the industry they train for and how this can contribute to foster a green transition.

Keywords: Systems thinking, interdisciplinarity, new paradigm, system mapping, fashion design

1 CONCERNS AND MOTIVATION

There is an increased attention on the necessity of creating a substantial green transition. Changes and alterations can no longer be viewed as sufficient to solve the environmental crisis, we need an actual paradigm shift. *"Instead of changing the world to suit us we need to change the us to suit the world"* [1: vii]. The educational system has repeatedly been emphasized as one of the fields to drive the necessary change [2]. However, critics are simultaneously emphasizing how the educational system in general fail to disrupt the current traditional Western paradigm [3,4] and that this preservation in itself is the obstacle to a substantial green transition and a radical paradigm shift.

Design educations are thus faced with the challenges of implementing new - relevant and constructive - teaching goals aiming to build student competences to foster the necessary green transition and the emergence of a new paradigm. Consequently, Design & Business students at VIA Design & Business have continuously been introduced to a variety of different strategic approaches, models, and tools aiming for responsible design and business developments; for example, the triple layered Business Model Canvas [5], various approaches to Circular Economy [6], and critical design [1].

Despite the increased focus on responsible development, our daily empirical realities and experiences as lecturers reveal that students' projects tend to be somehow superficial in the development of sustainable solutions and that originally well-meaning suggestions and innovations fail to address sufficient perspectives and to take obstacles, potentials, and the wider systemic consequences into account. It seems curricula fail to provide the students with substantial knowledge of systems and system intersections.

For design students, the environmental challenges create a field of tension between dreams and reality [7]. A field of tension between dreams of making and needs of responsibility and action in relation to the environment.

On the one hand, we have students who are preoccupied with becoming skilled designers and create dreams. On the other hand, they are concerned about the environmental impact of their creations and the fashion system in general and wish to act consciously and responsibly to contribute to a more sustainable industry.

Research demonstrates that students at Higher Education (HE) in general show a significant - and worrying - lack of systemic understanding and competencies when working in sustainable, social or complex real-world challenges [8,9]. According to UNESCO [2], future curricula must address and enhance students' connectivity with nature and biosphere as an educational space using knowledge commons, social and emotional learning and community involvement practices. Over the past 10-20 years, a new field of research and practice within the area of Education for Sustainable Development (ESD) has emerged in HE, revising the concept of education and illustrating how ESD can become the core of a transformation of the societies in the Anthropocene [2]. Teaching and learning in the 'Anthropocene' involves generating new educational practices and perceptions when entering an epoch where all human activities affect all life critical zones on Earth [10]. With the 17 UN Sustainable Development Goals (SDG), a platform of construing the world's challenges has provided a normative argument for the political educational path forward. In this regard, the 'Anthropocene' requires developing a new profound systemic revision and understanding of the view of the planet Earth and a recognition of the interconnectedness between human activities and nature in educational practices [9]. Among the recommended future student competences, UNESCO highlights systemic understanding as a crucial key competence.

The feedback from students states that they lack knowledge about sustainability. On the other hand, an increased implementation of sustainability workshops collides with their - and the institutions' - aims and wishes to become and create skilled designers with a deep knowledge of products, properties, materials, manufacturing, and on top 2D and 3D communication. The aim of the institutions is to prepare students to create desirable products that make a change for future design. Consequently, our aim is to educate designers that know about the systems and are able to navigate in them and reach out to other disciplines to combine 'design of products' with 'systems thinking.'

The authors of this paper acknowledge, value and represent both perspectives. The design discipline including the practical skills is in a juxtaposition with systems thinking and circular economy. This paper is thus based on an interdisciplinary approach that intends to foster transdisciplinary approaches that will look into ways to broaden the systemic perspectives.

2 SYSTEMS THINKING OR SYSTEMIC THINKING

The UNESCO 2021 Roadmap report shows how the problems facing humanity are highly interconnected and complex. The educational paradigms are currently changing towards a 'systemisism' scope as new principles of educational thinking and policies emerge [3]. In 2011, Wiek et al. [11] made a comparative study on the future requirements to competence development and defined five key competences for developing an educational framework for sustainable future. One of the five competences in line with the UESCO key competencies is a 'systems thinking competence.' As such, a new systems thinking approach to understanding educations as a crucial part of the needed change marks a shift in the urgency to radically rethink how the ecological, living or whole systems view of the world becomes a part of the future educations. It also challenges the question of what the students should learn – what competences are needed for handling the present and future challenges.

When defining 'systems thinking,' endless pathways open up. Checkland [12] described the scientific change from reductionist to systems thinking as a movement rather than a discipline.

> *"The systems movement comprises any and every effort to work out the implications of using the concept of an irreducible whole, 'a system,' in any area of endeavour. [. . .] Because systems ideas provide a way of thinking about any kind of problem, systems thinking is not itself a discipline."* [11:99]

The systems approach argues that all phenomena can be seen as a network of relations among parts - a system. All systems, social, technical, biological or electrical consist of common properties, patterns and behaviours which can be analysed and used to develop insights into the order and reactions of the complex phenomena. By following the ideas of mapping the roots of the system, there is even more need to try to identify new areas. Says Abson *"even more powerful but still undiscovered areas of intervention even those less obvious and radical"* [13].

In this paper, systems thinking will be used as a lens to investigate how sustainability issues are interconnected in the fashion system and its surrounding systems - as a sub-system and as a "system of interest." A "system" is bounded and defined by the researcher's prejudices, interests and constructs -

but does not as such exist as a real physical "thing." It is a construction, made by the researcher, providing an epistemological approach in which the researcher chooses to delineate a system. To establish an understanding of the fashion system, we need to acknowledge and adapt interdisciplinary approaches to the inquiry but also define its boundaries. But, without a set of boundaries for a given complex problem scenario, it is unlikely to develop an understanding of its nature to other stakeholders and thereby establish solutions for the area of concern and stakeholders.

A system view of the fashion industry and the fashion educations can help us understand and influence the challenges of the industry and its many consequences across the community. This can be done by establishing a framework to identify the many interconnected elements, which allow us to better understand the multiple implications of the present practices and decisions. Systems thinking could be applied to areas of science, knowledge and organizational settings connected to the fashion industry and fashion educations systems and as such we can construct an epistemological lens and understanding which can provide new insights and help us identify patterns of connections and failure.

3 WORKING WITH SYSTEMS THINKING

The point of departure is our concern that the green transition and a paradigm shift is moving too slow. Future graduates will be the bearers of change, the necessary change agents, and our curricula need to support and foster the graduates' ability to act as such. Our approach is thus partly motivated by the articulated need for a paradigm shift, partly by the approach that SDG 17 has to be viewed as an obligation and not an option, and partly by our empirical experiences of students' lack of systemic knowledge. Our approach is grounded in the conviction that students need to understand the systems to be able to intervene and thus contribute to change them.

VIA Design & Business students are predominantly employed in the fashion and lifestyle industries. These industries are characterized by a complexity of systems, complex systems, and system intersections. There are obvious intersections between e.g., the political, economic, ecological, and technological systems. Simultaneously the social, cultural, and emotional systems with their layers of intangible mechanisms, preferences, and predispositions intersect with the above mentioned as these systems drive the why, what, and how of consumption. Understanding these diverse systems individually is a prerequisite for understanding their intersections and the influences they bestow on each other. However, to obtain understanding of the individual systems requires diverse type of knowledge and approaches. Understanding business models, which are part of the economic system, requires a set of tools differentiating from the set of tools required to understand the cultural and social mechanisms, and yet the latter intersect with the former. The introduction of the system of fashion intends to create awareness about the system and the intersections but does not expect students to become experts in the details of all sub-systems. On the contrary, we wish to educate students with a deep specialized knowledge within their specialty, but with the system knowledge that enable them to envision consequences, obstacles, and potentials of actions in one sub-system and how that intersects and interacts with other sub-systems. This knowledge and awareness are prerequisites for the realization that you need to involve other professions in future developments.

The introduction of a more systemic approach to understanding the surrounding world is still in its infancy at VIA Design & Business. The first students have been introduced to the concept of 'system mapping' through lectures. The initial visualization as shown in (Figure 1) was developed in connection with a course in education for sustainable development competence for lecturers at VIA University College, Denmark, the; 'Circular Economy and Sustainable Development in the Education' course (CESDE) 2020 [14]. The visualization (Figure 1) has been continuously evaluated and developed based on feedback from peers as well as students. The visualization is thus preliminary, in no way exhaustive, and should be viewed as work in process as well as progress.

The point of departure was mapping the elements constituting the obvious system of fashion from business model to production and consumption. Next step was to approach each of the elements to expand the mapping in any possible direction, e.g., which business models do we know within the fashion system (fast fashion, made-to-order, etc.), which system (the capitalistic) conditions these business models are based. Which actions support the models, e.g., consumption and then which mechanisms drive consumption etc. Each of the main elements multiplied into new sub systems and entities. Working iteratively, we then approached business models again. The business model of fast fashion is – among other things – conditioned by the previous outsourcing decades ago that gave access to cheap labour. Laws and regulations allow or prevent the emergence of new business models, while the consumption behaviour of users determine whether a new business model succeeds or fails. The intention is that lecturers subsequently use the visualization to place their lecture subjects in the model and thus emphasize the depth of knowledge connected to each sub-system.

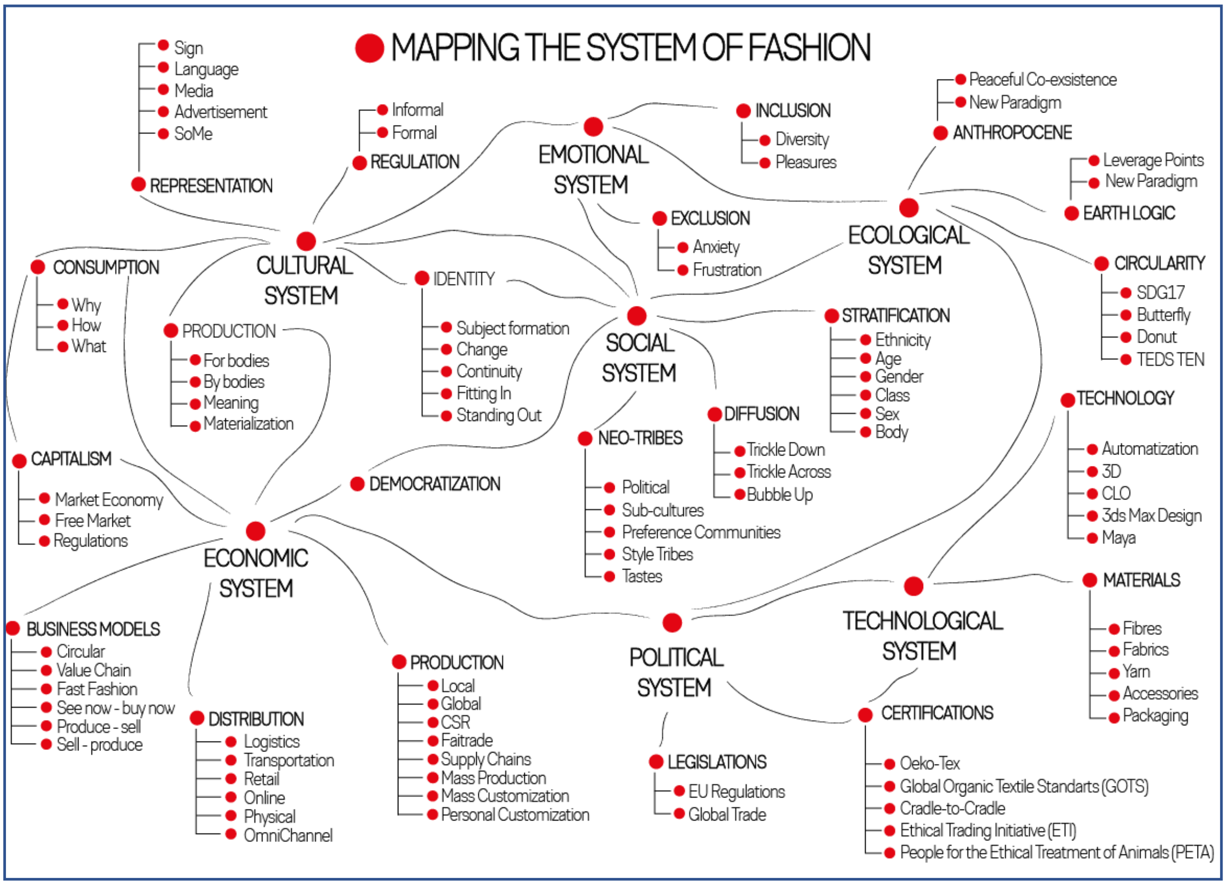


Figure 1. Mapping the fashion system, preliminary work

The actual design is inspired by Paez's approach to mapping as a tool. In this case, the concept of mapping has focused on visualizing the system and the numerous intersections representing the current paradigm of fashion rather than suggesting an alternative and at the same time to *"[...] establish a dialogue between what exists and what is yet to come..."* [15:21].

The visual tool, lectures relating to the various sub systems, and workshops focusing on identifying the elements constituting the system and sub systems each contribute to students' understanding of the complexity of the fashion system and the multiple intersections emerging within it. Students at 1st semester level have been introduced to the visualization through lectures in autumn 2020 and 2021. In the incubator environment, other students have participated in workshops during autumn 2021 where they themselves have had to identify elements within selected system headlines, but none of these students have yet come so far in their education that the effect has been read or is measurable in their individual projects.

By Professor Dilys Williams and Education for Sustainability Leader Nina Stevenson at the Centre for Sustainable Fashion, at London College of Fashion, University of the Arts (LCF); a *"...framework and set of pedagogic principles have been developed to support evolutionary and transformatory approaches to fashion education, communicated through its research, teaching and learning and knowledge exchange projects. This includes the development of a framing of fashion education as a system, which has been applied to this plan"* [16:8]. The LCF approach is interesting in this connection as it is a full-scale attempt to implement both values, didactic and pedagogical principles and collaborations with the surrounding communities.

4 DISCUSSIONS

The western educational practices have produced a destructive Separation Paradigm with futile learning processes – including sustainability education – merely reproducing a reductionist and linear western tradition [3]. Students are taught to live their lives through separation mechanisms. This can lead to dehumanisation, slavery, oppression or even destruction of our non-human relatives or earth systems. Separatism is everywhere in the construction of our knowledge institutions and practices [3]. In this way, we tend to forget how things were separated to study them, rather than use the separated example as an indicator of something from reality. Separatism is imbedded deeply inside our modernist assumptions: *"reductionism separating the parts; scepticism with opposed ideas to ascertain truth; dualism implicit in dichotomies, oppositions, and binaries; rationalism marginalising other ways of knowing; the scientific method as outside of ethical concerns; and anthropocentrism separating humans as well as human and non-human species"* [3:30]. Lange et al. [3] demonstrate how paradigms of separation have created separation of everything in our lives.

> *"When stepping outside of the paradigm of Separation, and into a perception and embodiment of Relationality, it is common to understand Relationality as interpersonal relations; but this remains within the boundaries of anthropocentric humanism. We expand the notion of relationing further, into a cosmo-ontological approach, understanding the cosmos as inherently connected and all beings and non-beings as always relationing, thus decentring humans"* [3:217].

Changing curricula and subject descriptions are fraught with challenges as the former is politically determined and covers national learning objectives. However, it is possible to navigate within the framework and still incorporate more systems thinking. A relational as well as systems thinking approach can be pursued by critically evaluating current teaching elements and placing them in a system mapping similar to our example of fashion mapping.

One thing is to understand systems and models, another thing is to break them down into action and combine them with disciplinary core competences of - in this case - fashion design. In this paper, we have described the dichotomy between disciplinary skills and the necessity of an interdisciplinary collaboration that broadens the perspective and create impact.

The urgency and complexity of contributing to foster the necessary paradigm shift tends to overwhelm and disillusion students. The intention with the introduction of the system approach is to assist the students in dealing with this complexity and to realize how and where their focus get impact. At the same time, the system approach intends to open the students' eyes to the shortcomings of their own knowledge, to respect and embrace it, and reach out for the lacking knowledge in transdisciplinary collaborations.

5 CONCLUSIONS

We highly agree with Abson [13] who advocates for a new research agenda *"inspired by systems thinking that focuses on transformational 'sustainability interventions', centred on three realms of leverage: reconnecting people to nature, restructuring institutions and rethinking how knowledge is created and used in pursuit of sustainability"*. This is also in line with fellow VIA researchers' work [14] where they argue that we tend to hit the wrong layers with our present disciplinary and silo-based sustainability research. We agree about the need to look into the potential for transformational change changing the way we educate radically. In this paper, we argue that it could be supported by systems thinking and by adapting transdisciplinary research approaches that provide new methods for integrating values, norms and knowledge of humans in both scientific and societal processes. Despite the lack of empirical evidence of the actual benefits of implementing systems thinking as part of the curricula at VIA Design & Business, we still contend that the approach can contribute with knowledge and understanding that enable students to suggest more substantial changes to the industry. But it also requires that the institution management has the courage to break away from the current paradigm and educate graduates, the future employees, with alternative competencies and knowledge than the clienteles, the industry, expect. Following Sterling [4], we see an urgent need for contributing to a paradigmatic shift of HE in fashion design responding to necessary socio-economic and ecological conditions and trajectories.

The next step is to collect empirical data to strengthen our work with systemic thinking. Therefore, in August 2022 we have decided to apply systems thinking as a frame for understanding in a common module with 300+ design and business students on BA-level.

REFERENCES

[1] Dunne A. and Raby F. *Speculative everything; design, fiction, and social dreaming*, 2013 (MIT Press).

[2] UNESCO: *REIMAGINING OUR FUTURES TOGETHER, A new social contract for Education*, 2021 (UNESCO).

[3] Lange E. A., O'Neil J. K. P. and Ross K. Educating during the great transformation: relationality and transformative sustainability education. In: *Studies in Adult Education and Learning*, 27, 2021, pp. 23-46.

[4] Sterling S. Concern, Conception, and Consequence: Re-thinking the Paradigm of Higher Education in Dangerous Times. In: *Frontiers in Sustainability*, 2, 2021, pp. 1-13.

[5] Joyce A. and Paquin R. L. The triple layered business model canvas: A tool to design more sustainable business models. In: *Journal of Cleaner Production*, 135, 2016, pp. 1474-1486.

[6] Ellen MacArthur Foundation. *A new textiles economy: Redesigning fashion's future*. Available: http://www.ellenmacarthurfoundation.org/publications [Accessed on 2022, 20 May], (2017)

[7] Bang A. and Harsaae M. Old Wine in new Bottles – an alternative Didactic Approach to Tools used in Fashion Design. In: Grierson, H., Bohemia, E. & Buck, L. (red.). *Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021)*, VIA University College, Denmark. 9th -10th September 2021, (Design Society).

[8] Østergaard T. The Designer as Agent of Community. In: Meroni, A., Medina, A. M. O. & Villari, B. (red.). *Proceedings of the ServDes.2018 Conference*. Linköping University Electronic Press, 2018, s. 76-91 16 s. (Linköping Electronic Conference Proceedings; nr. 150).

[9] Friedman K. *Chatterjee Global Lecture. Design Education Today: Challenges, Opportunities, Failures.* 2019 (Cincinnati, Ohio: College of Design, Architecture, Art and Planning the University of Cincinnati).

[10] Paulsen M. Cautiousness as a new pedagogical ideal in the Anthropocene. In Petersen, K., Brömssen, K., Jacobsen, G. H., Garsdal, J., Paulsen, M. & Koefod, O. (eds.). *Rethinking education in light of global challenges: Scandinavian perspectives on culture, society and the Anthropocene*. 2022 (London: Routledge).

[11] Wiek A., Withycombe L. and Redman C. L. Key competencies in sustainability: a reference framework for academic programme development, In: *Sustainability Science*, 6, 2011, pp. 203–218.

[12] Checkland P. B. *Systems Thinking, Systems Practice*, 1981 (Wiley: Hoboken, NJ, USA).

[13] Abson D. J., Fischer J., Leventon J., Newig J., Schomerus T., Vilsmaier U., von Wehrden H., Abernethy P., Ives C. D., Jager N. W. and Lang D. J. Leverage points for sustainability transformation. In: *Ambio*, *46*(1), 2017, 30–39.

[14] Østergaard T., Sack-Nielsen T., Nielsen B. W., Marcussen B. H. and Frederiksen K. Learners Learning to Become: Exploring experiences with developing educators ESD competencies across sectors in Higher Education. In: *Futures of Education, Culture and Nature – Learning to Become 1*. 2022, pp. 102-117.

[15] Paez R. *Operative Mapping. Maps as Design Tools*, 2020 (ACTAR).

[16] London College of Fashion: *UAL, Interim report 2016-19 Education for Sustainability Transformation.* 2019 (London College of fashion).

TEACHING DESIGN IN A VIRTUAL CLASSROOM – A NEW NORMALITY INITIATED BY THE PANDEMIC CONTEXT

Harald SKULBERG
The Oslo School of Architecture and Design, Norway

ABSTRACT
After the Covid-19 pandemic emerged and developed into a global health crisis, we experienced that all sectors of society became affected. Within academia, we as educators in higher design education in Norway experienced how intrusive infection control restrictions from 12th March 2020 forced us to alter our teaching methods. Physical presence at campus was suddenly terminated, and online teaching was established through a virtual classroom where students had to attend digital lectures from home.
After running this regime, we wanted to investigate the consequences and effects of this pedagogic transition. How has our remote teaching practice influenced the students' learning experiences? As we wanted to investigate our students' new learning situation from their own point of view, we developed a questionnaire where we asked our design students how they have experienced their study situation during the pandemic. To adapt our teaching strategies to the new context, we also asked for new and radical ideas to reduce the negative impact from the pandemic, aiming at damage reduction - or improvements - of our teaching and tutoring. We believe that this survey has gained us positively, as it has produced new knowledge and proved fruitful to enable us to reorganize and adapt to a new normal.

Keywords: Covid-19, design education, virtual classroom, teaching methods, new normal

1 INTRODUCTION
Directly after the Covid-19 pandemic evolved from its origin in Asia towards Europe in early March 2020, Norwegian health authorities issued infection restrictions in all sectors of society. Our academic institution experienced a sudden shut-down, forcing staff to move from physical lectures and tutoring in class to a new teaching regime, utilizing digital teaching platforms and new learning tools which had to be implemented into our daily routines. When reviewing the impact of the pandemic on our institution in 2020, we had only very few cases of infection, counting three employees and two students. It is therefore not the cases of the disease, but the comprehensive infection control measures that have affected our institution the most. Retrospectively, we acknowledge that the shift in our learning methods has influenced how the students learn. But, to know exactly how this manifests itself is yet to be evidenced, as we assume that the effects take time to be fully understood, and it is also likely to assume that the magnitude of these effects depend on the timespan of the pandemic, making them hard to predict.

1.1 Research in the field
Despite the relatively recent outburst of the pandemic, there are several studies focusing on the pandemic's implications on teaching in higher education in general. Regarding the challenges of predicting the effects of Covid-19, Burki, T., The Lancet (2020) [1], states that online learning could make education more accessible for some students, while disadvantaging others if an equitable approach that takes a system-wide view is not implemented. This resonates with our own view, as we acknowledge the vulnerability that many students might experience under lockdown conditions, if adequate efforts in engaging, inspiring, and motivating these students are not successful.
The impact of the pandemic on students in higher education has been thoroughly investigated in a broad psycho-social perspective by Romero, M., Montserrat, Y-B., Miguel, A., and Maria, J. in their research paper *Impact of the COVID-19 Pandemic on Higher Education*, Frontiers in Psychology (2021) [2]. By taking a quite holistic view, this comprehensive study clearly confirms the overall negative impact - discomfort, irritability, and impatience- on students while being in remote studying mode.

To establish a backdrop for our case study, and to fully understand the magnitude of the pandemic and its implications in academia, we found it relevant to take a holistic perspective by comparing student satisfaction before and during the pandemic, and by that providing insight from both situations. Table 1 displays national statistics from 2019. The 'Studiebarometeret' [3] is a national survey monitoring students' perception of quality. Given the time of capture, these data reflect a pre-Covid-19 situation, and these questions are general, as they are given to all institutions within the visual arts and crafts sector. The total percentage of respondents is 36,4. The score 1 = not satisfied, while 5 = very satisfied.

Table 1. Institutional score, pre-covid response (2019)

Main area	*Description*	*Institutional score*	*General score, visual arts and crafts in Norway*
Teaching	Dissemination and teaching	4,4	3,8
Feedback	Feedback and guidance from professional staff	4,4	3,8
Expectations	Academic staff's expectations of students	4,5	3,7
Learning environment	Social and professional environment, facilities, and equipment	3,8	3,6
Organization	Information, administration, and professional context	3,5	3,0
Inspiration	Whether the study produce challenges and engagement	4,4	3,7
Overall assessment	Overall satisfaction with the study program	4,3	3,9

Firstly, by taking a historical view of student satisfaction in our own institution, Table 2 displays the historical average student score based on the learning environment in our own institution. The score 1 = not satisfied, while 5 = very satisfied.

Table 2. Student score, covid response – learning environment (2018 – 2021)

Learning environment	**Average**	**21**	**20**	**19**	**18**
The social environment among the students in the study program	**4,1**	4,1	4,0	4,1	4,0
The academic environment among the students on the study program	**4,2**	4,2	4,0	4,3	4,1
The environment between the students and the academic staff on the study program	**4,1**	4,1	4,1	4,5	4,2

To compare these insights with the latest response on student satisfaction in our own institution, Tables 3-5 compile the results from the Studiebarometeret in 2021 [4] which is the most recent questionnaire available from Norwegian higher education providing statistics from our institution. The total percentage of respondents is 39,5. The score 1 = totally disagree, while 5 = totally agree.

Table 3. Student score, covid response – digital tools (2021)

Digital tools	**Average**	**1**	**2**	**3**	**4**	**5**
Digital tools are used in such a way that I become actively involved in the teaching	**3,6**	7	14	21	29	29
The professional staff has the necessary competence to use digital tools in teaching	**4,1**	4	11	7	32	46
The use of digital learning platform works well on my study program	**2,5**	43	18	11	7	21
I receive training in using digital tools / programs that are relevant to the subject area	**4,1**	-	11	7	39	43

The most noticeable observation from Table 3 is the low score reflecting how the use of digital learning platform works, expressing a clearly negative student experience with a score of only 2,5, as 43 percent of the respondents expressed that they quite strongly disagree with the statement.

Table 4. Student score, covid response – learning environment (2021)

Corona: social and physical learning environment	**Average**	**1**	**2**	**3**	**4**	**5**
I have had a suitable place to work on my studies (at home, at university / college, or elsewhere)	**4,0**	4	8	12	35	42
I have become well integrated in a social student environment	**4,0**	-	12	23	23	42
I have had good access to a reading room, library (etc.) at the university / college	**3,6**	8	8	19	38	19

In Table 4, the relatively low score from the last statement on access to reading rooms, library etc. at campus seems to relate to the fact that the campus has both been closed and opened during different periods of the pandemic, so this response seems to cover experiences from both these situations.

Table 5. Student score, covid response – online teaching (2021)

Corona: online teaching during the corona pandemic	**Average**	**1**	**2**	**3**	**4**	**5**
The teachers are good at engaging students in online discussions	**2,4**	18	45	9	9	9
The technical solutions for online teaching work well	**3,4**	5	5	41	45	5
The teachers provide good arrangements for online teaching	**3,4**	5	18	32	27	18
I believe the quality of education is as good as it would be if we had had more physical teaching	**2,0**	45	23	9	5	9

The most startling observation in Table 5 is the dominantly negative response given to the last statement concerning the quality of education, if this was based on more physical teaching, having a score of only 2,0. Summed up, we believe that these quantitative and qualitative statistics build relevant and useful insight and backdrop for understanding and contextualizing the challenges of teaching in a virtual classroom or studio.
We have experienced how ‘zoom fatigue’ has evolved during lockdown, but what are the mechanisms behind this phenomenon? In her research paper *Connecting Through Technology During the Coronavirus Disease 2019 Pandemic: Avoiding “Zoom fatigue”,* Researchgate (2020) [5], Wiederhold, B. discusses the reasons for this phenomenon. Scientists acknowledge the phenomenon ‘synchrony’ as humans’ precisely timed vocalizations, gestures, and movements relying on precise responses from others to determine if they are being understood. Even if a millisecond’s delay is introduced into this system, subconsciously our brain will register the issue and work harder to try to overcome it and restore synchrony. By systemically deconstructing zoom fatigue from a psychological perspective, Jeremy Bailenson, founding director of the Stanford Virtual Human Interaction Lab (VHIL), suggests in his research paper *Nonverbal Overload: A Theoretical Argument for the Causes of Zoom Fatigue* Technology, Mind and Behaviour (2021) [6], the following four reasons:

- Excessive amounts of close-up eye contact are highly intense
- Seeing yourself during video chats constantly in real-time is fatiguing
- Video chats dramatically reduce our usual mobility
- The cognitive load is much higher in video chats

1.2 Context
These observations resonate largely with our own experiences from teaching, but as they are quite general, they must be contextualized into our specific teaching model to relate to design teaching in a design studio environment. Here, teaching and instruction depends on a physical, direct face-to-face communication between tutor and student or student group, while being surrounded by a rich design space. As design is very much experiential learning, this creative environment plays a fundamental role as catalyst for exploration, testing, validation, and presentation of design proposals. Having the physical workshop facilities inaccessible -especially for industrial design students- disable them to accomplish their design tasks according to expected learning goals.

Table 6. Challenges while in hybrid and online teaching modes

Hybrid mode	Lectures	- Physical: Teacher 1: Big lecture screen set-up for present students / groups
		- Online: Teacher 2: Enable required quality of communication through camera and microphone(s). Time spent on obtaining clear sound and image - Chat: Respond in chat with online students in parallel with physical lecture - Encourage active video feeds amongst students
	Instruction	- Physical: Teacher 1: Face-to-face instruction for present students /groups
		- Online: Teacher 2: Establish breakout rooms for students or groups - Time spent on obtaining clear sound and image
Online mode	Lectures	- Enable online lectures setup of video camera and microphone(s). Time spent on obtaining clear sound and image - Chat: (Alternatively teacher 2): Respond in chat with online students - Encourage active video feeds amongst students
	Instruction	- Establish breakout rooms for individual students or smaller groups

Based on our own experiences while teaching in zoom mode, we have observed practical challenges that over time have led to frustration, both amongst teachers and students. Table 6 compiles the challenges being experienced while in hybrid mode and online mode. Hybrid teaching is the most resource demanding teaching mode as it is multi-modal, requiring at least two teachers taking care of respectively physical and online communication. While in hybrid mode, we have experienced that the most frequent challenge is to avoid neglecting either student group. To exemplify a typical design project while practicing hybrid teaching mode, Figure 1 displays a structure of the activities involved, where G1+G2 are present groups, and B1+B2 are breakout room groups.

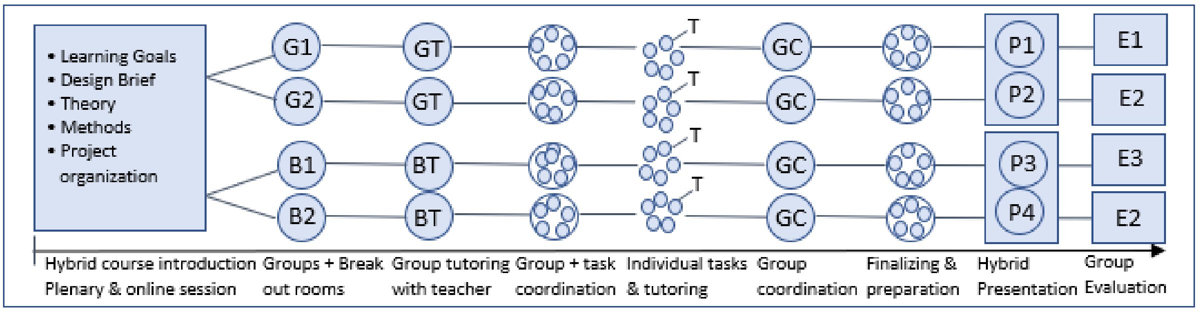


Figure 1. Structure of hybrid teaching mode

1.3 Scope

Currently, our design institute doubles the number of design students from 30 to 60, 30 each year in our Master's programme. At time of capture, the questionnaire was presented to all 230 design students. As personal feedback from a pandemic is likely to be of a sensitive character, the data collection aimed at preventing any personal identification. In accordance with current GDPR legislation, the questionnaire was based on full anonymity. We reported in advance to The Norwegian Centre for Research Data -NSD- [7] and awaited their approval before launch.

2 THE QUESTIONNAIRE

To obtain best possible qualitative feedback from the students, we chose to divide our questionnaire (Table 7) into two different sections. The first section (Q1-6) asked for student experiences. To capture different nuances of opinions, question 3 invited additional free-text answers. The second section (Q7) invited new ideas for future change and improvement.

Table 7. Questionnaire

1. Do you feel that Covid-19 has led to reduced contact with teachers?

Answers	*Number of respondents*	*Percentage*
To a large degree	5	**9,8 %**
To some degree	24	**47,1 %**
To a small degree	15	**29,4 %**
Not at all	9	**17,6 %**

2. Have you experienced that reduced contact with fellow students has been a problem?

Answers	*Number of respondents*	*Percentage*
To a large degree	14	**27,5 %**
To some degree	18	**35,3 %**
To a small degree	11	**21,6 %**
Not at all	9	**17,6 %**

3. Have parallel lectures (physically on the big screen + digitally on Zoom) worked well?

Answers	*Number of respondents*	*Percentage*
To a large degree	7	**13,7 %**
To some degree	30	**58,8 %**
To a small degree	11	**21,6 %**
Not at all	5	**9,8 %**
Not relevant, not been done*	2	**3,9 %**

** If it did not work well, please specify why.*

4. Do you find that your home / dormitory / apartment works well for long-term self-study?

Answers	*Number of respondents*	*Percentage*
To a large degree	9	**17,6 %**
To some degree	13	**25,5 %**
To a small degree	21	**41,2 %**
Not at all	8	**15,7 %**

5. Suggestions for improvement.

You are hereby challenged -as a designer- to suggest improvements that can make your own everyday study during covid-19 better or more efficient. Think outside the box. As a designer, we seek opportunities! Feel free to think radically and untraditionally, innovative and visionary!

3 FINDINGS

Firstly, the gender distribution of respondents in our questionnaire comprises 83 male and 147 female students giving a female overweight of respondents. Secondly, 51 of 206 students responded and answered the questionnaire, constituting a 25% participation rate. Discussions with students reveal a certain general 'questionnaire fatigue' due to the covid situation, explaining the quiet low response rate.

3.1 Observations from the questionnaire

Due to the quiet low response rate, we must assess the answers through an indicative view, while also relying on additional response from the 2020 and 2021 questionnaires by Studiebarometeret as described in Chapter 1.1 to see the full picture. This response supports by making the pandemic's effect on students' situation more comprehendible. The most noticeable responses are compiled as follows:

3.1.1 Multiple choice section

- In Q1, a group of 56.9% reply that Covid-19 to a large or to some degree has led to reduced contact with teachers, resonating with our own concerns.
- In Q3, a group of 58.8% reply that parallel lectures (physically on big screen and digitally on zoom) to some degree has worked well. This has been one of our practical concerns.
- In Q4, a group of 56.9% reply that their home / dormitory / apartment works to a small degree or not at all for long-term self-study, indicating that student housing is less appropriate and does not fulfil students' needs in a pandemic situation. At first glance, this question might seem irrelevant, but the reality is that the students' home suddenly became part of the virtual studio, and therefore we found it interesting to receive feedback from how this affected the remote teaching situation.

3.1.2 Free-text section

- Responding to Q3, the students specify the following problems:
  - Inadequate technical expertise amongst the teachers for facilitating clear sound and image.
  - Teachers' lack of using appropriate microphones and cameras in the right manner.
  - Poor quality of dialogue while using zoom, often caused by technical / audio-visual delays.
  - Neglect of those students being at home, as they may feel not included in the conversations.
  - Teachers tend to forget to follow up questions in the zoom chat.
  - Hard to concentrate during lectures on zoom, due to poor working conditions at home.
- Responding to Q5: Freedom and flexibility, less monotony, better sleep, awareness on personal hygiene, learning digital communication tools, and seeing things from a new perspective.

3.2 Ideas for improvement

Apart from most ordinary ideas -like cleaning routines- the students suggest these ideas:

- Wearable Tech: A measuring device that alarms when people get too close to each other.
- VR-tech building holograms in meeting rooms making absent students 'appear' in the room.
- Infection tracking system using student's admittance card to track movements in campus.
- Compulsory zoom-courses to all teachers to make them more skilled zoom users.
- Establish trans-course colloquium groups enabling more discussion and social contact.
- Providing a starter-kit to those working at home, covering needs and comfort.
- Compulsory walks outdoors for more fresh air and general restitution.

4 CONCLUSIONS

As seen through an educator's eyes, our questionnaire provides useful insight for investigating our students' new learning situation from their own point of view, and the personal feedback from the students is highly valuable in our effort of adapting to a new 'normal' teaching situation. When viewing the general feedback from the questionnaire and comparing this with the statistics of student satisfaction under normal pre-covid-19 conditions, our findings -not surprisingly- resonate with current research suggesting that Covid-19 pandemic in general has produced a negative impact on student's situation. Although we consider some of the suggested ideas less radical than expected, we find student's feedback fruitful and inspiring, and valuable for considering when discussing how to optimize our future practice.

5 DISCUSSIONS AND FUTURE INITIATIVES

The pandemic situation raised many questions. Directly after the lockdown, our ordinary classrooms were instantly given the role as audio-visual studios, without really being designed for that purpose.

Set in an old, industrial building not initially designed for teaching, our campus facilities should be rearranged to enable hybrid and online teaching. Appropriate and manageable audio-visual equipment should be installed in all studios to facilitate efficient and flexible communication especially in hybrid teaching mode. However, high-tech itself will not solve our teaching challenges. While design teaching builds so much on stimulus of the sensory apparatus, and cognition based on visual and tactile experiences, physicality, and materiality, it is obvious that design teaching easily suffers while relying on solely digital communication tools. Due to the nature of teaching design, our Master's courses requiring direct one-to-one individual communication are extraordinarily vulnerable in a remote teaching situation. Furthermore, a large group of students struggle with their home as workplace, indicating that we should facilitate presence at campus as much as possible. To encourage and stimulate isolated students, a personalized 'Covid-kit' delivered on their doorstep could do the trick. It could be in the form of a physical collection of items covering physical needs and comfort, which also could strengthen the feeling of connection to their campus. As the pandemic has triggered an increased feeling of isolation which causes mental health concerns, we see that reduced social interaction should be met with increased contact both with teachers and fellow students. The biggest challenge related to remote teaching is to strengthen student morale and to create a sense of community within the student body, while being physically apart. Maybe Istituto Marangoni Mumbai should be a source of inspiration. They started an online campaign to boost student morale, while also acknowledging the limitations of remote teaching. As Director of Education at the same institute, Diana Marian Murek [8], states; 'Design is experiential learning, so there is only so much that can be done online.'

It seems that in those design schools having limited expertise and resources for establishing appropriate audio-visual facilities for remote teaching, it is likely that many teachers spend a substantial number of lecturing hours trying to become audio-visually capable, rather than spending their time teaching their profession. However, in our institution, a recent initiative from teachers to share practical experiences regularly from teaching with digital tools has raised optimism for future practices and improvements. These are amongst the topics that would be interesting to discuss at the approaching E&PDE conference.

REFERENCES

[1] The Lancet, 2020, Burki, T. Covid-19: The Consequences for higher education, 2020. https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(20)30287-4/fulltext

[2] Marina R., Montserrat Y-B., Miguel A. and Maria J. Impact of the COVID-10 Pandemic on Higher Education; Characterizing the Psychosocial Context of the Positive and Negative Affecting States Using Classification and Regression Trees. *Department of Social Psychology and Quantitative Psychology, Department of Clinical Psychology and Psychobiology. Frontiers in Psychology 2021.*
https://www.frontiersin.org/articles/10.3389/fpsyg.2021.714397/full

[3] Studiebarometeret, 2020,
https://www.studiebarometeret.no/no/student/studieprogram/1220_masterid/detaljer

[4] Studiebarometeret, 2021,
https://www.studiebarometeret.no/no/student/studieprogram/1220_masterid/tidsserie

[5] Wiederhold B. Cyberpsychology, Behaviour and Social Networking. Researchgate Volume 23, June 2020.
https://www.researchgate.net/publication/342295196_Connecting_Through_Technology_Duringthe_Coronavirus_Disease_2019_Pandemic_Avoiding_Zoom_Fatigue

[6] Bailenson J. *Nonverbal Overload: A Theoretical Argument for the Causes of Zoom Fatigue,* Technology, Mind and Behaviour. Feb. 23, 2021.
https://tmb.apaopen.org/pub/nonverbal-overload/release/2

[7] NSD, The Norwegian Centre for Research Data.
https://www.nsd.no/om-nsd-norsk-senter-for-forskningsdata/

[8] Diana Marian Murek, Director of Education, Istituto Marangoni Mumbai
https://www.stirworld.com/think-opinions-tracing-the-impact-of-covid-19-on-design-education

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

USING DIGITAL TECHNOLOGIES FOR COLLABORATIVE CONCEPTUAL DESIGN

Joseph MILLS and Ross BRISCO
Department of Design, Manufacturing and Engineering Management, University of Strathclyde, United Kingdom

ABSTRACT
Since the COVID-19 worldwide pandemic outbreak, and the requirement to 'stay at home' and 'work from home', we, as a collaborative species have been forced to find ways of computer-supported collaboration. Going beyond global design and distributed design. We now find ourselves as a human race, not with a desire to collaborate using computers, or with a requirement, but it is now a necessity. In many ways, a paradigm shift has occurred.
This research investigates the use of novel technology to support student teams in the conceptual design phase of an engineering design project. A review of published literature identified a lack of understanding in the impact that a digital distributed environment can have on the outcomes of a collaborative ideation task. The literature suggested there would be little to no change between working in a collocated and digital distributed environment.
An experiment was designed that asked 16 participants working in pairs to complete an ideation task in both a synchronous traditional collocated environment and a synchronous digital distributed environment. The results from the experiment suggest that conducting the ideation task within a digital environment has a negative effect on the outcomes of the ideation task.

Keywords: Computer-Supported Collaborative Design (CSCD), conceptual design, design technology, ideation, concept generation

1 INTRODUCTION
Technologies to support design development are commonplace. 3D Computer Aided Design (CAD) has long been established as an industry standard for the later stages of the design process including detailed design, embodiment design, finite element analysis and manufacture and assembly modelling[1]. CAD software has been developed to support the creative design phases in 2D and 3D [2], and in recent years in particular with novel technologies such as Virtual Reality (VR). There has been a focused effort to develop CAD tools for design engineers. However, there has been a lack of focused development of CAD tools within the conceptual design stage of the design process which has resulted in minimal uptake within industry and education [3].
Throughout concept generation, designs are quickly evolving, the focus is not on great detail but more so on generating and adapting high volumes of concepts quickly [2], [4]. The initial concept generation phase is free flowing in nature and requires creativity from the designer to produce sketches that allow others to visualise their ideas. These sketches are vital while working collaboratively as it allows team members to modify, adapt and evolve the ideas to progress through the concept development [5].
The issue with the use of CAD tools within conceptual design is the required level of detail can hinder the creativity of the designer. Although sketches are incomplete and rough, CAD tool's completeness can discourage the designer from modifying and adapting the concepts [6]. This is due to CAD tool's rigidity and need for a high level of detail which is not required throughout the conceptual design phase.
In a digital space, a useful tool to replace paper is a digital whiteboard, however, the usefulness and effectiveness of this design tool has been questioned. Tang et al., [3] investigated the differences between digital and physical sketching. Teams were given a sketching task to conduct in both environments. By assessment of experts, the designs created in both mediums were of equal quality with a slight preference towards the outcomes of the physical sketched posters. Mulet et al., [7] investigated the role of technology in the novelty of designs. By assessment of experts, the novelty of the designs

created by teams in a collocated space and in a distributed online space were equal. There were several technical issues with the technology which may have been improved.

Jensen et al., [8] conducted an ideation activity using physical sticky note and a tablet and sticky note software. Experts determined similar levels of quality in the concepts created using physical sticky notes and digital. The research was limited in the use of one tablet used by one team member where typical sticky note activities allow all participants to take part at the same time.

Brisco et al., [9] created a digital design tool based upon an established design method 6-3-5. The tool enabled students to draw sketches based on an original idea or the ideas of other team members. Students had no preference for or against using the tool and there were several technical issues in its use.

Pre-pandemic research was focused on technologies to support distributed work as a novel concept, as secondary to in-person working. Now, research must consider remote working as the default, or as equal [10]. One solution to this problem would be the development of distributed digital design methods that are as effective as those well established and used in a collocated physical space. To do so, the design research community must build an understanding of the similarities and differences between collocated design activities and distributed design activities facilitated by computer technologies. This requires researchers to look beyond the norm and develop design methods inspired by technology functionality, and not as an afterthought. Solutions must allow those who have the knowledge to contribute to a product development to do so in person or digitally with equal impact. Universities and businesses can prepare for any mode of learning and working. The best design methods, online or offline, can be chosen to ensure resilience when barriers to physical working arise.

2 METHODOLOGIES

The methodology chosen was inspired by that used by Tang et al., [3] and Mulet et al., [7] as a state-of-the-art research method identified through a literature review. 16 final year Master's students studying Product Design Engineering at the Department of Design, Manufacturing and Engineering Management were invited to take part in the study. The participants were selected because they had previous experience of working in both distributed and collocated environments.

The participants were asked to join as teams of twos and every participant had previously worked in a group with their partner. The participants were grouped in pairs due to the constraints on the time and number of participants available. Groups of two provided allowed high enough number of groups to provide a statistical analysis of the results. There were 8 male and 8 female participants. The average age was 22 years and 4 months with a standard deviation of 1 year and 4 months.

The collaborative concept ideation task chosen for this experiment was "brainstorming." Brainstorming as a concept ideation technique was originally developed in 1954 by Alex Osborn within his book Applied Imagination [11]. It is frequently used as a concept ideation technique by every level of designers, from professionals to novices [12] and is commonly carried out with the use of sticky notes. Both Ball and Treffinger argue that sticky notes are the perfect material for brainstorming as they allow many solutions to be generated and aid collaboration between teams [13]. Therefore, the selection of brainstorming through the use of sticky notes was justified as there has been extensive literature verifying it as a proven technique. It was also selected as every participant within the experiment has previous experience with it meaning they did not need time to get familiar with the ideation task

During the experiment, the participants were given two design project briefs which they used to conduct the brainstorming ideation task. The participants completed one of the briefs in a traditional environment, being offline and collocated, and one in a digital environment, online and distributed. The two briefs were chosen from a list of design briefs generated within a previous study conducted by [14]. The briefs generated within the list were designed to be of equal difficulty. To ensure the level of difficulty did not affect the results of the experiment, half of the groups completed *Brief 1* in the digital environment first and vice versa. The chosen briefs were:

Brief 1: Rain and wind Protection

Rain and wind make it difficult for pedestrians to keep dry and pose dangers e.g., slipping, falling trees. Generate concepts for products to reduce the discomfort and danger of poor weather for pedestrians.

Brief 2: Lighting in Towns and Cities

Lighting towns and cities at night have negative environmental impacts e.g., fossil fuel depletion; light pollution; and disruption to wildlife. Generate concepts for products that may improve the environmental impacts of lighting urban areas.

The experiment in the traditional environment is as follows. The participants were seated together at a desk (*Figure 1*) and were given a selection of sticky notes and black or blue pens. The participants were free to interact in any way and collaboration was highly encouraged. This experimental setup is something each participant was familiar with and had experienced during their education.

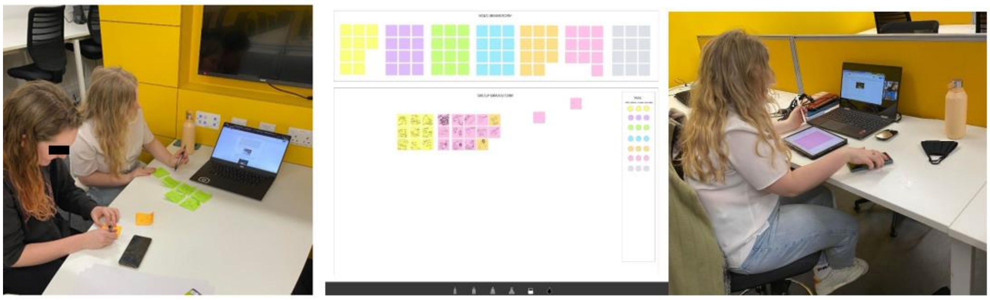


Figure 1. Students conducting the traditional (Left) and digital experiment (Centre, Right)

The digital environment involved a more complex experimental setup. First, the participants were in separate rooms to mimic a distributed design experience. Video conferencing on Zoom was provided (*Figure 1*), as opposed to the audio only experiments conducted by Jensen et al., [8] and Mulet et al., [13]. This also allowed for the team to share the experiment procedure onto the screen so they could both view the brief and instructions while completing the task. To facilitate digital sketching both group members were given an iPad 11 Pro. This minimised the limitations from poor quality digital sketching devices as identified within both Brisco et al., [9] and Mulet et al., [13].

During a preliminary investigation, MURAL was selected as the most functional whiteboard tool to support brainstorming. Participants were given five minutes to familiarise themselves with MURAL and to ask any questions on its operation. The experimental procedure was as follows: five minutes were provided to read the design brief, ten minutes to draw as many concepts as possible, and two minutes to categorise their concepts. Concepts were saved for analysis. It was emphasised to the participants that the quality of the sketches did not matter as this is not something that was being assessed within the experiment. Upon completing the first design brief the team swapped to the other environment.

Participants were instructed to produce as many concepts as they could for each brief and to then group the concepts into categories. Therefore, the characteristics which the "outcome" of the ideation tasks will be evaluated is Fluency and Flexibility. Fluency is the total number of concepts produced for one brief. This was assessed by simply counting the number of concepts produced. Flexibility is the total number of different categories of concepts produced for one brief. This was assessed by counting the total number of different categories produced.

Fluency, flexibility, originality, and elaboration are the four key characteristics for evaluating creativity with the Torrance Test of Creative Thinking (TTCT) [15] There are two reasons that originality and elaboration have not been considered within the evaluation of the ideation task outcome. Firstly, this study is not directly investigating the effect the different environments have on creativity but the outcome of the ideation task. Secondly, originality and elaboration are subjective in nature and to generate quantitative data for these characteristics at least two qualified external reviewers would be needed to remove bias from the results [16]. Due to the time limitations of this project, it was not possible to test for originality and elaboration in the concepts.

Two hypotheses were created based on the outcomes of the literature review.

H0: Participants will produce a higher fluency score while working in the traditional environment.

H1: Participants will produce a higher flexibility score while working in the traditional environment.

3 RESULTS

The total scores for both fluency and flexibility (*Table 1*) were higher within the traditional environment (Fluency=134, Flexibility=31) compared to the digital environment (Fluency=99, Flexibility=26). Using this data, the percentage decrease of both the total fluency and flexibility scores when moving from the traditional to the digital environment were calculated. The total fluency score decreased by 26.12% when comparing the traditional to the digital environment and the total flexibility score decreased by 16.12% when making the same comparison.

To test if the data was normally distributed a Shapiro-Wilk Test of Normality was conducted. This test was selected over the use of Normal Q-Q plots because the sample size was small (<50 participants). The Shapiro-Wilk test confirmed that the data was normally distributed since $p>0.05$ [17] for the difference between the fluency ($p=0.279$) and flexibility ($p=0.156$) in the traditional and digital environment. This confirmed that a Paired Sample T-Test could be conducted.

Table 1. Fluency and Flexibility Scores for each group in both environments

	Traditional Environment		Digital Environment	
Group	Fluency	Flexibility	Fluency	Flexibility
1	34	4	23	3
2	13	4	15	5
3	21	5	10	3
4	8	3	8	2
5	16	4	11	3
6	9	2	10	3
7	22	6	16	3
8	11	3	6	4
Total	134	31	99	26
Mean	16.75	3.88	12.38	3.25

A Paired Sample T-Test was used to identify if there was a statistically significant difference between the fluency and flexibility scores between the two collaborative environments. Participants had a higher fluency score while in the traditional environment (16.750 ± 8.68) as opposed to the digital environment (12.375 ± 5.42), a statistically significant mean increase of 4.375 (95% CI, 0.137 to 8.613), $t(7) = 2.441$, $p = 0.045$, $d=0.863$. This was determined to be statistically significant since $p<0.05$ [19]. Participants also produced a greater number of concept categories within the traditional environment (3.875 ± 1.246) compared to the digital environment (3.250 ± 0.886) a mean difference of 0.625 (95% CI -0.634 to 1.88) $t(7) = 1.17$, $p=0.279$, $d=0.42$. However, since $p>0.05$ the difference cannot be considered significant.

Significance	**Value**
Small	0.2
Medium	0.5
Large	0.8

Figure 2. Cohen's d Significance Table

Cohen's d (*Figure **2***) was used to calculate the effect size one variable has on another. In this case, the effect size refers to the effect the collaborative environment has on the fluency and flexibility scores.
Where MM is the mean difference between the two related groups and SD is the standard deviation of the mean. The significance of this effect can be approximated using Cohen's d significance table [18].
The results of the Paired Sample T-Test have shown that the effect the different collaborative environments had on fluency is large and can be considered statistically significant. However, the effect on flexibility is small and is statistically insignificant.
Although the majority of teams displayed a similar pattern considering preference for traditional over digital environment, two anomalies were found. Group two and six had higher Fluency and Flexibility scores for digital over traditional. This could be a result of individual preference or experience, something this study could not determine.

4 DISCUSSIONS

Results from the experiment reveal that both fluency and flexibility scores were higher for the traditional environment. To confirm or reject the hypothesis the results underwent statistical analysis. Although there was variance in the scores between the groups, there were no data outliers that could affect the statistical analysis. The Shapiro-Wilk Test for Normality was conducted which confirmed that the results were normally distributed since $p>0.05$ for both fluency and flexibility scores [17].

The results of the Paired Sample T-Test revealed that participants had higher mean fluency and flexibility scores while conducting the ideation task within the traditional environment. The test displayed that the effect the collaborative environment had on the fluency scores was statistically significant since $p<0.05$ [19]. Cohen's d was used to calculate the size of the effect the collaborative environment had. The results showed that the different collaborative environments had a large effect on the fluency scores since $d>0.8$. Therefore, confirming that conducting the collaborative ideation task in a digital environment has a large and statistically significant negative effect on the number of concepts produced when comparing it to working in a traditional environment.

Although the mean flexibility scores were higher within the traditional environment, the Paired Sample T-Test showed that the difference was statistically insignificant and after calculating Cohen's d the results showed that the effect size is considered small. This showed that when working in the different collaborative environments there is a minimal and insignificant effect on the number of categories produced within the ideation task. However, further testing with a larger sample size and other ideation tasks could be conducted to see if the effect on flexibility is still minimal.

The results from the experiment reveal the results of the hypotheses:

H0: Participants will produce a higher fluency score while working in the traditional environment.

H1: Participants will produce a higher flexibility score while working in the traditional environment.

The results from the experiment showed that hypothesis H0 could be confirmed as the flexibility scores while working in the traditional environment were higher and the mean difference was confirmed to be statistically significant. Although the scores for the flexibility scores were also higher in the traditional environment, hypothesis H1 could not be confirmed as the analysis of the results showed that the difference was too small to be considered statistically significant. Therefore, the results from the analysis, could not confirm hypothesis H1.

Limitations of the study include a small sample size, inconsistent familiarity with the iPad as a sketching tool, inconsistent familiarity with MURAL as an ideation tool, limited evaluation of the outcomes of the ideation which may in the future include novelty, elaboration, quality and originality. The limitations of this work could be minimised through repeating the experiment with a larger sample size as this would result in more accurate mean values which could be used to display the true effect the different collaborative environments have on the ideation task. The participants chosen for the experiment should be given a longer training period with both digital sketching on the device and the use of MURAL for the ideation task so that they can be more familiar with the software. The digital set-up could also be improved by having a separate screen displaying the MURAL board as a whole, to allow better visibility of the participants partner's concepts to be used as inspiration. Finally, the experiment could also be repeated with external reviewers measuring for novelty, elaboration and originality to display the effects the collaborative environments have on creativity as a whole.

5 CONCLUSIONS

The use of CAD technology has been long established within the later stages of design, such as 3D CAD for detailed design, finite element analysis and manufacture and assembly modelling. However, there are a lack of effective technologies developed to support collaborative conceptual design as this has traditionally been completed in a face-to-face environment using paper-based sketching. This poses a risk to the design process during the move to distributed working. To support distributed 'working from home' the research community needs to build an understanding of the similarities and differences between collocated design activities and distributed design activities so that effective solutions can be developed so that conceptual design tasks can be conducted in person or digitally with equal impact.

The experiment was designed to test the effect the different collaborative environment has on the outcome of an ideation task. The experiment was complete with 16 participants. The ideation task selected for this experiment was "brainstorming" using sticky notes. During the experiment, the participants were given two equally difficult design project briefs which they used to conduct the brainstorming ideation task. The participants completed one of the briefs in the digital environment and the other brief in the traditional environment.

The experiment results concluded that conducting the ideation task within the digital environment had a large and statistically significant effect on the fluency scores, confirming hypothesis H0. There was only a small and statistically insignificant effect on the flexibility scores, therefore, H1 could not be confirmed. Further testing with a larger sample size and different ideation tasks would be required to display the effect on flexibility more accurately and confirm whether this is truly insignificant.

REFERENCES

[1] Vuletic T., Duffy A., Hay L., McTeague C., Pidgeon L. and Grealy M. *The challenges in computer supported conceptual engineering design*. Computers in Industry, vol. 95, pp. 22–37, 2018.

[2] Oti A. and Crilly N. *Immersive 3D sketching tools: Implications for visual thinking and communication*. Computers & Graphics, vol. 94, pp. 111–123, 2021.

[3] Tang H. H., Lee Y. Y. and Gero J. S. *Comparing collaborative co-located and distributed design processes in digital and traditional sketching environments: A protocol study using the function–behaviour–structure coding scheme*. Design Studies, vol. 32, no. 1, pp. 1–29, 2011.

[4] Zhong K., Kang J., Qin S. and Wang H. *Rapid 3D conceptual design based on hand gesture.* 2011 3rd International Conference on Advanced Computer Control, ICACC 2011, pp. 192–197, 2011.

[5] Yang Z., Xiang W., You W. and Sun L. *The influence of distributed collaboration in design processes: an analysis of design activity on information, problem, and solution*. International Journal of Technology and Design Education, vol. 31, pp. 587–609, 2021.

[6] Fuge M., Yumer M. E., Orbay G. and Kara L. B. *Conceptual design and modification of freeform surfaces using dual shape representations in augmented reality environments*. Computer-Aided Design, vol. 44, no. 10, pp. 1020–1032, 2012.

[7] Mulet E., Chulvi V., Royo M. and Galán J. *Influence of the dominant thinking style in the degree of novelty of designs in virtual and traditional working environments*. Vol. 27, no. 7, pp. 413–437, 2016.

[8] Jensen M. M., Thiel S.-K., Hoggan E. and Bødker S. *Physical Versus Digital Sticky Notes in Collaborative Ideation*. Computer Supported Cooperative Work (CSCW) vol. 27, no. 3, pp. 609–645, 2018.

[9] Brisco R., Grierson H. and Lynn A. *Lessons learned in the development of an online 6-3-5 digital design tool for distributed idea generation*. DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), 2021.

[10] Duehr K., Kavakli E. and Albers A. *Improving distributed collaboration – methods for identification and developing of improvement potentials*. Procedia CIRP, vol. 100, pp. 750–755, 2021.

[11] Osborn A. F. *Applied Imagination; Principles and Procedures of Creative Thinking*, 3rd ed. New York: Scribner, 1954.

[12] Gonçalves M., Cardoso C. and Badke-Schaub P. *What inspires designers? Preferences on inspirational approaches during idea generation.* Design Studies, vol. 35, no. 1, pp. 29–53, 2014.

[13] Ball L. J., Christensen B. T. and Halskov K. *Sticky notes as a kind of design material: How sticky notes support design cognition and design collaboration*. Design Studies, vol. 76, 2021.

[14] Hay L., Duffy A., Grealy M. and Campbell G. *Quantitative and qualitative data from a functional magnetic resonance (fMRI) study of ideation in product design engineering*. Dataset DOI:10.15129/a82c32a8-689a-4be5-a61f-17d60eaad10c 2019.

[15] Torrance E. *Torrance tests of creative thinking*. Norms-technical manual. Research edition. Verbal tests, forms A and B. Figural tests, forms A and B. Princeton: Personnel Press, 1966.

[16] Wodehouse A., Maclachlan R. and Gray J. *The best form of medicine? Using humour to enhance design creativity*. International Journal of Design Creativity and Innovation, vol. 2, no. 3, pp. 125–141, 2014.

[17] Rochon J., Gondan M. and Kieser M. *To test or not to test: Preliminary assessment of normality when comparing two independent samples*. BMC Medical Research Methodology, vol. 12, no. 1, pp. 1–11, 2012.

[18] Cohen J. *Statistical Power Analysis for the Behavioural Sciences*. Statistical Power Analysis for the Behavioural Sciences, 1988.

[19] Andrade C. *The P Value and Statistical Significance: Misunderstandings, Explanations, Challenges, and Alternatives*. Indian Journal of Psychological Medicine, vol. 41, no. 3, p. 210, 2019.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

STUDENTS PERCEPTION OF RISK: TEAM MEMBERS CONTRIBUTION WITHIN COLLABORATIVE PROJECTS

Charlotte Alexandra KELLAND, Ross BRISCO and Ian WHITFIELD
Department of Design, Manufacturing and Engineering Management, University of Strathclyde, United Kingdom

ABSTRACT
Collaboration is an important aspect of design, supporting ideation and the ability to tackle greater challenges. Teamwork supports the delivery of project goals across academic and professional fields. It has long been suggested that risk plays a defining factor in collaboration. Through analysis of the literature, few papers reported on the perception that students share risk when they collaborate in teams. This research project aimed to investigate if examples of shared risk can be identified in an educational environment? and how might these risks be perceived by students involved in collaborative projects? To fill this knowledge gap, a survey was conducted to collect the opinions of 44 students within the Department of Design, Manufacturing and Engineering Management, University of Strathclyde. This will build an understanding of the design student experience and identify if these students acknowledge they share risk when collaborating within a team. The cohort of students identified that risk is a defining factor among collaborative design within an educational setting. Students identify that teamwork is essential to provide a real-world comparable experience to industry, yet, has an impact on their educational experience and achievement. Recommendations are made to limit the impact of risk on student collaborative projects within an educational environment. The reduction of risk has the potential to improve teamwork aspects including fairer workload distribution.

Keywords: Risk, collaboration, cooperation, student teamwork

1 INTRODUCTION
Collaboration occurs to achieve a greater outcome than working individually. These benefits include appreciations of diverse opinions, adaptability, broader creativity and communication skills within a team. However, with all modes of working challenges exist including conflicting working styles, lack of organisation, limited knowledge, miscommunication and unequal task distribution [1]. Authors have gone as far as to state that the challenges of collaboration "by far outweigh the benefits" [2]. However, with appropriate planning, novel research areas such as Computer-Supported Collaborative Design (CSCD) interested in the use of technology to support collaborative design activities online can support with the identification of the best ways to conduct design activities in a digital environment [3].

1.1 Risk in Collaboration
Qiu [4] defined a "common confusion" of the differences between the terms "Collaboration" and "Cooperation". Authors Dillenbourg et all [5]and Roschelle and Tea-sley [6] stated it was necessary to make a clear separation between both terms to prevent misinterpretation. Collaboration involves the joint engagement of contributors to make a conscious effort to solve a problem collectively. Teams who are cooperating are inclined to work more independently to achieve the end goal of a project [7]. Both Collaboration and Cooperation involve the interaction of people, however this interaction manifests in different ways [8]:

> *"Cooperation is characterized by informal relationships that exist without a commonly defined mission, structure or effort. Information is shared as needed and authority is retained by each organization so **there is virtually no risk**. Resources are separate as are rewards…"*

"…Collaboration connotes a more durable and pervasive relationship. Collaborations bring previously separated organizations into a new structure with full commitment to a common mission. Such relationships require comprehensive planning and well-defined communication channels operating on many levels. Authority is determined by the collaborative structure. ***Risk is much greater because each member of the collaboration contributes its own resources and reputation.*** *Resources are pooled or jointly secured, and the products are shared."*

As the term *risk* becomes more frequently used, the definition of *risk* has evolved. For example, in 1981 during the first meeting at the Risk Definition Committee of the Society for Risk Analysis (SRA), thirteen varying definitions of risk were generated and defined due to personal interpretation of the term [9]. Barkley [13] stated that "risks are generally understood as uncertainties that seep into a project and deviate from the expected outcome". Whereas Haimes defined risk as "a measure of the probability and severity of adverse effects" [9].

Team based collaboration in academic environments has become an essential part of learning in education [10] [11]. Compared to traditional learning techniques, collaborative learning achieves higher overall results, increased motivation, more positivity and better understanding taught material during collaboration exercises [13]. No collaborative project is without risk.

Lee & Ra [13] identify factors which influence risk in IT projects including lack of trust amongst project members and stakeholders, diversity of team members, communication barriers, and lack of teamwork present in IT projects. If these challenges are not resolved quickly and fully this could have a detrimental impact on the project, with the potential to lead to project delays and possibly project failure. Hence it is important for design students to collectively work together and tackle challenges as they arise to prevent unnecessary complications and setbacks in achieving the sought-after goal of the project [1].

1.2 Risk in students' teams

Designers often generate a multitude of design ideas and concepts meeting user requirements whilst working in a multidisciplinary team. Team-working skills are vital for the evaluation and selection of the most suitable design for a project [14]. As a result, team-working skills, are classed as fundamental when entering the working environment and have become intrinsic to some academic curriculums [10][11] and as an essential requirement for job application for example design graduate schemes [14]. In an educational environment, students thoroughly enjoy groupwork as they find it more engaging, stimulating and overall, more fun, whereas others prefer the traditional methods of learning such as lecturing in a classroom setting. Group collaboration can introduce introduces "extra costs" [11] for example a shared grade when other team members may not contribute fairly to the submission and has been criticised as an "unfair or inappropriate assessment" method [14].

Tucker and Abbasi's [14] conducted a survey of 198 design students, which highlighted positive and negative perceptions and experiences of design student collaboration. The survey established that *Preparation* was the most common theme towards a positive outcome, where 51.7% of students stated they valued team projects as effective groundwork for their future career in the real world. *Development of Skills* was second with 39.02% of participants responding that they find groupwork helps to improve communication, knowledge, confidence and negotiation and are beneficial skills to develop further before entering the workplace. *Unequal workload contribution* was the most responded negative theme. This was characterised as disharmony within the team with a proportion doing the majority of the work and others making limited/no contribution yet gaining free time which can be utilised elsewhere in their academic studies, potentially improving their overall grade.

Mennecke, Bradley and McLeod [11] state that student's negative attitude towards teamwork comes directly from a lack of formal experiences of projects in the real world. Poole [15] suggests that representative experience could be obtained through organisation, training, scheduled meetings and management processes students' perspective may alter positively. The term *real world* is often a conflicting concept, where it can be interpretated as working together in a team in an organisation, institution or industry however this environment details undefined boundaries [16], therefore hindering on the ability to successfully achieve this experience.

Students share risk in teamwork activities as they are collectively graded and share this grade. If one team member does not contribute the team share the risk of a lower grade. Do students consider this in their teams, and do they understand the impact this may have on their degree classifications?

2 METHODOLOGIES

To answer the research question, *do students perceive risk during student projects*, two sub questions were created *what risk do student share?* and *do student perceive a shared risk?* A digital and physical survey was distributed to students studying at Department of Design, Manufacturing and Engineering Management (DMEM), University of Strathclyde. The students were undergraduates in their 3rd,4th and 5th year of study and had 2+ years' experience with group design projects. 44 students completed and submitted the survey.

Questions asked during the survey were:

1. How do you find the experience of working in a team in general?
2. Is risk an area of concern prior to collaborating in teams?
3. Is risk an area for concern whilst collaborating in teams?
4. Is risk an area of concern after to collaborating in teams?
5. Have you ever experienced risk as a design student whilst collaborating in a team within an educational setting?
6. Does risk play a defining factor on teamwork within an educational setting?
7. Can the group selection process be improved to minimise risk during collaboration?

Questions were designed in two forms to establish the different types of risks individuals might identify when collaborating in teams. Those with a simple binary response and those with a subjective response to capture arrange of opinions and possible concerns.

3 RESULTS

The results of the survey are as follows:

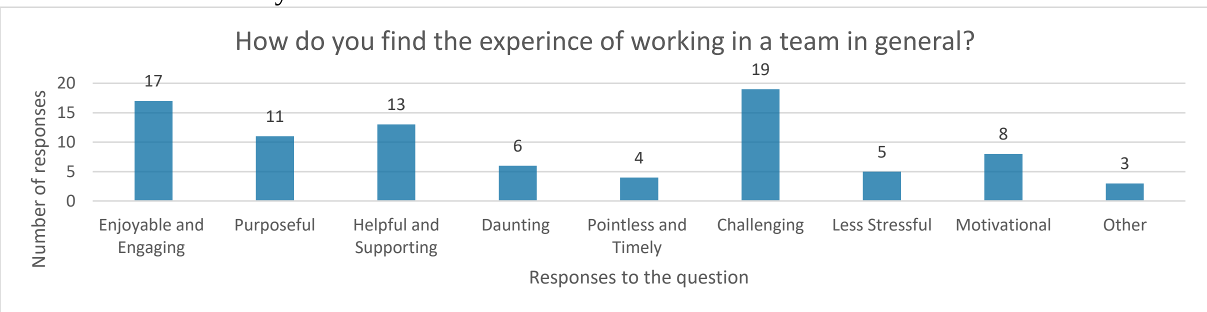


Figure 1. Results to the question on the experience of working in a team

Question One asked *How do you find the experiences of working in a team in general?* The results are displayed in *Figure 1*. Each student was able to select multiple answers to describe how they found working collectively in a team, in order to reflect a more complete expression of their thoughts and experiences. Interestingly, the answer selected most frequently was that students find teamwork *Challenging* with 43.18% of the results. Challenging can be considered as a negative experience. However, in second place and in contrast, 38.60% some students stated they find working in a team *Enjoying and Engaging*. Additionally, 29.54% of students deemed working in a team to be *Helpful and Supporting* compared to working individually. In addition, some of the students sampled, selected the option, *Other*, where they were able to comment and state how working in a team made them feel.

Question Two asked *Is risk an area of concern prior to collaborating in team?* The results are displayed in *Figure 2*. 59.09% of students who completed the survey stated they either *Strongly Agree* or *Agree* that risk is an apprehension before commencing collaboration. Whereas only 18.18% of students stated that they *Disagree* or *Strongly Disagree* that risk is a concern prior collaborating. The remaining 22.72% of students were neutral and selected that they *Neither Agree nor Disagree* with the question asked.

Question Three asked *Is risk an area for concern whilst collaborating in teams?* The results are displayed in *Figure 2*. The results clearly show that most students believe risk to be an area of concern whilst collaborating in teams with 95.00% of students having selected either *Strongly Agree* or *Agree* to this question. In comparison to question two above, where respondents provided a spread of results concerning risk, question three produced a clear and unequivocal response that students identified risk *whilst* collaborating in teams. Prior to working in teams some students anticipated that the positive benefits of teamwork may help cancel or neutralise possible risks that may occur. However, once in a team student experience indicated that any potentially benefits are negated by the risks experienced. This result shows that students do acknowledge that there are significant risks whilst working in teams.

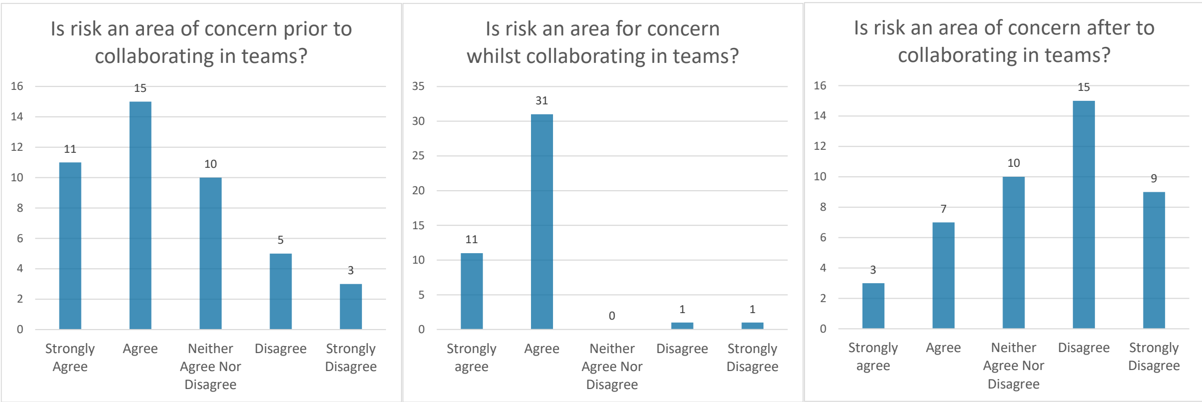


Figure 2. Changes in perception of risk across the project timeline

Question Four asked *Is risk an area of concern after collaborating in teams?* The results are displayed in *Figure* **2**. 54.54% students responded reflecting that once the work has been completed and submitted to the university, their concerns regarding risk are less evident.

It may be considered that once a group project has been submitted, student focus moves to the next topic with many students no longer reflecting on the risk of the project completed and possibly do not reflect on the experience of working in that group project until the project is graded by the university.

However, 22.72% of the responses state that they *Strongly Agree* or *Agree* that risk is a consideration after collaborating in teams. This highlighted that some students continue to be concerned on the possible impact of collaborating within teams, and potentially worry about the grade outcome. Interestingly a similar 22.72% of students *Neither Agree nor Disagree* with the question asked, and it might be considered that they are indifferent as they realise, they can no long influence the outcome of the grade, or their focus has simply moved on to their current workload.

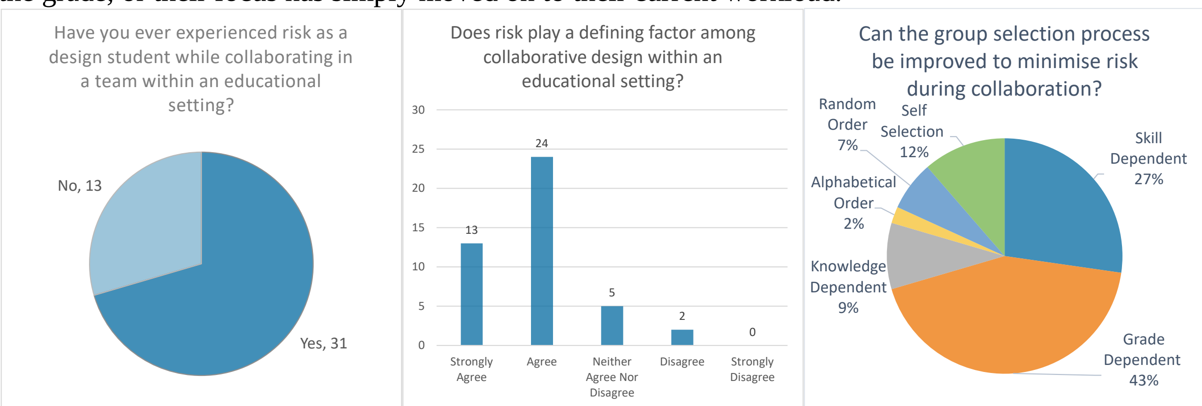


Figure 3. Results to questions on experience of risk, if risk is a defining factor and minimising risk

Question Five asked *Have you ever experienced risk as a design student whilst collaborating in a team within an educational setting?* The results are displayed in *Figure* **3** and display that 70.45% of students who took part have experienced risk whilst collaborating in a team within an educational setting. In contrast, the remaining 29.55% say they have not experienced risk in a team.

Question Six asked *Does risk play a defining factor among collaborative design within an educational setting?* The results are displayed in *Figure* **3** including that 84.09% of students sampled believe that risk is a defining factor among collaborative design within an educational setting. This is a significant result which has helped to answer the original research question. The results of this question have helped emphasis that students do recognise that they share risk in collaborative projects.

Question Seven asked *How can the group selection process be determined to minimise risk during collaboration?* It was important to understand if the current method of group selection, *Random Order*, within the department of DMEM was the preferred selection method to help minimise risk during collaboration for the students. It was recognised (*Figure* **3**) that 43.18% of students indicated that group selection being *Grade Dependent* would be their desired method. This is a significant percentage given that six selection methods were provided as possible answers. Interestingly, the second most preferred group selection option was the current method of group selection *Random Order* with 27.27% of students indicating this was their preferred method of group selection to minimise risk.

4 DISCUSSIONS

The survey revealed that student's acknowledgement risk during collaborative design projects. 84% of students surveyed believe that risk is a defining factor of collaborative design within education, interestingly the students who completed the survey only focused on their own individual risk and they did not extend the possible of risk to the group as a whole.

Question One highlighted a range of reflections (Figure 1), both positive and negative, on the group composition. For example, *when given a group who do not cooperate* and if you are *in a good group, it can mean you are usually less stressed*. It may be concluded that students have a positive attitude towards teamwork, if they perceive the group members to be a team player.

Questions Two, Three and Four (Figure 2) revealed that students have different perceptions of risk before, during and after projects. Prior to a project beginning, students agree that risk is an area of concern. There is apprehension of team members prior to starting based on previous experiences and reputations. This could be because a project was not as successful as it could have been, all going to plan, or because of breakdowns in cooperation and communication to complete a task on time. Also, prior knowledge of academic ability could have an influence on perception of the team member.

There was a stronger corelation that risk is a concern during projects and less so for before or after. This is to be expected as students have little control over the risk before or after, but they do have the ability to influence the risk during projects and mitigate this risk. After collaborating the trend was towards risk not being a concern. This is the period of marking and assessment, yet students do not have any influence over the outcomes post-submission. The work is complete and beyond the students control at this stage, yet they have been the ones to prepare the work for assessment.

One third of students reported that they had not experienced risk as a design student whilst collaborating in a team within an educational setting. For those who have not experienced risk when collaborating in a team the following was suggested as potential reasons: If a team member had limited experience or skills working in group projects, if they have been fortunate to always experience positive teamwork experience (i.e., never had a bad team member), if the respondent did not fully understand what risk is within the context of student teamwork, if the student has always performed better in teamwork and achieved better grades, they were always in the role of team leader and had control over the coordination and achievement of the team.

It is surprising to have such variation in the number of students who have experienced risk (Figure 3) and who believe it to be a defining factor and brings into question the definitions of collaboration by [8]. Perhaps risk is present but is not perceived by the students. This raises questions about why the risk was not perceived, and if risk were perceived would it have influenced the way the team conducted their collaborative projects?

There is variation of the types of risks experienced by students. However, common themes are *communication*, *achieving a poor grade*, *unequal distribution of workload* and *unreliable and unresponsive team members*. It was evident that each participant has different perspective on which risks are most challenging to them yet there are common risks that apply to all students. Only the risks indicated by the participants were considered, no other risks were introduced as this may have directed participant responses. Likewise, the researcher's opinion of risk was not included as it too may have introduced bias, and in fact the researcher was considered as a safe space for open discussion.

For the department involved in the study to change the way group members are assigned to groups based on the outcomes of the survey would be a risky experiment and it is unclear how future student would perform and respond to such a policy. *Grade Dependent* assignments as apposed *Random* assignments would allow a recognition of the risk present in group assignments.

5 CONCLUSIONS

This research investigated the views of 44 Design Engineering students using a survey to determine if students share risk when they collaborate in teams. The primary outcome was the understanding that 84% of students sampled believe that risk is a defining factor for collaboration. Risk played differing roles at different stages of the design process which may lead to mitigation strategies in future research. Also, a minority of students have either never experienced risk as part of their projects or did not identify risk, this should be further investigated to determine if risk plays an influence on achievement.

This research has determined that selective assignment of team members based on grade from previous projects was a preferred method of team assignment. This method brings challenges to implement and may be contested by students who are assigned to lower achieving teams. However, it is an interesting suggestion which would be a change to the norm for most institutions. A future study could consider academic perception of risk in this area and contrast with the information collated in this paper.

REFERENCES

[1] Green B. N. and Johnson C. D. Interprofessional collaboration in research, education, and clinical practice: working together for a better future, *Journal of Chiropractic Education*, vol. 29, no. 1, pp. 1–10, Mar. 2015, doi: 10.7899/JCE-14-36.

[2] McMahon M. and Bhamra T. Mapping the journey: visualising collaborative experiences for sustainable design education, *International Journal of Technology and Design Education* 2016 27:4, vol. 27, no. 4, pp. 595–609, Mar. 2016, doi: 10.1007/S10798-016-9365-0.

[3] Brisco R., Whitfield R. I. and Grierson H. A novel systematic method to evaluate computer-supported collaborative design technologies, *Research in Engineering Design*, vol. 31, no. 1, pp. 53–81, Jan. 2020, doi: 10.1007/s00163-019-00323-7.

[4] Dillenbourg P., Baker M. J., Blaye A. and O'Malley C. The evolution of research on collaborative learning, in *Learning in Humans and Machine: Towards an interdisciplinary learning science*, E. Spada and P. Reiman, Eds. Oxford: Elsevier, 1995, pp. 189–211. Accessed: Mar. 03, 2022. [Online]. Available: https://telearn.archives-ouvertes.fr/hal-00190626

[5] Sykes C., Moerman L., Gibbons B. and Dean B. A. *Re-viewing student teamwork: preparation for the 'real world' or bundles of situated social practices?*, vol. 36, no. 3, pp. 290–303, Sep. 2014, doi: 10.1080/0158037X.2014.904784.

[6] Roschelle J. and Teasley S. D. The Construction of Shared Knowledge in Collaborative Problem Solving, *Computer Supported Collaborative Learning*, pp. 69–97, 1995, doi: 10.1007/978-3-642-85098-1_5.

[7] Holliman R. and Scanlon E. Investigating cooperation and collaboration in near synchronous computer mediated conferences, *Computers & Education*, vol. 46, no. 3, pp. 322–335, Apr. 2006, doi: 10.1016/J.COMPEDU.2005.11.002.

[8] Mattessich P. W. and Monsey B. R. *Collaboration: what makes it work*. Amherst H. Wilder Foundation, 1992.

[9] Haimes Y. Y. *On the Complex Definition of Risk: A Systems-Based Approach*, *Risk Analysis,* vol. 29, no. 12, pp. 1647–1654, Dec. 2009, doi: 10.1111/J.1539-6924.2009.01310.X.

[10] Steenkamp A. L. A Standards-Based Approach to Team-Based Student Projects in an Information Technology Curriculum, in *Proceedings of the International Academy for Information Management (IAIM) Annual Conference: International Conference on Informatics Education Research (ICIER)*, 2002, pp. 54–62. Accessed: Mar. 03, 2022. [Online]. Available: https://eric.ed.gov/?id=ED481738

[11] Mennecke B., Bradley J. and McLeod M. Making Project Groups Work II: The Impact of Group Process Training and Role Assignment on the Performance and Perception of Information Systems Project Teams, in *Proceedings of the 13th Annual Conference of the International Academy for Information Management*, 1998, pp. 110–121. Accessed: Mar. 03, 2022. [Online]. Available: https://eric.ed.gov/?id=ED431423

[12] Fowler R. R. and Su M. P. Gendered risks of team-based learning: A model of inequitable task allocation in project-based learning, *IEEE Transactions on Education*, vol. 61, no. 4, pp. 312–318, Nov. 2018, doi: 10.1109/TE.2018.2816010.

[13] Ra P. and Lee O.-K. (Daniel). Identifying Risks in IT Projects for Developing Economies, *PACIS 2015 Proceedings*, Jan. 2015, Accessed: Mar. 03, 2022. [Online]. Available: https://aisel.aisnet.org/pacis2015/46

[14] Tucker R. and Abbasi N. Bad Attitudes: why design students dislike teamwork, *Journal of Learning Design*, vol. 9, no. 1, pp. 1–20, Apr. 2016, doi: 10.5204/JLD.V9I1.227.

[15] Amano I. and Poole G. S. *The Japanese University in Crisis*, *Higher Education* 2005 50:4, vol. 50, no. 4, pp. 685–711, 2005, doi: 10.1007/S10734-004-6372-Y.

[16] Sykes C., Moerman L., Gibbons B. and Dean B. A. *Re-viewing student teamwork: preparation for the 'real world' or bundles of situated social practices?,* vol. 36, no. 3, pp. 290–303, Sep. 2014, doi: 10.1080/0158037X.2014.904784.

INNOVATIONS IN THE DESIGN OF AN ARCHITECTURAL ENGINEERING CURRICULUM

Shannon CHANCE[1,2] **and Emanuela TILLEY**[1]
[1]University College London
[2]Technological University Dublin

ABSTRACT
This paper introduces a new curriculum, launched in October 2021, in Architectural Engineering, designed out of London, UK for implementation in Giza, Egypt. The developers of this newly formed higher education institution, Newgiza University, sought to introduce more contemporary approaches as well as cutting-edge curricular innovations to the education landscape in Egypt. To achieve this, they enlisted curriculum developers in architecture and engineering from University College London who have expertise in education research, curricular innovation, and the delivery of engineering and architecture modules and degree programs. The team worked in collaboration with experts and educators from Egypt to create a bespoke curriculum, drawing from a range of innovative approaches and educational theories, combining these with many well-established approaches. This paper, which represents the "scholarship of integration", highlights distinctive aspects of the curriculum, and illustrates how prior research was integrated into the curriculum design, with a focus on the first year. The paper is geared toward design educators as well as curriculum developers.

Keywords: Curriculum design, interdisciplinary, scenarios, challenges

1 INTRODUCTION
In keeping with the theme of the 2022 conference on Engineering and Product Design Education, we aim to "Disrupt, Innovate, Regenerate and Transform" in the design of a new degree course in Architectural Engineering (AE) for Newgiza University (NGU) located in Giza, on the outskirts of Cairo, Egypt. The new AE curriculum brings architecture, building design, art, planning and business together with engineering. We draw together the best of engineering and architecture education pedagogy and practice, and incorporate novel components developed and tested at University College London (UCL), as part of the Integrated Engineering Programme (IEP) there [1] and reported as ground-breaking in reports published by MIT [2, 3].

AE is one of a suite of degree courses that UCL Consultants have designed for implementation at NGU. Medical degree programs (i.e., Medicine, Dentistry and Pharmacology) were previously designed for NGU and are up and running. In October 2021, NGU launched its first two engineering programs – one in AE and the other in Computers, Communication and Autonomous Systems (CCAS). The design of all these draws from UCL research on learning and teaching and principles of an "integrated curriculum" as defined by Fung [4].

Here, we describe our integrated approach to the development of architectural engineering professionals. Fundamental topics are not taught separately but integrated into applied engineering topics and synthesized with the theoretical and practical architecture-based modules. This integrated approach bolsters the students' understanding of various artistic and fluid architectural methodologies. After discussing distinctive qualities of the AE curriculum, the paper provides an overview of the first-year AE studio syllabus and identified theories that underpin its design.

2 DISTINCTIVE QUALITIES OF THE AE CURRICULUM
We have set out to inspire design innovation, aiming to equip students to develop creative, poetic, novel and artistic visions and approaches to the more experimental and technically rigorous elements which sit within the structural, mathematical, technological, and engineering aspects of the degree. We want to produce well-rounded, future-oriented, creative architects equipped with know-how that draws

together the artistic creativity of architecture, combined with technical and digital skills of other engineering disciplines, to help forge a better living environment for clients, communities, and the world at large. We also want to infuse architectural practice in this region with rich Egyptian history, and artistic and cultural influences of past and present Islamic and Arab civilisations. We integrate global themes in artificial intelligence, sustainability, and climate change.

2.1 Vertical threads

The AE curriculum design has threads that run vertically through the years to support and link core technical, theoretical, and practical modules. These vertical threads are shared, and taken by all students, within NGU Engineering: (a) Arts, History, Culture and Society (AHCS); (b) (c) Business, Management and Entrepreneurship; and (c) Professional Skills. AHCS draws from the local context and Egypt's proud heritage in architecture, technology, and knowledge production. Further complementing the first year AHCS module taken by all AE and CCAS students, Egyptian history features prominently in the primary textbook [5] for the first year, first semester "condensed" design studio (see Section 3 below).

2.2 Challenges and Scenarios

Students are challenged to develop their theoretical knowledge, engage with experiential learning, and simultaneously put that knowledge into practice, while developing professional skills and exploring their own creativity and design practice, through a series of projects (termed 'Challenges' and 'Scenarios'). These projects add another dimension to the studio-based study and practice of the AE program, as they are interdisciplinary (i.e., Challenges are shared project modules with students from the CCAS program) and time-intensive (i.e., Scenarios are 1- to 2-week long intensive projects that focus on discipline-specific content which allow student teams to go deeper in their understanding and practices of core technical and learning outcomes). These authentic and industry- or community-inspired and supported activities help students connect their learning and practice to the techniques and skills that will be critical for their future professional success.

In the first semester of first year, all NGU Engineering students undertake a sustainability and quality of life Challenge project in interdisciplinary teams. In the second semester, students experience two one-week long Scenarios scheduled approximately seven weeks apart. Halfway through the semester, all classes are paused for the students' first Scenario experience called "Pebble in the Pond" focused on applying physics-based concepts and calculations, creating a Rube Goldberg type machine to move a pebble and deposit it into a "pond", discussing the rippling effect of an engineer/architect's actions, and analysing an ethics-related case study. The semester culminates with a second week-long AE specific Scenario to introduce students to the architectural charette and competition formats, challenge them to develop new graphic communications and media skills in the design of a linear trellis for a site they previously diagrammed. The focus here is on the site context, sustainability, user needs, and consideration for mitigating risks.

2.3 Teamwork and other student-centred learning approaches

Teamwork is central to engineering education, where students are prepared for global, transnational work and design is seen as a group effort enriched by diverse perspectives. This stands in contrast to the traditional view of architects as lone figures—design geniuses and "starchitects" working in isolation to craft the perfect/utopian design. This new AE curriculum draws from the blossoming field of "engineering education research" and innovative engineering education practice and includes a focus on team-based design skills. It integrates engineering problem-solving and teamwork [6] approaches with more artistic and poetic aesthetic practices typically celebrated in architectural education. It also draws from a litany of research on student-centred learning, such as phenomenographic research by Barrie [7] who identified six different categories of concept held by university-level educators about where and how students would develop transversal skills or "graduate attributes" like communication, teamwork, and time management. In the AE program, a balance is struck between implicitly developing such skills because of the inherent structure of the curriculum and consciously and purposefully integrating assignments that would build these skills into the modules whilst helping to create a holistic campus environment where students learned to connect and integrate across various types of formal and informal learning experiences.

2.4 Trans-disciplinarity

In addition to connecting the AE and CCAS curricula in every academic year via shared modules and providing interdisciplinary design projects (as detailed above), trans-disciplinarity enhances the uniqueness of our program. Over time, NGU will expand its offerings to include other fields of engineering and will provide increasingly trans-disciplinary integrated design opportunities via Challenges and Scenarios, because students will work in project teams with more and more engineering and architecture fields represented. Regarding trans-disciplinarity, the AE program has been designed to include four graduate pathways, one of which aligns with the CCAS curriculum whereby AE students will specialize in technologies for smart building design through the learning of programming, integrated sensory system design and IOT. AE students also encounter trans-disciplinarity in their first year, where the introductory design studio has been condensed to make space for engineering-related coursework (e.g., calculus and physics) to a higher level than expected in a standard architecture-only curriculum, and because NGU have requested options for students to switch streams during their first year.

3 AN OVERVIEW OF THE FIRST-YEAR STUDIO CURRICULUM

The first-semester's condensed AE studio includes reading and discussion of basic design fundamentals and gives students a chance to apply these in practice via abbreviated design activities focused on developing specific technical skills and applying simple design concepts. The student has one hour to discuss the readings, guided by the teacher presenting images to supplement the textbook [5], and another four hours wherein techniques are demonstrated and then applied in design exercises. Between formal sessions, students are expected to read and to spend nine additional hours developing their designs. Due to the condensed format, the exercises are straightforward and are drawn from established sources [e.g., 8].

The second semester studio is more highly customized and involves four projects. The components of Project 1 are named: **Transverse** (learn about buildings by drawing sections); **Travel** (learn to diagram experience); **Wrap** (analyse and deconstruct an item one wears). Project 2 comprises: **Colour** (study how colour works and make colours); **Fold** (learn to create space by cutting and folding paper geometrically); **Light** (learn to modulate light by designing a light fixture). Project 3 involves: **Stepped** (study carved spaces geometrically); **Water** (demonstrate the physical and phenomenological properties of water to others); **Labyrinth** (create a sequence of cavernous spaces that reveal the essence of water to others). Project 4 involves a digital portfolio where students reflect, document, and present their learning journey.

3.1 Digital portfolio of learning journey

In the first-semester AE studio, students curate a digital repository of their design work as well as reflective essays that use the Gibbs model of reflective practice [9]. In the second semester students extend their repositories, drawing from them to develop digital portfolios to showcase their work and their development as a learner and designer, and to explain how they have met the learning objectives of the course and of the various projects.

4 UNDERPINNING THEORIES

Lessons from the first semester textbook [5] are recalled and discussed again during the second semester, where students are also asked to purchase practical guides, and provided with a list of recommended modernist texts. Students are assigned a reading on phenomenology and their teachers read articles on Egyptian daylighting strategies, design theory, and learning strategies.

4.1 Informed Design Matrix

A cornerstone of the beginning design curriculum (i.e., the first two years of architect studio learning) is the "the informed design teaching and learning matrix" [10]. The matrix, developed using the scholarship of integration with an extensive literature review, identifies patterns that distinguish naïve design from more informed design practices. Part of the matrix is provided in Table 1. The full matrix suggests how to build informed practices among students. In the full version, each pattern is paired with a list of suggested learning goals and teaching strategies.

Table 1. The Informed Design Teaching and Learning Matrix [10, p. 738-797]

Design Strategies	Beginning vs. Informed Designer Patterns	
	WHAT BEGINNING DESIGNERS DO	**WHAT INFORMED DESIGNERS DO**
Understand the Challenge	***Pattern A: Problem Solving vs. Problem Framing***	
	Treat design tasks as a well-defined, straightforward problem that they prematurely attempt to solve.	Delay making design decisions in order to explore, comprehend and frame the problem.
Build Knowledge	***Pattern B: Skipping vs. Doing Research***	
	Skip doing research and instead pose or build solutions immediately.	Do investigations and research to learn about the problem, how the system works, relevant cases, and prior solutions.
Generate Ideas	***Pattern C: Idea Scarcity vs. Idea Fluency***	
	Work with few or just one idea which they can get fixated or stuck on and may not want to change or discard.	Practice idea fluency in order to work with lots of ideas by doing divergent thinking, brainstorming, etc.
Represent Ideas	***Pattern D: Surface vs. Deep Drawing and Modelling***	
	Propose superficial ideas that do not support deep inquiry of a system, and that would not work if built.	Use multiple representations to explore and investigate design ideas and support deeper inquiry into how systems work.
Weigh Options and Make Decisions	***Pattern E: Ignore vs. Balance Benefits and Trade-offs***	
	Make design decisions without weighing all options, or attend only to pros of favoured ideas, and cons of lesser approaches.	Use words and graphics to display and weigh both benefits and trade-offs of all ideas before picking a design.
Conduct Experiments	***Pattern F: Confounded vs. Valid Tests and Experiments***	
	Do few or no tests on proto-types or run confounded test by changing multiple variables in a single experiment.	Conduct valid experiments to learn about materials, key design variables and the system work.
Troubleshoot	***Pattern G: Unfocused vs. Diagnostic Troubleshooting***	
	Use an unfocused, non-analytical way to view prototypes during testing and troubleshooting of ideas.	Focus attention on problematic areas and subsystems when troubleshooting devices and proposing ways to fix them.
Revise/ Iterate	***Pattern H: Haphazard or Linear vs. Managed and Iterative Designing***	
	Design in haphazard ways where little learning gets done or do design steps once in linear order.	Do design in a managed way, where ideas are improved iteratively via feedback, and strategies are used multiple times as needed, in any order.
Reflection Process	***Pattern I: Non-Reflective vs. Reflective Thinking***	
	Do tacit designing with little self-monitoring while working or reflecting on the process and product when done.	Practice reflective thinking by keeping tabs on design strategies and thinking while working and after finished.

Pattern A, for instance, "Understanding the Challenge" can be developed via learning goals where students (a) **define** criteria and constraints of challenge and (b) **delay** decisions until critical elements of challenge are grasped and with teaching strategies that have students (c) **state** criteria and constraints from design brief in one's own words; (d) **describe** how preferred design solution should function and behave; and (e) **reframe** understanding of problem based on investigative solutions [quoted from 10].

4.2 Theories on student learning and development

In addition to explicitly discussing informed design patterns with students across the first and second years of design studio, we also present many architectural and design precedents and deliver, during the studios, presentations on technical aspects (such as laser cutting, 3D printing, and graphic design software). Each semester, we provide lectures, via the design studio, on various aspects of learning, including Kolb's learning cycle and experiential learning model [11], strategies for test-taking [12], and Dewck's theory on growth mindset [13] and integrating research on how the theory is used in engineering [14]. We also draw from Sanford's theory of challenge and support [15], Astin's theory of student engagement [16], and theories related to how students develop intellectual, moral, and ethical [e.g., 17], and reflective judgement [18].

4.3 Research on feedback and assessment

We respond to published critiques of the studio format and the jury format for assessment [19, 20] in our design for feedback and assessment [that draws from 21]. We developed assessment rubrics to be used formatively (while the students are in the process of developing their designs) as well as summatively (at the end of the project and the semester).

We aim to provide written and verbal feedback to students at least once during each project sequence, preferably at a formative stage when they can directly act upon the advice and integrate it into their work. For formative feedback, we recommend using ***Closed Juries & Open Feedback*** with assessment as a reflective tool. In this format, upon submission of students' work, it is reviewed by tutors in private. Then grades as well as written feedback are provided to the students. Students are expected to reflect on the feedback given before meeting with their tutor privately to discuss it [21, 22, 23].

In the second-semester design studio, summative assessment happens at the end of each project when students are given their first opportunities to present verbally in a formal setting. For this, UCL has suggested to try the ***'Red Dot' Review*** format (or ***Gallery Review***) [developed by 22, drawing from 23, 24]. This review format involves inviting guests, faculty members, and students to place one red dot (or, similarly, up to three sticky notes) on exhibited projects they wish to hear presented. Based on the number of red dots/votes received, a limited number of student projects is selected for presentation. The spirit of this presentation is celebratory, and the discussion which ensues includes conversation among the students. During the primary exhibition phase, students may have the opportunity to discuss their work in small groups, where experts, faculty members, and students mill around and discuss the work in a somewhat casual way. The teacher also makes a holistic end-of-semester assessment of each student's readiness to progress into the subsequent studio.

5 CONCLUDING REMARKS

An overview of the innovative curriculum design of an Architectural Engineering program purposefully built for implementation at a new higher education institution in Egypt is presented in this paper. It enlists a "scholarship of integration" approach aimed at embedding: vertical threads of contemporary learning through all years of study; student-centred team-based learning through a variety of design project opportunities in the form of Challenges and Scenarios alongside the architecture studios; and trans-disciplinary learning opportunities alongside other engineering students within the school. The details provided of the first-year studio curriculum give insights into its atypical approach, whereby the introductory semester studio is designed as a heavily guided and structured student learning experience leading into a much more student-driven final semester studio customized through a set of interrelated projects. Finally, the richness and diversity of the educational theories underpinning the detailed design of the first-year studios support and help manifest our interpretation of the Crismond and Adams "informed design teaching and learning matrix" aimed at moving students from naïve designers to designers with more informed practices during their years studying at NGU.

REFERENCES

[1] Mitchell J. E., Nyamapfene A., Roach K. and Tilley E. (2021). Faculty wide curriculum reform: the integrated engineering programme. *European J. of Engineering Education*, *46*(1), 48-66.

[2] Graham R., Crawley E. and Mendelsohn B. R. (2009). Engineering leadership education: A snapshot review of international good practice. *White paper sponsored by the Bernard M. Gordon-MIT Engineering Leadership program*.

[3] Graham R. (2018). The global state of the art in engineering education. *Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA.*

[4] Fung D. (2017). *A connected curriculum for higher education* (p. 182). UCL Press.

[5] Ching F. D. and Eckler J. F. (2013). Introduction to architecture. John Wiley & Sons.

[6] Helmi S. A., Mohd-Yusof K. and Phang F. A. (2016). Enhancement of Team-based Problem-Solving Skills in Engineering Students through Cooperative Problem-based Learning. *International Journal of Engineering Education 32*(6), 2401-2414.

[7] Barrie S. C. (2007). A conceptual framework for the teaching and learning of generic graduate attributes. *Studies in higher education*, *32*(4), 439-458.

[8] Friedman J. B. (2000). *Creation in Space: Fundamentals of Architecture, Volumes 1 and 2*. Kendall/Hunt.

[9] Gibbs G. (1988). *Learning by doing: A guide to teaching and learning methods*. London: Further Education Unit.
[10] Crismond D. P. and Adams R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education 101*(4), 738-797.
[11] Kolb D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.
[12] Kitsantas A. (2002). Test preparation and performance: A self-regulatory analysis. *The journal of experimental education*, *70*(2), 101-113.
[13] Dweck C. (2017). *Mindset-updated edition: Changing the way you think to fulfil your potential*. Hachette UK.
[14] Campbell A. L., Direito I. and Mokhithi M. (2021). Developing growth mindsets in engineering students: a systematic literature review of interventions. *European Journal of Engineering Education*, *46*(4), 503-527.
[15] Sanford N. E. (1962). *The American college: A psychological and social interpretation of the higher learning*.
[16] Astin A. W. (1997). *What matters in college?* JosseyBass.
[17] Perry Jr W. G. (1999). *Forms of Intellectual and Ethical Development in the College Years: A Scheme. Jossey-Bass Higher and Adult Education Series*. San Francisco: Jossey-Bass.
[18] King P. M. and Kitchener K. S. (1994). *Developing Reflective Judgment: Understanding and Promoting Intellectual Growth and Critical Thinking in Adolescents and Adults.* Jossey-Bass.
[19] Boyer E. L. and Mitgang L. D. (1996). *Building Community: A New Future for Architecture Education and Practice. A Special Report*. California Princeton Fulfillment Services; Ewing, NJ.
[20] Anthony K. H. (2012). Studio culture and student life: a world of its own. MIT Press.
[21] Flynn P. (n.d.). Testing the New Model for Feedback. Whitepaper form the project "*Rethinking the Crit: A new pedagogy in architectural education*". Technological University Dublin.
[22] Cameron M. (2014) The Jury's Out: A Critique of the Design Review in Architectural Education, University of Canberra.
[23] Anthony K. H. (1991). Design juries on trial. London: Van Nostrand Reinhold.
[24] Sara R. and Parnell R. (2013). Fear and learning in the architectural crit. *Field Journal*, *5*(1), 101-125.

PRODUCTIVE FAILURE IN ACTION

Stefan PERSAUD, Bas FLIPSEN and Erik THOMASSEN
Delft University of Technology, Industrial Design Engineering, The Netherlands

ABSTRACT
In September 2021 the faculty of Industrial Design Engineering has implemented a completely revised bachelor. Important differences between the old and the new bachelor are its focus on design for higher complexity, the teacher as a coach, and the need for students to learn in an autonomous way. Within the bachelor, first year engineering students are introduced to the world of physical embodiment of products. This includes materials and design, manufacturing techniques, functional analysis, product architecture and mechanics modelling. In the past years we used a classical approach in teaching mechanics of materials using direct instructions and problem-based learning as the learning approach. Unfortunately, many design coaches observed that the acquired engineering knowledge was applied superficially or even left out of scope in students' design projects.
The complete overhaul of the bachelor and the seemingly short retention of topics related to product engineering, made us change our learning approach from Direct Instruction to Productive Failure (PF). Making mistakes is an important condition for learning, and Productive Failure incorporates this while promoting autonomous learning. In essence, Productive Failure is a method that fosters effective learning and fits very well with a general design approach of iterative and explorative learning.
During the development of UPE, we designed several workshops in a PF kind of fashion and applied it in the 2021 course. During the run we came across several hurdles in teaching, related to workshop design, and the impact of changing learning culture, and the teachers' role. This paper will discuss our findings when applying Productive Failure in our own class which is used to improve the course and line up the educational team in becoming productive-failure teachers.

Keywords: Product engineering, autonomous learning, productive failure, direct instruction

1 INTRODUCTION
In September 2021 the new bachelor revision is implemented at the faculty of Industrial Design Engineering. In this new bachelor's programme, more than 335 first-year students start their journey of becoming a professional designer. Based on the changes in the industrial design profession the curriculum has changed, and currently consists of courses in the field of technology, organizations and people, and is extended with new courses in the field of data, digital interfaces, and understanding values [1]. The approach within the new bachelor also shifted, and students are now always designing in semester-long design courses, and apply theory and skills educated in parallel theoretical courses. We also promote an inquisitive and eager learning attitude, where students learn more autonomously, where students are encouraged to take responsibility for their own learning and development. The autonomous learning approach does not only involve students to change their way of learning, but also demands a different teaching approach for all staff members involved. Teachers must make the transfer from being an instructor towards a facilitator, coaching students in their learning process.
For decades, the Faculty of Industrial Design Engineering (IDE) has taught mechanics in classical ways. Students are introduced to different topics on a weekly basis and practice the taught theory at home with book exercises and during workshops with guided direct instructions [2]. This is often intensive, as it is not only about knowledge transfer but more about understanding, the penny must drop. Over the years we observed that students apply their engineering knowledge superficially in design projects, or even leave them out of scope completely. Either the students forget about the knowledge taught, or they are not confident to apply it successfully, scared to make mistakes and therefore hesitant to apply engineering in their projects. Students experience technology as difficult, which means that some students drop out quickly. We see that Direct Instruction does not lead to self-study, except when the exam deadline is approaching. Unfortunately, it also appears that the knowledge does not retain, because

the practical application of the theory can be found sporadically in many following-up design projects, such as the bachelor's capstone project. Little is substantiated with mathematics, force calculations, materials science, and the use of engineering software. Our experience is that with this way of learning the material does not stick and that in many cases it does not become a sustainable part of the set of competences.

After finishing secondary school, Understanding Product Engineering (UPE) is one of the first courses where students are confronted with autonomous learning. While developing UPE, we investigated multiple teaching approaches which could spark an inquisitive learning attitude, make knowledge stick longer, and which fits with a designerly-way of learning as described in the Kolb experiential learning cycle [3]. Academic designers have in general a trial-and-error approach, where the Kolb cycle is commonly used to experience, fail, reflect, learn, and improve. The goal is to motivate students in exploring the physical embodiment design-space and preparing them for a curious life-long learning. Productive Failure (PF) came across as a theory that incorporates experiential learning, where learning from mistakes promotes autonomous learning. In essence, Productive Failure is a method that fosters effective learning and fits very well with a general design approach of iterative and explorative learning [4].

The productive failure theory and method is new and unknown to both our students and our teaching team. Within this paper we want to investigate how we can effectively apply PF in UPE, which techniques work, and how we can train and help our team of teachers to change their ingrained ways of lecturing. Based on existing literature PF works well with small number of students, but when applied to a larger number of students with a larger team of educators, seams not been investigated. This paper will discuss our first experiences when applying Productive Failure in a larger design course where the complete teaching staff has to make the transfer from Direct Instructions and Problem Based Learning to Productive Failure. First, we will discuss the productive failure approach which is used as a basis for autonomous and life-long learning, followed by a description of the developed course, Understanding Product Engineering. We will discuss the weekly designed activities and the hurdles we came across when applying PF in the course, both from a student's perspective and that of the teaching staff. We will finalize the paper with a reflection on our learnings and concluding remarks [4].

2 PRODUCTIVE FAILURES

In the coming years we want to work less with Direct Instruction (DI) in our pedagogical approach and make more use of the Productive Failure (PF) approach [5]. Productive Failure is a teaching method where designed guidance in the initial learning is proven to be more effective than guided direct instructions and problem solving, which is less intensive than Problem Based Learning. The method has proven that students who engage in problem solving prior to instruction, demonstrate better performance on conceptual understanding than those who engage in problem solving after instruction [6]. It is also found to be less efficient, but on the longer term it sticks better and appears to be more effective. In essence, the student experiences a certain situation, reflects on his actions, searches for the theory and applies it within the context.

The method consists of two phases: (i) generation and exploration and (ii) consolidation. In the first phase, students solve an unguided problem and engage in a targeted concept, using prior knowledge to generate or discover suboptimal or incorrect solutions (the failures). The nature of these solutions provides teachers and students valuable insights into the types of knowledge that was activated and how this knowledge is relevant in relation to the targeted concept. In the consolidation phase students use relevant solutions to turn them into ‘canonical solutions’ [7] like stepwise approaches solving mechanics problems. This provides opportunities for students to notice the inconsistencies in their prior knowledge and realize their current limits. It supports students to attend to and better encode critical features of the new concept while comparing the student-generated solutions with the correct (instructed) solutions. So, it provides opportunities for teachers to formatively assess the progress of the students by having a dialogue with the students on the right and wrong approaches of problem solving. An important affective benefit of this approach is greater engagement and motivation to learn the targeted concept [7]. To design a course using PF several guiding rules are to be followed [8], for both the Generation and Exploration phase, and the Consolidation phase.

3 UNDERSTANDING PRODUCT ENGINEERING

In 2018 our course-development team has been commissioned to develop a course which merges knowledge from multiple courses in the previous curriculum - Statics (7.5EC), Engineering for Design (7.5EC), and Manufacturing & Design (7.5EC) - to one introductory course of 5EC. This demands a complete overhaul of teaching engineering design where the basic knowledge of mechanics, materials and manufacturing must be taught in a very short period and with fewer contact hours, demanding more self-study, a higher intrinsic motivation and student's autonomy. Within the developed course of Understanding Product Engineering (UPE) we introduce our students to the world of physical embodiment of products where we use the engineering wheel as a metaphor for product engineering design (Figure 1). In the course five major aspects of embodiment design are considered: modelling of mechanics (loads and statics, "Belasting"), product and part functionality ("Functie"), materials and their performance ("Materialen"), manufacturing and assembly ("Productie"), and product architecture ("Opbouw").

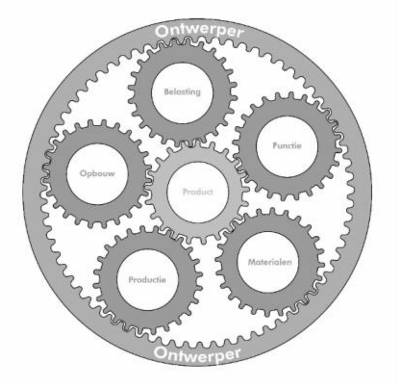


Figure 1. The five aspects (loads, function, materials, manufacturing, and product architecture) of Product Engineering as taught in UPE

During the development of UPE, we designed several workshops following the PF design rules as stated before [8] and applied them in the 2021-2022 course. The year started out with 335 first-year students. Within the course we use a weekly rhythm of online Monday-morning lectures, and on-campus Wednesday-afternoon workshops, where the lecture consists of three parts:

1. A reflection on last-week's learnings and clarifications of unclear topics.
2. Introduction to the topic-of-the-week, the needed content and where to find it.
3. An outlook on the upcoming Wednesday workshop and the student' preparations every student should carry out.

Figure 2. Left, collaborative learning solving engineering problems using the whiteboard; Right, experiencing mechanics using a hammock construction

The workshops are in a studio setting with a maximum of 30 students per classroom, where students collaborate in groups of 5 to 6 students working on the topic-of-the-week, solving engineering problems together and experiencing mechanics (Figure 2), and experimenting with real-live test-setups and product autopsies (Figure 3).

The course consists of 8 weeks of knowledge acquisition, one week of exam preparation and the final paper exam. The course's development team consisted of three experienced lecturers in the field of product architecture, materials and manufacturing, and mechanics, assisted by two teaching assistants. The team prepared the content using constructive alignment, where learning objectives, feedback and assessment, and the learning activities are aligned [9]. The team developed a general approach consisting of weekly learning objectives, and learning activities, using relevant literature bundled in a reader [10] and two books [11,12]. The course was designed in such a way that both the bachelor revision requirements (autonomous learning, formative assessment and teacher as a coach) and the guiding rules for applying PF were satisfied.
In preparation for the course, the teacher needs to get acquainted with the new bachelor vision, UPE and PF. For this we organized a session where the course design team presented the integration of these three elements prior to the start of the course. In this lecture-session, the teaching staff discussed the content of the course, the workshop setup and elements of PF. Teachers shared their previous experiences of other courses and it served as a social bonding moment.

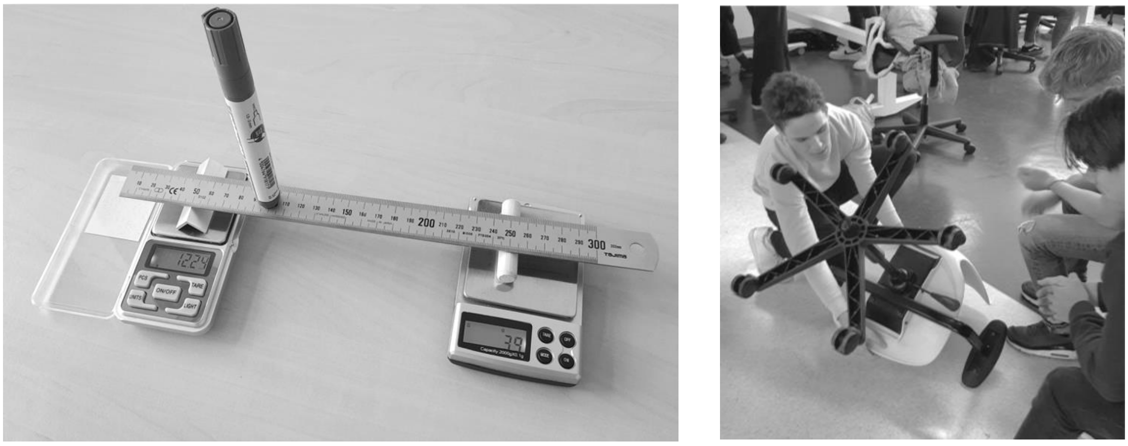


Figure 3. Left, experiential learning by measuring the reaction forces and comparing them with the calculated outcome; Right, product autopsy, analysing an office chair on materials and manufacturing

4 RESULTS WHEN RUNNING THE COURSE

During the implementation of PF in our new course we stumbled upon several hurdles. We experienced three phases in applying PF: (i) week 1 to 3, where we made our *first steps* in PF applied in the course; (ii) week 4 to 6, where we learned how to apply PF in the right manner, *getting it right*; and (iii) week 7 to 9 where the students' urge for direct instruction became stronger than applying PF in the course, the *exam preparations* phase. Underneath these three phases are discussed further and conclusions are drawn.

4.1 First steps

The first three weeks were varying in success. Students were in their first week at university not knowing the culture and whereabouts at the faculty. We observed that most students and teachers struggled with autonomous learning. From secondary school, the most common way of learning had been Direct Instruction. Students did not start working on the workshops, waiting for teachers to instruct step by step what to do. Finding the "sweet spot" did not work well yet. Retrieving their prior knowledge on mathematics and physics turned out to be a struggle, many students could not recall basic calculations and concepts.
Besides struggles in autonomous learning, the formative aspect did not come across. Most students wanted to know if their answers were correct and found it very difficult to explore with minimal guidance. The strong urge to have correct answers and getting the workshop done frustrated both the teachers as the students. These elements combined with not knowing each other very well yet, made it quite difficult for teachers to create a safe space.
Collaborations in smaller studio groups of 5 to 6 students using the whiteboard and sharing the results to other groups via a Miro board went quite well and supported sharing representations and solution methods.

4.2 Getting it right

Each week prior to the workshop, the teachers reflected on the integration of the renewed bachelor requirements, the content of UPE, and the implementation of PF in the course. With guided dialogues, the team of teachers became a safe space for expressing concerns but also ideas on for instance, different coaching techniques, the use of different resources, different levels of understanding, and different levels of engagement. It became clear with doing the first run of the course, the teacher team was also in a "productive failure" development.

In week 3 the workshop was grounded in the Experiential Learning Cycle (ELC) [3]. The teachers were provided with an in-depth lecture of ELC. It provided clarity and guidance for students and teachers. In this week students investigated a hammock (figure 2, right) which engaged students in experiencing forces, and mechanics of materials. Students collaborated in data collection, started retrieving knowledge from the first two weeks and collaborate in whiteboard calculation. This approach should lead to collaborative forming of the canonical concept of tensile forces substantiated with algebraic equations. Unfortunately, figuring out these concepts did not work out due to the limited time available.

The workshop of week 4 can be considered as the first time we found the "sweet spot". The workshop had a clear time frame, where the first hour was spent on a recap of the previous week and an exercise using their previous knowledge on statics. In the first hour students address a bending beam and had a choice in methods to calculate and produce normal, shear, and bending diagrams (e.g., by hand calculations and CAS software, online visual tools like BeamDesign and STRAIN, and physical prototypes using Fisher Technik). The teacher walked around the classroom, not providing answers, only asking questions to promote solution finding. During the second hour students had to apply their learnings to a real product they brought from home. Solutions were shared via an online Miro-board and both the groups and teacher reflected on the result within the studio during the third hour of the workshop. The remainder of the workshop, students were provided with the step-by-step method, guided by the teacher who attended each student group individually.

At the beginning of week 5, some teachers still found it difficult to make their classroom a safe enough space. To address this need, we organized a lecture about how to create safe classrooms to support the first stage of PF. While executing the tips, teachers visited each other's classrooms to provide valuable feedback for improvement if needed and discussed their coaching during the coffee breaks. The "sweet spot" of the workshop set up could be continued from week 4 to week 6. Only the topic changed but the workshop setup remained the same and was successful.

4.3 Exam preparations

During week 7 our students noticed the final exam getting closer. Their focus shifted from needing to know new concepts to being able to pass the exam. The need to have exam training and correct answers promoted higher stress for our students. This state of being made it impossible to work in an unguided explorative manner as defined in the first phase of PF. To support the wellbeing of our students, we decided to transform the workshops into instruction-based exam preparation. We additionally organized Q&A sessions, to comfort and increase the confidence of our students on their abilities.

5 DISCUSSION AND CONCLUSIONS

We have developed a new course using PF as an approach to promote inquisitive, autonomous and life-long learning. This is done by designing activities in such a way that students solve an unguided problem and engage in a targeted concept, using only prior knowledge, generating suboptimal or incorrect solutions. In collaboration with the coaches these "failures" are used to provide insights into the current student's lack of knowledge (need to know) and guide them using the relevant solutions as instructed by the teachers. With this approach, we expected more motivated students and teachers who enjoy practicing technology, with more courage to make mistakes and thus continue life-long learning.

The course development team applied PF design rules in producing the relevant workshop activities, but both the students and the teaching staff came across several issues during execution. The teaching staff and the students had to unlearn old, and often ingrained habits and become accustomed to the new learning culture. Generally, our student and teacher population are used to instructed teaching, and during the first three weeks both found it difficult to transfer from the ingrained instruction-based learning to a more autonomous learning. The first phase of PF prescribes the student's need to "generate and explore multiple representations and solution methods" of the theory. The workshops were set up freely and too general, and students took too much time to go through the exercises. Students kept on requesting instructions and solutions to the presented problems, and the teaching staff did not know how to deal with these requests conflicted with the promoted autonomous learning. Clearly students find it hard to take autonomy, but also teachers find it hard to give. Within the first three workshops we never achieved phase two of PF where the "discoveries are linked to the theory".

In our own "failing" of transitioning to phase two of PF we changed the setup stimulating collaboration between students (e.g., by using the whiteboard to solve problems) and set a clear timeframe consisting of an exploration and consolidation phase (phase 1 and 2 of PF). This renewed structure kept students away from struggling through, getting frustrated, and running out of time. In week 4 we first found the "sweet spot". We learned that the educational team needs to switch roles during the workshop from facilitator in during the exploration phase of the workshop to an instructor in consolidation phase. The timeframe helped the teaching staff knowing when to switch roles. .

To facilitate collaboration and create a safe space for the teaching staff we collaborated with all members of the educational team and (re)designing the workshop structure and activities together. During weekly staff meetings we elaborated on the content and the workshop structure. Creating a safe space in the studio environment was found to be very important to connect with the students and work in the same playing field. We therefore discussed creating a safe space by increasing mutual student-teacher respect and trust by dialogue and positive coaching techniques. We organised a lecture on creating safe classrooms and coaches visited each other's classrooms to provide valuable peer feedback during regular coffee breaks.

In hindsight, we had prepared the workshops in a PF-kind of fashion and learned to do it better during the run of the course. In essence we also went through the process of productive failure. For the next run of the course, we propose the following approach to design a workshop. First, the course learning objectives must be dissected into related *concepts* students need the learn. Second, these concepts need to be related to the student's prior knowledge, and the *blind spot* (knowledge gap or misconception) must be defined. The exercise for the week's workshop should be designed around this blind spot. Students will work on the exercise and fail, after which they are introduced to their misconceptions and learn the new concept. A safe space to experiment and make mistakes, together with a clear timeframe are key to successful learning.

Transforming from an instructive teaching culture to a more autonomous learning environment demands some changes in the teaching and learning culture. During the development and running of UPE we experienced that taking along the complete teaching staff in these changes is key. It is impossible to make this culture shift in one go, and therefore we also must fail productively.

REFERENCES

[1] IDE (2022). Discover the IDE Bachelor. Website visited March 1, 2022: https://www.tudelft.nl/en/ide/education/bsc-industrial-design-engineering/programme

[2] Kirschner P. A., Sweller J. and Clark R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, 41:2, 75–86.

[3] Kolb D. and Kolb A. (2017). The Experiential Educator: Principles and Practices of Experiential Learning, Experienced Based Learning Systems, Kaunakakai, HAWAII.

[4] Schön D. A. (1983). The reflective practitioner. How professionals think in action. Basic Books, Inc.

[5] Kapur M. (2008). Productive failure. *Cognition and Instruction, 26*, 379–424.

[6] Sinha T. and Kapur M. (2021). When Problem-Solving Followed by Instruction Works: Evidence for Productive Failure. *Review of Educational Research,* October 2021, Vol. 91, No. 5, pp. 761–798.

[7] Kapur M. (2014). Productive failure in learning math. *Cognitive Science*, 38(5), 1008–1022.

[8] Kapur M. and Bielaczyc K. (2012). Designing for Productive Failure. *Journal of the Learning Sciences*, 21:1, 45–83.

[9] Biggs J. (2003). Aligning Teaching for Constructing Learning.

[10] Flipsen S. F. J. and Spek D. (2021). Understanding Product Engineering, Syllabus IOB1-2.

[11] Ashby M. and Johnson K. (2014). Materials and Design, the art of science and material selection in product design. Third ed. Elsevier.

[12] Craats J. van de and Bosch R. (2009). Basisboek Wiskunde, 2nd ed. Pearson.

DOES ONLINE DIDACTICS AFFECT THE PERCEIVED QUALITY OF MACHINE DRAWING COURSES?

Sergio RIZZUTI and Luigi DE NAPOLI
University of Calabria, Italy

ABSTRACT
Considering reviewers' opinions on the paper, presented at EPDE2021, in which the data were not sufficient to compare different cohorts, now we are able to answer if there have been differences in students' assessments, based on some questions of the academic survey on didactics, comparing answers for courses held pre-and-during Covid19 pandemic.
In 2020 every educational institution moved their didactics toward an online platform.
Every course had to introduce and experiment with new forms of didactics that prevent in-person events, either in lectures or laboratory.
Courses of design traditionally require a strict relation between student-instructor and student-student.
The need to operate by moving the contact to an online connection creates, at the beginning of the period, a lot of distrust among teachers of such courses. The “Machine Drawing” course is one of these.
Briefly recalling how the courses have been revised, with the employment of a communication platform like Teams®, the answers, given by students, are collected and the differences along the time are highlighted. Three academic years have been considered: 2017-2018, 2019-2020, and 2020-2021.
A further correlation has been made considering different didactics and the global efficiency of the course in terms of abandonment, number of successes (number of people that pass the exam), and the effects on the grades (marks) obtained.
Reflecting on such data, a new consideration has been done on the methodologies that can still continue to be used in the future when the explicit problem of pandemic emergency does will not influence anymore the traditional way of teaching.

Keywords: Online didactics, students’ assessments, teaching quality improvement

1 INTRODUCTION
Covid-19 pandemic during the years 2020 and 2021 pushed educational institutions to move several activities performed in-person, as traditionally have been done and will continue to be done in the future, towards the systematic employment of online supports [1], [2]. During this time, which involved in Italy three semesters, from March 2020 till June 2021, new experimentations have been proved in all kinds of subjects.
Really since 2000 many experiments have been proposed for teaching supported by LMS (Learning Management Systems) for Online Distance Learning (ODL). These kinds of tools require a lot of time for their design and implementation and teachers should be skilled in their usage. Only those Institutions that invested in these tools were able to migrate all their teaching towards online with few tuning [3].
More generally, technology-enhanced learning and teaching have been explored in some detail, to identify which specific aspects have been or can be enhanced in higher education by not traditional means. [4]
Starting quarantine orders, all the other teachers worldwide in a lapse of a few weeks organized their teaching by means of video-conferencing/meeting software, such as Teams®, made available to all attendees.
All teachers had to face their ability to teach in-person in the employment of such new methodologies, even though it must be considered that not all subjects can be validly supported by them. And not all teachers dealt with the emergency effectively [5].
At the same time, some studies were undertaken to analyse how much the quality of online education, in its various forms (hybrid, blended, etc.) is perceived by students, both in terms of content and the role of teachers [6].

In any case, designing online courses is not a trivial activity [7], and can lead to success in an increasingly global and distributed education market [8].
Machine Drawing is a topic quite complex because interests a lot of competencies and skilfulness, cognitive attitudes, and ability of synthesis necessary for students for using the language of drawing to communicate design intent to all stakeholders of the design process [9].
The laboratory is an activity of basic importance in such kind of course because the topics heard in the lesson must be put into action in drawings that depict in the right way the geometry and the form of a 3D part or assembly and that integrate all the symbols introduced by rules and standards to clarify many other elements, such as manufacturability, measurements, tolerances, necessary to guarantee that what has been drawn can be produced.
The history of the evolution that this course underwent during the pandemic emergency highlighted how, despite an initial phase of scepticism, new opportunities have emerged for the aspects of coaching, mentoring, and tutoring, in order to create the conditions for students' mechanical engineering skills to emerge and begin to form.
The paper is focused on analysing three academic years in which the course of Machine Drawings for Mechanical Engineering degree was delivered in different ways, comparing the answers that students gave to the surveys for didactic assessments and some of their performances in examinations.

2 COMPARISONS BETWEEN THE METHODS OF DELIVERING THE COURSE

The three academic years examined have been 2017/18, 2019/20, and 2020/21. The first one 2017/18 was carried out in-person; in the year 2019/20 the first semester was in-person and the second online; the year 2020/21 was carried out completely online.
Till the first semester of 2019/20, the didactic in-person was followed by the same scheme: the laboratory was supported by professionals and/or junior lecturers that aided students in the development of drawings and projects with increasing difficulty, interacting with them during the time weekly scheduled for this.
Every year a set of homework is assigned to students, that must be completed validly in order to have access to the exam. Weekly in the timetable, two hours are assigned to laboratory in which all the questions related to the homework are discussed. During the in-person modality, students arrived in the classroom with the materials on which they were working and discuss with instructors the difficulties encountered, then they gained the OK about the correctness of graphical representations.
The second semester of 2019/20 was really stressful and tiring for all, students and teachers. During the course, and the laboratory overall, a lot of time was spent supporting students individually or in groups to discuss and correct all kinds of mistakes done in the drawings. This introduced the question to share the homework online. Drawings in fact were exchanged by Teams or email as jpeg images or pdf files. Interesting was the first usage of online tutoring with video conferencing and live corrections on drawings by means of a pen tablet and graphic tools such as SketchBook®. Also, during this semester, laboratory was supported by professionals and junior lecturers.
During 2020/21 the course was completely delivered online. A second event was the difficulty in recruiting professionals for laboratory activities. This pushed the teacher to give all activities of the course (lectures, laboratory) alone. This was not heavy or boring as much as the in-person interactions with students, because the online connection gave the opportunity to discuss one-to-many all common issues or mistakes in drawings. This simplified a lot of the ineffective repetitions. The experience did in the previous semesters aided a lot with such kinds of didactics. All sets of exercises were managed by means of "Activity" proposed in Teams, defining the timing of each work and collecting all materials directly in folders and squeezing to gain files dimensions. It was easy to have a strict check on the materials delivered and the students that were attending the course. Each graphical representation was examined and a report for each activity was sent to the classroom. Further group or individual meetings were organized to explain where mistakes were done.
In the examination, because was the first time that a digital platform was employed, special stress occurred trying to avoid cheating.

3 DIFFERENCES IN PERCEIVED QUALITY STUDENTS' ASSESSMENT

Every year the University of Calabria organizes a survey on all courses taught in all Degrees. All students attending the courses are invited to fill out a questionnaire, anonymously, in order to have a clear map of points of weakness or strength in all areas of teaching.

The survey is proposed when about 2/3 of the course has been taught and students can express their assessment with sufficient consciousness. The survey is interested not only in teacher assessment, but organization and scheduling, general satisfaction, and if the tasks are reached. Table 1 contains the percentages of positive answers to selected queries, those more significant for the paper. Each query admits 4 levels of assessments on a 4-point Likert scale, from strong negative to strong positive with two intermediate levels. Each percentage represents the ratio between the numbers of positive answers (strong and mild) with respect to the total number of answers for each query.

Table 1. Percentage of positive answers

Query	2017/2018	2019/2020	2020/2021
Q1: Is the teaching load proportionate to the credits assigned?	84.7	86.1	84.35
Q2: Does the teacher explain the arguments clearly?	71.0	71.45	70.65
Q3: Is the teacher available for clarifications and explanations?	93.5	92.5	98.4
Q4: Are the exercises useful for learning the subject?	76.4	88.1	90.6
Q5: Do the exercises have an appropriate level of difficulty (neither too low nor too high)?	79.2	80.85	90.6
Q6: Are you overall satisfied with how the exercises were carried out in laboratory?	65.3	77.3	82.45
Q7: Are you interested in the topics covered in the teaching?	91.6	94.0	92.6
Q8: Are you overall satisfied with this teaching?	75.0	75.4	84.05

Which differences occurred over the years? The figures depict an evolving dynamic that must be examined carefully.

There are answers that remain almost steady in time. These are Q1, Q2, and Q7. Students are interested in the topics covered by the course (Q7 = 92.7 ± 1.2) and that the workload is commensurate to the number of 12 ETCS established (Q1 = 85.5 ± 1). Also, the assessment of the teacher's didactic ability remains steady (Q2 = 71.0 ± 0.5) among the three different groups of students. These three answers give a sort of continuity along the time, that can aid to reflect on the other questions.

Queries Q4, Q5, and Q6 have a growing trend. Q4 and Q6 interest the satisfaction and the usefulness of laboratory. From the 2017/18 academic year to 2019/20, there is a high jump of about 12% that can be associated with a double phenomenon: the change of didactic approach from in-person to online; the change of instructors in the laboratory. In any case, there has been a further increase of 2.5% (Q4) and 5% (Q6) from 2019/20 to 2020/21, in consideration that instead of several instructors there has been only the teacher to support students by means of video conferences managed by Teams.

Query Q5 interests the level of difficulty of the exercises proposed in laboratory. This reached in both initial academic years taken into consideration (2017/18 and 2019/20) a similar value of 80 ± 0.8. The answer to this query jumped to 90.6 with an increase of +10% with the passage to full online didactics. In this context, the systematic employment of video recording of lectures and laboratory gave the opportunity to reply several times all the steps not well understood, without spending a lot of time waiting for asking teacher/instructors to clarify concepts or passages.

Query 3 follows the same trend of Q5 with a steady value of 93 ± 0.5 in the first years and a jump of +5% in the academic year 2020/21, reaching the highest value of 98.4. This is absolutely associated with the perceived level of the nearness of the teacher guaranteed by chat-call-video and online discussions in which drawings are shared and mistakes are corrected by pen tablet and SketchBook®, in session one-to-one or one-to-many sessions, as described by authors in [10].

Also, the general level of satisfaction, relieved by Query 8, had a jump of about 9% from the first years (75%) and the last one (84%).

4 DIFFERENCES IN MARKS OBTAINED BY STUDENTS

The second point of view is the analysis of the marks obtained by students at examinations. For the degree in Mechanical Engineering at Unical (University of Calabria), 5 calls are provided to students throughout the academic year to attend the examination of every course. Considering that the course of Machine Drawings ends in the second semester, the schedule of the calls is so planned: two in the period June-July; one in September; two in the following January-February.

Table 2 collects data from all calls in each academic year. Each column represents a call and the figures along with each row are associated with the number of people that turned in the assignment, those who failed it, and who passed the exam, then the average mark obtained and the standard deviation.

The first three calls, after the completion of the course, are more crowded. The last two can be considered supplementary and they are attended by a few students.

Table 2. Percentage of positive answers

A.Y. 2017/2018

Calls	June 2018	July 2018	Sept 2018	Jan 2019	Feb 2019	Total	%
Participants	16	25	25	10	7	83	
Not sufficient	4	10	15	3	7	39	47
Passed	12	15	10	7	0	44	53
Average Mark	25.33	25.60	25.60	23.57	0	25.20	
St. dev.	3.20	2.59	2.27	3.91	0	2.92	

A.Y. 2019/2020

Calls	June 2020	July 2020	Sept 2020	Jan 2021	Feb 2021	Total	%
Participants	33	22	20	7	7	89	
Not sufficient	15	14	12	3	3	47	53
Passed	18	8	8	4	4	42	47
Average Mark	26.44	23.63	23.50	21.50	21.75	24.30	
St. dev.	2.28	2.26	1.14	3.32	2.87	2.90	

A.Y. 2020/2021

Calls	June 2021	July 2021	Sept 2021	Jan 2022	Feb 2022	Total	%
Participants	33	41	42	4	8	128	
Not sufficient	21	21	22	4	6	74	58
Passed	12	20	20	0	2	54	42
Average Mark	27.33	25.79	24.20	0	24.5	25.44	
St. dev.	3.42	2.62	2.44	0	1.5	2.92	

Two are the elements that appear comparing the sub-tables. In the a.y. 2020/2021 there was a great number of students that attended the exam and turned in the assignments; 128 with respect to 85 (average value of both previous academic years). In the first call after the completion of the course, the average mark obtained in 2020/2021 was the highest with respect to all other calls.

A further investigation concerns the number of students that participate at least in one of the calls of the year. It should be taken into account that in Italy there is the possibility to attend to all the calls scheduled before passing the exam. This creates a really different dynamic to the fruitful pedagogical procedure and a frequent overlapping (or so close) of calls among different courses. As a matter of fact, the total number of participants to all year's calls, reported in Table 2 represents the summation of all the attendees to all calls, and some students can have been present in several calls, due to having failed in some of them. They do not pass the exam, probably, because they require additional time to produce sufficient content. Just to recall from the previous work presented at EPDE 2021 [10] the exam consists of the production of a certain number of parts/components extracted from an assembly complete with dimensions and tolerances (dimensional and geometrical), and the solution of a stack-up of one-dimensional tolerances.

Table 3 have been counted only the people that were present at least one time to the calls, without considering repetition. They can have passed or not the exam in the period taken into consideration. In any case, they are people that have completed all the preparatory work developed throughout the year in the laboratory. This number is significant to assess the level of abandonment of this course, evaluated as complementary to the number of people attending the calls and compared to all people enrolled each year.

Table 3. Percentage of students that attended at least 1 call.

Academic Year	Students attending at least to 1 call	Students that compose the class	Participation to exam (%)	Abandonment (%)
2017/2018	56	132	42.42	57.58
2019/2020	57	135	42.22	57.78
2020/2021	81	143	56.64	43.36

The level of participation of students during 2020/2021 has been extraordinary. The level of abandonment reduced by more than 14 points, and relative to the initial years (almost at the same level) by about 25%.

Combining data from Table 2 and Table 3 the number of students that passed the exam can be compared among the different academic years. In 2017/2018 there was 44/132=33.33%; in 2019/2020 there was 42/135= 31.11%; in 20201/2021 there was 54/143= 37.76%. So, in this comparison, there has been an increase of +5.5% in passing the exam from the online edition with respect to the previous ones, characterized by an average value of 32.22%.

5 CONCLUSIONS

The employment of online didactics during the Covid19 pandemic has greatly changed the way in which the teacher/student relationship has been traditionally pursued [11]. Some results from data comparison among the academic years taken into account in the paper reveal that essentially the great advantages of online didactics have been:

- the nearness between teachers and students that allowed them to “give prompt feedback” to all kinds of questions asked by students, as documented by the value of 98.4% to the query Q3 in Table1.
- a finer check of the assignments and the completion of the homework managed by the “activity” organized in Teams, “emphasizing time on task”.

These two points are respectively the fourth and the fifth principle of the report on didactic quality for undergraduate education made in 1987 [12] in the USA. Now, these suggestions have been naturally performed by the online connection and the employment of the meeting software.

Even if in the current year didactics returned in-person, online methodic, tested during pandemic years, continues to be used especially for the management of homework and the connection with students for discussing the mistakes done on drawings.

Lectures are given in the classroom and conjointly online for supporting those students that are not able to attend them, because of a disease. At the same time, video recording is made for all lectures that can be consulted in an asynchronous way. Also, this year can be considered further experimentation, but with the consciousness to employ technologies that have become really friendly and fruitful.

REFERENCES

[1] Dhawan S. Online Learning: A Panacea in the Time of COVID-19 Crisis. *Journal of Educational Technology Systems*, 2020, 49(1), 5-22.

[2] Mishra L., Gupta T. and Shree A. Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *International Journal of Educational Research Open*, 2020, vol. 1, p. 100012.

[3] Sun A. and Chen X. Online education and its effective practice: A research review. *Journal of Information Technology Education: Research*, 2016, 15, 157-190.

[4] Kirkwood A. and Price L. Technology-enhanced learning and teaching in higher education: what is ‘enhanced’ and how do we know? A critical literature review. *Learning, Media and Technology*, 2014, 201439(1) pp. 6-36.

[5] Marek M. W., Chew C. S. and Wu W. V. Teacher experiences in converting classes to distance learning in the COVID-19 pandemic. *International Journal of Distance Education Technologies*, 2021, 19, 89-109.

[6] Hung M. L. and Chou C. Students’ perceptions of instructors’ roles in blended and online learning

environments: A comparative study. *Computers & Education*, 2015, vol. 81, pp. 315-325.

[7] Annamalai N., Ramayah T., Kumar J. A. and Osman S. Investigating the Use of Learning Management System (LMS) for Distance Education in Malaysia: A Mixed-Method Approach. 2021, *Contemporary Educational Technology, 13*(3), ep313.

[8] Martin F., Ritshaupt A., Kumar S. and Budhrani K. Award-winning faculty online practices: Course design, assessment and evaluation, and facilitation. 2019, *Higher Education*, 42, 34-43.

[9] Bernardes M. and Oliveira G. Teaching Practices of Computer-Aided Technical Drawing in the Time of COVID-19. In: *23rd International Conference on Engineering and Product Design Education, E and PDE 2021*, September 2021.

[10] Rizzuti S. and De Napoli L. Machine Drawing: Troubles and Opportunities in Managing Laboratory Activities in an Online Classroom. In: *23rd International Conference on Engineering and Product Design Education, E and PDE 2021*, September 2021.

[11] Svennevig P. R. and Heimdal A. Teaching during a Pandemic. In: *23rd International Conference on Engineering and Product Design Education, E and PDE 2021*, September 2021.

[12] Chickering A. W. and Gamson Z. F. Seven Principles for Good Practice in Undergraduate Education. *AAHE bulletin*, vol. 3, 2-6, 1987.

SUCCESSES & CHALLENGES OF SUPPORTING PRODUCT DESIGN EDUCATION FOR DEAF & HARD OF HEARING LEARNERS DURING A PANDEMIC: A CASE STUDY

Francesco Luke SIENA[1], Samuel RUSSELL[2], Richard MALCOLM[1], Emily Elizabeth BROOK[1], Allan CUTTS[1], Liam MARTIN[1], and Kevin NAIK[1]
[1]Product Design Department, School of Architecture Design & The Built Environment, Nottingham Trent University, United Kingdom
[2]Product Design Student, School of Architecture Design & The Built Environment, Nottingham Trent University, United Kingdom

ABSTRACT
The impact of the COVID-19 pandemic on Higher Education has been considerable, none more so for practical/vocational subjects such as Product Design. However, consider being deaf/hard-of-hearing (D/HOH) whilst being forced to study predominantly online, with reduced practical in-person teaching opportunities, being socially distanced, and having to contend with face coverings limiting your ability to hear and lip read. The everyday challenges for D/HOH students in higher education is constantly demanding, but the global pandemic exacerbated this, presenting significant educational challenges. This paper presents a case study focused on the 2020/21 academic year whereby we examine the challenges and successes of supporting a product design student with Auditory Neuropathy Spectrum Disorder (ANSD) and permanent bilateral severe-profound hearing loss. The scope of this paper presents the learner arrangements for their product design education and highlights methods of managing the blended learning/teaching environment in combination with the use of British Sign Language (BSL) interpreters, electronic/handwritten notetakers and accompanying technologies. Numerous challenges were presented ranging from, managing rapidly developing online learning tools, adapting personal protective equipment to facilitate lip reading, managing multiple recording technologies to facilitate captioning/transcription, amongst others. The perspectives of the learner are presented, with reflections on how different session types, timetabling, delivery methods, etc., affected their day-to-day learning. Recommendations are made for improved collaboration with student support staff (i.e., BSL interpreters and electronic/handwritten note takers) and the need to implement digital technologies to facilitate the optimal blended learning and socially distanced teaching environment.

Keywords: Blended learning, collaborative/cooperative learning, deaf/hard of hearing learners, flexible learning, product design education

1 INTRODUCTION & CONTEXT
2020/21 has been challenging across the higher education sector for students and academics alike. The switch to blended learning has presented a substantial number of challenges requiring delivery methods to be overhauled, especially for product design education, where students expect to learn by doing but instead had to learn in online/remote settings and socially distanced face-to-face (F2F) environments. Due to the evolving nature of the COVID-19 pandemic, teaching and learning arrangements would change regularly [1], requiring constant adjustments to online and F2F teaching settings/requirements. This had a significant impact on the Higher Education (HE) sector globally [2], but none more so than for students with disabilities where numerous challenges were encountered [3]. Critically, online and distance learning has been recognized as a difficult and challenging experience that lacked efficient communication channels for D/HOH students during the COVID-19 pandemic [4].
The National Deaf Children's Society identified that the switch to blended learning for D/HOH learners in higher education has undoubtedly brought about many significant challenges [5]. The challenge has not only been for D/HOH learners managing their own education, but also for academics planning and

delivering education to a student cohort with a variety of accessibility requirements. Furthermore, many students had been out of education for at least 6 months before commencing university studies due to the pandemic, thus the product design knowledge base for the 2020/21 cohort was even more varied, posing greater inclusivity/parity challenges. Switching to a blended learning approach meant academics had to quickly adapt and innovate their delivery methods when providing remote/socially distanced education. Factoring in accessibility/disability considerations that differ between students required significant planning and testing to enable D/HOH learners to gain access to the same level of education, regardless of the setting. This paper presents a case study examining the challenges and successes of supporting a student with significant hearing challenges whilst studying product design during the 2020/21 academic year where numerous national lockdowns/sudden changes to learning arrangements had to be made based on the requirements set out by the Department for Education (DfE) [1].
To enable D/HOH learners to make informed decisions on their education/support needs, the Disability Rights UK: Into HE 2019 report identifies the range of support services/arrangements on offer [6]. Supporting D/HOH learners in any education setting poses many challenges [7], however by implementing a number of critical accessibility strategies, these challenges can be mitigated when delivering synchronous teaching both F2F and online [8]. Furthermore, evidence shows that D/HOH learners benefit in some settings when undertaking blended learning courses [9], as the use of technology can not only overcome a number of communication issues, but it also can provide opportunities for greater personalized interaction with peers and faculty, leading to increased overall satisfaction.

2 LEARNER ARRANGEMENTS

As universities are increasingly aware of the varying needs of students with disabilities, especially audio and visual disabilities, support services are provided to enhance the learning experience. This case study focusses on a student who has Auditory Neuropathy Spectrum Disorder (ANSD) and permanent bilateral severe-profound hearing loss. They joined BSc (Hons) Product Design SW at Nottingham Trent University (NTU) during the height of the COVID-19 pandemic providing details of their disability based on a Disabled Students' Allowance (DSA) assessment in preparation for the commencement of their studies. In addition to acquiring student finance, the DSA service supports/covers study-related costs incurred by any mental health problem, long term illness or disability and is allocated based on the individual's needs [10]. The learner's needs were defined by a statement of access (SOA), this identified that the student wears hearing aids in both ears due to hearing loss (deafness), requires sessions where possible timetabled in rooms with induction loops, and transcripts of all audio visual materials.
Environmental factors also needed considering as the student uses radio aids requiring lecturers to wear a supporting microphone. The student uses British Sign Language (BSL) interpreters therefore requiring lecturers to speak at a reasonable pace to allow for accurate translation. All sessions/meetings with the student required an interpreter present. Interpreters were required for field trips with advance notice required. The student could request copies of lecture notes/reading materials in advance of sessions. Additional information about how to access school-based support was provided. Discussions regarding placements/external trips must take place in advance to ensure access requirements are met. The student is allowed to demonstrate a preference to sitting in a particular location to facilitate lipreading. Lecturers must ensure they face the class when speaking and repeat any questions asked during teaching sessions where the person speaking is not in the student's direct line of sight. To allow comprehension/processing of academic feedback, the student receives specific feedback identifying key areas of improvement and allowed one-to-one inductions for specialist services i.e., libraries, workshops etc. In addition to the SOA, to aid the planning/delivery of sessions the student was provided with an extensive range of specialist one-to-one support including a specialist notetaker for HOH students (448 hrs/yr.), a specialist support professional for HOH students (36 hrs/yr.) and a BSL Interpreter (840hrs/yr.).

3 COURSE OVERVIEW & SESSION ARRANGEMENTS

Over the course of the academic year, 1st year BSc Product Design students undertook three, ten-week, forty credit modules. This followed the structure of two full day online design studio sessions on Mondays and Thursdays, in combination with in-person design sketching and CAD sessions on Tuesdays, online context and materials workshops on Wednesdays and in person electronics and online mechanics sessions on Tuesdays or Fridays. Each session type has its own syllabus/learning outcomes and was suitably adapted to facilitate optimal learning for D/HOH students. Guidance from the National Deaf Children's Society on supporting deaf young people in education informed session design [11].

3.1 Design studio & workshops

Twice weekly online design studio sessions facilitate project/portfolio development work. Students are briefed at the start of the day with the program of activities which often includes an individual/group tutorial, a self-directed study activity and a live studio activity which often incorporated the use of Miro (a visual collaboration platform). Miro was used to facilitate sharing of information for all students, but also allowed the D/HOH student to fully understand the activities to be undertaken through the use of well-planned instructional focused Miro boards (Figure 1). The daily ordering of activities was important in order to facilitate D/HOH student optimal concentration times. Online resources required meticulous planning with all presentations/resources needing to be 100% accessibility compliant with all images requiring ALT text. All pre-recorded self-directed study activities required full captions with supporting worksheets that helped facilitate student comprehension of subject topics, skills, and software literacy. Group work was limited to five people to facilitate optimal learning environments.

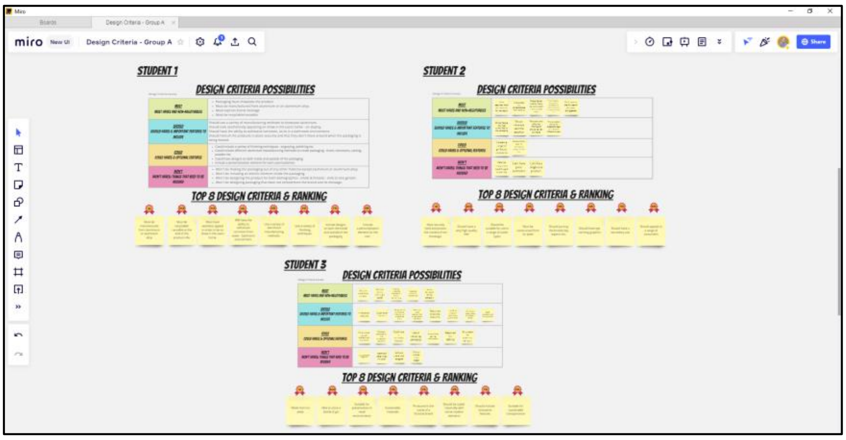


Figure 1. Example of a student collaborative design activity Miro board workspace

3.2 Electronics & mechanics sessions

Six weeks of introductory product design focused in-person electronics and online mechanics sessions were run. A key challenge was to communicate new terminology and the Arduino programming language which added extra complexity for the BSL interpreter. Electronic and mechanics kits were provided to the BSL interpreter/notetaker to provide context, but also to aid communication. One-to-one sessions with the BSL interpreter/notetaker had to be arranged to first ensure their comprehension of the subject was accurate thus to allow for accurate translation. A key challenge during live sessions was maintaining a static position while sharing instructions/demonstrations. Demonstrating circuits under a visualizer was challenging as the student would have to look at multiple sources of information, as the tutor would often have to look down to demonstrate circuits and mechanical movements; a view of the tutor's lips was therefore limited, thus requiring accurate BSL communication. Delivery of session slides required content adjustment to ensure effective visual graphics/ALT text. Extra resources were prepared to support student learning at home, utilizing loan kits. Adjustments for the BSL interpreter was challenging as the interpreter had no BSL signs available for terminology of electronics or Arduino coding. Furthermore, a live glossary needed to be prepared in advance to help student preparation.

3.3 Design sketching & 2D/3D Computer Aided Design sessions

For the twenty-four-week design sketching syllabus and twenty-six-week CAD syllabus over the 2020/21 academic year, sixteen/eighteen weeks were delivered in-person in a socially distanced design studio setting and eight weeks were delivered online due to a UK lockdown. All sessions were also pre-recorded and available with full captions (Figure 2) and located in the VLE learning room to accommodate any absences, COVID-19 self-isolations, or session recaps. A steady pace of narration for demonstrations was provided to encourage supportive learning, with pre-recorded videos providing an independent learning experience; this was the biggest challenge, but this has now benefited our practice for all students. Where possible, the lecturer's face/lips were also shown within the videos to facilitate lip reading. Extra tutorials were also made available when requested. The teaching spaces were set up for both the student's visual access of presentations, but also supported with both a BSL interpreter and notetaker who were strategically located to allow for optimal communication. For computer-based work, dual screen setups were provided to aid more efficient working. Teaching complex computer software can be a challenge, so for live sessions, pace of delivery was slowed down to ensure the BSL is provided with time to communicate effectively. A pre-recorded copy of the session was given to the BSL/notetaker 48 hours in advance therefore, it was important not to go off topic to ensure the BSL was always able to follow along. Copies of any handouts were also made available and were supported by a live document with terminology and definitions to allow for accurate BSL translation. For design sketching, visualizers were linked to large display screens for live demonstrations to be viewed by all. The visualizer quality provides scope for demonstrating clear, detailed drawing and related applications.

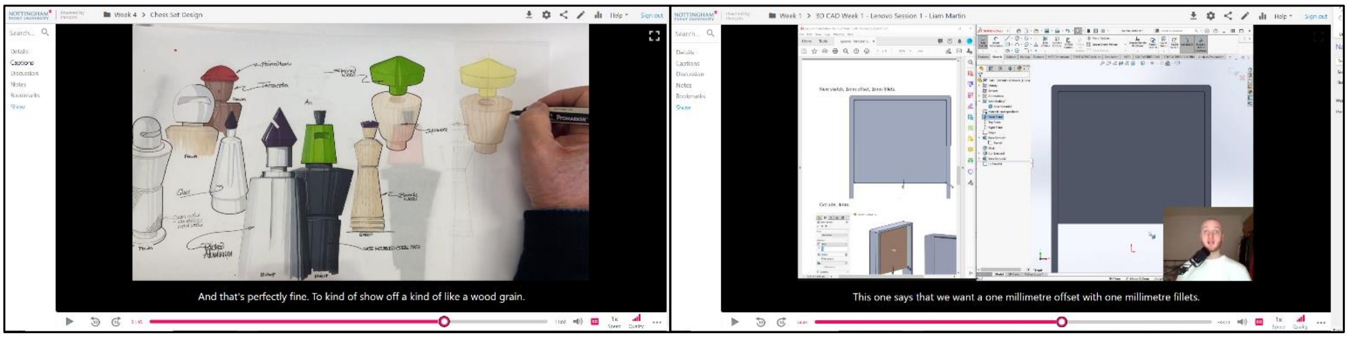


Figure 2. Pre-recorded design sketching & 3D CAD videos with fully embedded captions

4 LEARNER PERSPECTIVES & REFLECTIONS

Before commencing any sessions, the tutor team arranged an online meeting to identify how my needs could be best met. Across all sessions, all of the tutors were provided with a radio aid (Roger Select) and was worn by each speaker and passed between staff. All the lecturers understood that face coverings did not allow for lip reading; clear visors were worn. The year leader ensured all lecturers/guests were made aware of my needs and regularly checked with me to make sure I was on track. All sessions were supported by a pre-recorded video/live recording. A notetaker was present in all the sessions and content was always provided in advance to allow for accurate recording of notes. Across the year I took part in a wide range of different sessions; my reflections on my regular timetabled sessions are below:

4.1 Online design studio & workshops reflection

Design studio sessions ran for the entire year online. With it being a design course, there was a lot of unavoidable group-work. At the start of the year, I met with the year leader to discuss the best learning arrangements. The first issue we identified with online calls was the quality of lipreading and background noise. All sessions were recorded and although live captions were available these were not always correct. I utilized the live captions on MS Teams and used this in conjunction with my notetakers notes for clarification on topics. Pre-recorded sessions/activities were used too and were fully captioned. Where issues occurred with captions from videos, this was reported to the year tutor and resolved quickly. Another issue with online calls and with the quality of lipreading and sound was group sizes. After discussion with the tutor, I was placed in groups no bigger than five people. Where possible, the tutors were careful not to place me in groups with fellow students who had strong accents, which could hinder my understanding, as accents often took a while to get used to.

4.2 Electronics & mechanics reflection

For the electronics sessions, delivery was a short but intense six-week introduction and therefore a fast pace of delivery. A printout of the lesson was provided in advance, to allow me to familiarize myself with all the terms and language to be used. This was also provided to my BSL and notetaker to allow for consistency in the notes provided. The notes also provided a useful backup in case I missed anything during the in-person session. If I was unsure of anything, extra time was made available on a 1-1 basis, to clarify anything that I did not understand. An interpreter was also present in all of these sessions to support my learning. The mechanics sessions took place online, as such a BSL interpreter was not required and live captions on MS Teams could be used; a notetaker was still required. All session content was uploaded to the VLE or sent via email prior to the session to allow me to familiarize myself with all the terms and language to be used. In addition, small electronics and mechanics kits were provided to all the students but also to my notetaker to allow for accurate notetaking and recording.

4.3 Design sketching & 2D/3D Computer Aided Design reflection

Sketching classes were held in a large design studio room, unfortunately with poor acoustics. This was unavoidable due to class size/social distancing. An interpreter was always present at all of the sessions. I always sat at the front of the class, near the lecturer, in range of the radio aid. A general overview of the lesson was always provided, if any further information was needed in the session, the tutor came over to me and provided me with additional demonstrations/guidance. The tutor was always available outside of the sessions for additional one-to-one sessions to be organized. At the start of the year, the CAD tutors arranged a pre-term meeting to organize my needs and communicate how the lessons would be taught. 2D CAD (Adobe Creative Cloud Suite) was mainly delivered by supporting video, whereas 3D CAD (SolidWorks & Keyshot) was conducted via visual demonstration. A problem that came up in tutorials was live demonstrations not always being supported by videos/worksheets. Where students would usually be expected to follow a spoken tutorial/set of instructions demonstrated on the screen, this often-required specific values to be inputted into the CAD programs. As one cannot look at the main screen, work on a computer, as well as look at a BSL interpreter at the same time, this resulted in missed information. The tutor adapted their approach by slowing down, repeating the demonstration or the tutor temporarily pausing to allow the values to be input before moving on. A live vocabulary spreadsheet was produced to support my notes, this was important where terminology and abbreviations were used.

4.4 Course arrangements & reflection

The use of Miro worked much better than expected, providing me a collaborative online working space to interact with my peers. It provided the opportunity to read over any points that I may have missed during group discussions. What didn't work as well as hoped was online group work. Large, randomized groups were used initially meaning when part of larger group activities, I would struggle in the unknown circumstances, with people talking over each-other. With the variety of different accents and limited quality of MS Teams captions, following conversations became close to impossible. After notifying my tutor, we decided that five people in an online environment was the maximum group size I should interact with, this made a huge difference when engaging with activities. In an online environment, the biggest issue that couldn’t be overcome was the ability to lipread consistently. Camera/internet connection quality was a detrimental factor. The return to 100% F2F teaching has now allowed me to fully interact with my peers and reduced my anxiety of missing out on conversations/discussions.

5 CONCLUSIONS & RECOMMENDATIONS

Although as staff we were used to working with support services based on various student learning needs (Dyslexia, ADHD etc.), we found working with the disability team eye opening/inspiring. We strongly recommend embedding a consistent BSL interpreter and notetaker within the academic team for the period of a D/HOH student’s degree. This allows for consistency in student delivery and optimal communication for session planning/delivery. This also normalizes the learning environment and ensures a supportive space for all learners. The support team helped provide an understanding of the many complex learning and educational issues that D/HOH are exposed to, which resonates and connects to all student learners needs. It is essential that careful session planning for a D/HOH students and support staff is imperative. D/HOH students benefit from a regular timetable of sessions earlier in the day with frequent breaks to allow for optimum concentration. Their increased workload due to constantly looking between different resources i.e., lecture slides, screens, support staff, lecturers, captions/transcripts on resources etc., can be very tiresome. BSL interpreters can only sign for a period of 45 minutes before being given a break due to the high intensity of the communication activity.

Working with D/HOH students means sessions needs to be planned well in advance to ensure the delivery of each session is properly resourced and rooms set up appropriately. Content must be produced and uploaded to online VLEs 48 hours prior to the sessions start time; this allows for suitable time for caption correction and adequate time for BSL/notetaking preparation. To facilitate optimal comprehension for the student, creating live documents for glossary of terms/definitions helps with content lost in translation. For specialist subjects BSL interpreters need to create new signs and then communicate these to the student in advance of the sessions, to allow for effective comprehension.

Whilst socially distanced teaching meant that all teaching spaces needed to be carefully designed to provide a suitable environment for all students to be appropriately separated, it was critical to also consider the D/HOH learner requirements. Even though F2F teaching has resumed, groupwork arrangements still need to be setup in a semi-circle configuration to allow for D/HOH learners to be suitably positioned in the room to see their peers, the tutor delivering the content and the students support staff. Each D/HOH learner is unique, however from our experience groupwork needs careful planning and limiting, where possible to five participants. Consideration should also be made regarding the D/HOH learners' comprehension of accents when lip reading. The learning time of accents related to lip patterns must be carefully considered, therefore consistency in group allocation is critical.

A key dimension to the delivery of effective learning for a D/HOH learner is their pastoral support. At NTU first year students receive three personal academic tutorials (PATs) whilst having the opportunity to arrange further PATs as required. During our D/HOH learners first year, PATs were scheduled at the beginning of each new module to identify any possible issues and to confirm support staff arrangements. This was followed up with a meeting at the end of the first week of the module to assess the suitability of arrangements. This was followed up by short PATs (10-15 minutes in length) in weeks 3, 6 and 9 of modules. More regular, shorter PATs meetings scheduled over the academic year (minimum of twelve meetings) ensures the students wellbeing is carefully monitored and learning issues are resolved quickly/effectively, thus reducing the likelihood of other wellbeing issues having an impact.

Effective use of online resources for D/HOH students is imperative. Even though we have now returned to 100% F2F teaching, live/pre-recorded content is still provided for all sessions. This allows accessibility for all students whereby they can re-wind sessions, use closed captions etc., to help them facilitate/appreciate the skills/applications within their studies. Within recordings we strongly encourage the video of the lecturer's face to be embedded into the video to help facilitate lip reading where captions are not 100% accurate (Figure 2). In conclusion, every D/HOH student is unique and will have individual needs/requirements dependent on the severity of their condition. Some staff have been empowered to learn BSL to help with their communication. The recommendations above are now used as best practices within NTU to help facilitate optimal learning/teaching regardless of the setting.

REFERENCES

[1] GOV.UK. Further and higher education and vocational training during coronavirus. Available: *https://www.gov.uk/government/publications/higher-education-reopening-buildings-and-campuses* [Accessed on 2022, 27 February], (2022) 24 February.

[2] Cesco S., Zara V., De Toni A. F., Lugli P., Betta G., Evans A. C. and Orzes G. Higher Education in the First Year of COVID-19: Thoughts and Perspectives for the Future. *International Journal of Higher Education*. 2021, 10(3), 285-94.

[3] Smith C. Challenges and opportunities for teaching students with disabilities during the COVID-19 pandemic. *International Journal of Multidisciplinary Perspectives in Higher Education*. 2020, 5(1), 167-73.

[4] Alshawabkeh A. A, Woolsey M. L. and Kharbat F. F. Using online information technology for deaf students during COVID-19: A closer look from experience. Heliyon. 2021, 7(5), e06915.

[5] National Deaf Children's Society. Staying Connected: Impact Report 2020/2021. Available: *https://www.ndcs.org.uk/media/7420/staying-connected_national-deaf-childrens-society-impact-report_2020-to-2021.pdf* [Accessed on 2022, 27 February].

[6] Disability Rights UK. Into HE 2019; A guide to additional support in higher education. Available: *https://www.disabilityrightsuk.org/sites/default/files/pdf/IntoHE2019.pdf* [Accessed on 2022, 21 May].

[7] Lynn M. A., Templeton D. C., Ross A. D., Gehret A. U., Bida M., Sanger T. J. and Pagano T. 2020. Successes and challenges in teaching chemistry to deaf and hard-of-hearing students in the time of COVID-19. *Journal of Chemical education*, 97(9), 3322-3326.

[8] Sutton H. 2020. Guide offers best practices for meeting the needs of deaf students during COVID-19 pandemic. *Disability Compliance for Higher Education*, 26(4), 9-9.

[9] Long G. L., Vignare K. and Rappold R. P. Mallory J, 2007. Access to communication for deaf, hard-of-hearing and ESL students in blended learning courses. *International Review of Research in Open and Distributed Learning*, 8(3), 1-13.

[10] GOV.UK. Benefits and financial support if you're disabled or have a health condition. Available: *https://www.gov.uk/disabled-students-allowance-dsa* [Accessed on 2022, 27 February].

[11] National Deaf Children's Society. Supporting the achievement of deaf young people in higher education: For higher education staff. Available: *https://www.ndcs.org.uk/documents-and-resources/supporting-the-achievement-of-deaf-young-people-in-higher-education-for-higher-education-staff/* [Accessed on 2022, 21 May], (2017) 2 June.

FRAMEWORK FOR CRISIS-RESISTANT ENGINEERING PRODUCT DEVELOPMENT COURSES

Maximilian SCHRAMEK[1], Niccolò BECATTINI[2], Stanko ŠKEC[3], Nikola VUKAŠINOVIĆ[4], Manfred GRAFINGER[1] and Patrick ROSENBERGER[1]
[1]Technische Universität Wien, Austria
[2]Politecnico di Milano, Italy
[3]University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia
[4]University of Ljubljana, Faculty of Mechanical Engineering, Slovenia

ABSTRACT
This paper proposes a framework for the systematic adaptation and digitalisation of engineering product development courses in the event of a crisis. Applicants can use resources of the framework to identify crisis-related boundary conditions that impact the delivery of education and are assisted in determining the necessary level of course digitalisation to respond to the crisis. Furthermore, the framework comprehends a review of modern educational teaching objectives, as well as a table containing tools and methodologies linked to educational targets. These can be used to enhance course design to keep students independently of their learning profiles engaged in study activities and to uphold an excellent knowledge acquisition in a volatile environment. An exemplary application of the framework on a CAD course in a higher education context guides the educator through the processes.

Keywords: Engineering education, crisis scenarios, crisis education, digitalisation, post COVID-19 transition

1 INTRODUCTION
The COVID-19 pandemic forces higher education institutions to a radical shift towards digitising teaching activities and materials. Despite the availability of plenty of educational tools and methodologies, the question of how lectures can be composed for virtual teaching while complying with restricting crisis conditions has not been systematically answered so far. Therefore, educators need to rely on their own digital competencies and the institution's resources rather than on scientifically justified and tested approaches. The ongoing crisis demands that courses are taught online in the foreseeable future, and this situation will likely not change even after the end of the crisis. Instead, a continued and even growing demand for digital education and blended learning approaches is expected.
A framework for the systematic adaptation and digitalisation of engineering education courses in the event of a crisis is therefore proposed in this paper. It is designed to help find the most suitable approaches, thereby demanding general validity and broad applicability regardless of the application scenario. The differentiation between diverse crisis events is based on a set of boundary conditions that directly impact the realisable form of education. This prevents the unintentional focus on specific crisis events and ensures that future events can be classified. The framework also differentiates between various lecture types, allowing educators to match the presented approaches with their own courses, select the most suited ones and adapt the courses accordingly. To validate the framework, its usability will be tested as a part of regular product development courses, analysing feedback from educators and students of four European universities during the academic year 2021/22.
The paper presents an exemplary application of the framework on CAD courses, which are often composed of ex-cathedra lectures to impart general concepts of computer-aided design, in conjunction with tutorials to familiarise the student with CAD software. The example will show how the framework suggests educational approaches, methods and tools (educational items) to support each individual lecture type. Its recommended educational items enable a convenient matching with student learning styles, to enable a course design aligned with a modern student-centred learning approach.

2 PROPOSED APPROACHES

Aiming at developing a framework to answer the question of how design education can be adapted and digitalised in the event of a crisis, it is primarily important to understand how to describe crisis events and how to align course design with modern educational objectives (Section 2.1).

To determine a representing set of boundary conditions, which hinder the delivery of education and have general validity regardless of the type of event, an analysis of highly disruptive present and past crisis events has been conducted.

Then, as a starting point for the educational contents of the framework, common lecture and assessment types were defined by reviewing mechanical engineering study curricula in the higher education sector. Differentiating between lecture types allows educators to match the presented approach with their own courses. For the purpose of characterising the layout of a lecture type with respect to the degree of digitalisation, levels of technological support are introduced: from no technology to fully online lectures. This aids the educator to choose the appropriate digital lecture layout for their own course. Online learning is often attributed to a self-learning, text-based and passive environment: it is particularly difficult to provide educational services that facilitate different types of learners. Therefore, applicants of the framework are provided with an overview of modern educational objectives as well as a list of educational tools and methodologies based on "The Complete List of Teaching Methods" [1]. The items on the list have been reviewed with regard to their suitability for engineering education and assessed for their applicability to learning styles, lecture types and their respective levels of digitalisation in a two-step assessment round. In round one of the assessments, the authors of this study independently evaluated each item and proposed new product development specific items. Round two comprised a group discussion evaluating individual judgements, followed up by subsequent consensus-finding discussions (Sect 2.2).

2.1 Characterisation of crisis scenarios

To enable a generic description of disruptive crisis events, a set of characteristic crisis conditions is introduced. Crisis conditions can be grouped as either general, higher-education related or personal. **General crisis conditions** apply to the population within the affected area and are related to restrictions in mobility, the availability of electrical power and connectivity failures such as telephone or internet connections. **Higher-education related conditions** refer to the accessibility of institutional infrastructure, availability and accessibility of learning resources and educational personnel to deliver education. **Personal conditions** are restricted only to the equipment necessary to receive or deliver education. In addition, there is a variety of personal restrictions that can impact the ability to participate in education and training (e.g., motivation, personal capacity, etc.). This paper, however, is focused on methodologies and tools for crisis-resistant education and training. Therefore, person-specific psychological aspects that influence education are not considered. Depending on the severity of restricting crisis conditions (e.g., lockdown, travel ban), an educator is supported in choosing among physical, hybrid or completely-online teaching modes. A list of generic crisis conditions with varying degrees of severity provides the educator with assistance while assessing the severity of the crisis event. The list can be found online on www.cresdet.eu.

2.2 Educational design

The emergence of a crisis, whatever its scenario is, requires the educators to rethink the delivery of the course with reference to its Intended Learning Outcomes (ILOs). These are typically predefined, especially if the course is already in place before the crisis emerges. However, depending on the scenario at hand, the ILO should be revised and appropriately defined. The (revised) Bloom's Taxonomy [2] can be used as a target reference for this purpose, as it categorises educational goals into six major categories. Higher levels build upon more basic ones: a learner must *remember* (lvl-1) basic concepts in order to *understand* (lvl-2) them and organise them into a coherent framework. This makes it possible to *apply* (lvl-3) that knowledge to execute tasks in new situations. This enables the possibility to *analyse* (lvl-4) what was done and then *evaluate* (lvl-5) it, as the critical judgement of the outcomes is the key to *create* (lvl-6) new knowledge. The achievement of updated ILOs in a digitalised environment requires addressing the change of scenario and the relationship with the learner. A student-centred approach provides opportunities to learn, regardless of a student's learning profile (SLP) [3]. Whether they are Activists (they learn by doing); Reflectors (they elaborate on observations); Theorists (they abstract and create models to learn) or Pragmatists (they experiment), the educational methods and tools the educator will implement should enable them the opportunity to learn in the easiest way possible and let them familiarise with different learning styles. The Kolb's Cycle [4] appears to be one of the pedagogical approaches that are well suited to answer this request for student-centred learning. For these reasons, the table containing a list of educational items (tools, methods and approaches) already maps them to the stages of the Kolb's Cycle, suggesting how/where to use them in physical and/or remote settings and in which kind of educational activity (lecture, seminar, lab, etc.).

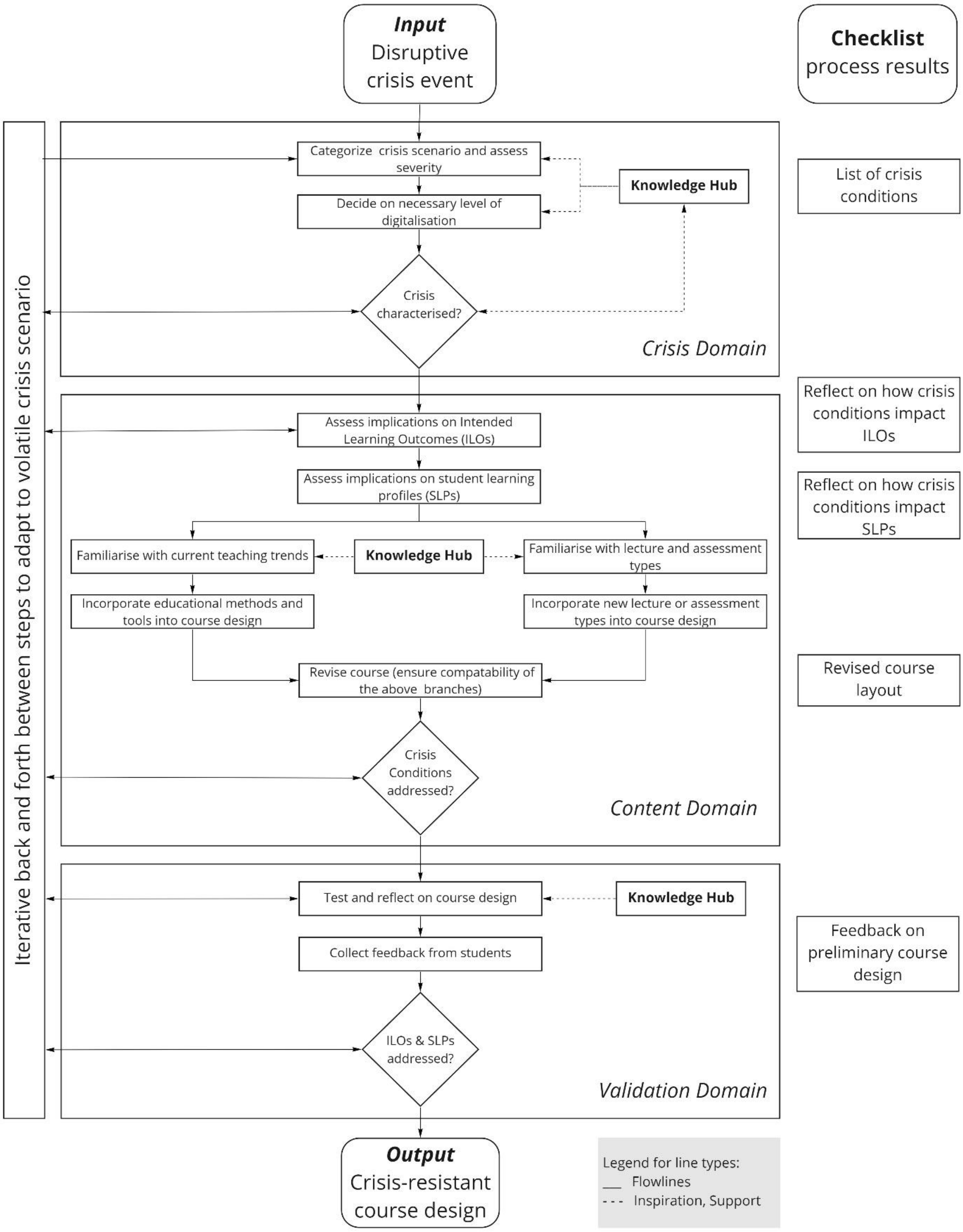


Figure 1. Depiction of the crisis-adaptation framework

2.3 Framework logical structure

Figure 1 depicts the framework within three major domains. The *crisis domain* composes of processes to identify and characterise crisis-related restrictions and to decide on the necessary level of digitalisation for the situation. To facilitate this, the list of generic crisis conditions provides guidance through the processes (Section 2.1). The Knowledge Hub is a planned platform that provides experience reports on how other educators adapted to crises, which should aid an applicant in classifying the event. A first decision gate ensures the quality of the outcomes from the first domain. Within the *content domain*, implications from previously defined crisis conditions on intended learning outcomes and student learning profiles should be considered. From these considerations and by consulting the review on modern educational goals (Section 2.2), the educator has to revise their course and integrate the situation-appropriate tools and methodologies into their revised course. The Knowledge Hub can present examples of revised courses and teaching practices from other educators. The second decision gate should ensure the proper fitting of adaptations in the revised course layout with crisis conditions. Assuming the implementation of the revised course, the applicant progresses to the *validation domain*. When testing the revised course layout in the crisis setting, the educator has to carefully monitor whether set learning outcomes are met and if student learning styles are addressed. This can be achieved by feedback from the students and a comparison of course layouts regarding irregularities in student behaviour and grading. The Knowledge Hub should again serve as a resource on how other educators experience a crisis and which problems were encountered during the implementation of their courses. A final decision gate provides necessary iterations for a complete *validation domain*. Determining a course layout is an iterative process, especially given the volatile setting of a crisis, which is indicated by the leftmost process (Figure 1) that enables the iterative back and forth between processes. To the right of the three domains (Figure 1), a checklist of process results can be found. It summarises activities within the domains and should facilitate the application of the framework.

3 VALIDATION - EXAMPLE OF FRAMEWORK APPLICATION

As a case example for the purpose of demonstrating how to apply the framework, an illustrative CAD course in the restricted scenario of a pandemic crisis is considered. Firstly, the addressed crisis situation has to be described with the list of crisis conditions (Table 1).

Table 1. Exemplary list of crisis conditions

General Conditions			**Level of digitalisation**
Movement	Geographic limitations	Severe restrictions due to lockdowns that prohibit all non-essential movement.	Completely Online
	Requirement-based limitations	Despite constantly changing requirements, it is generally enough to wear a mask and have a negative COVID test.	Physical, Hybrid, Completely Online
Connectivity	Internet connection	There are no problems with the internet connection.	Physical, Hybrid, Completely Online
Higher Education-Related Conditions			
Institution	Physical access	The institution and its resources are only partly accessible physically. Only essential personnel are allowed on campus.	Completely Online
	Online access	There are no limitations regarding the access to online services of the institution.	Physical, Hybrid, Completely Online
Learning resources	Online availability	There are insufficient online learning resources existent to support teaching activities. Educators need to create the missing online learning resources.	Physical, Hybrid, Completely Online

	Physical access	The learning resources are not accessible physically.	Completely Online
Personnel	Availability	Educators are fully available in general but can become unavailable once they contract the disease.	Physical, Hybrid, Completely Online
Personal Conditions			
Equipment	Availability	The equipment required for educational activities is partly available.	Physical, Hybrid, Completely Online
	Suitability	The available equipment is only partly suited for the intended educational activities.	Physical, Hybrid, Completely Online

Prior to the crisis, the example course consists of theoretical lectures that are carried out in an ex-cathedra format and tutorials supported by CAD tools. During practice exercises, students mimic the demonstration of CAD modelling by observing the lecturer's computer screen. Teaching assistants offer individual help during the exercises. The practical aspect of the course also comprehends a collaborative assignment, tasking students to develop a design solution to a real industrial problem. Students can ask for feedback or clarification during weekly consultation hours, whereby some meetings are compulsory. Grading consists of an individual test where students have to create 3D parts, an assembly, run simulations and create 2D drafts for documentation, in addition to an evaluation of the collaborative assignment. For the group evaluation, students present collaborative assignment results and prepare a report. All activities are carried out on-site. The intended learning outcomes of this course are to be able to create 3D models of parts and assemblies; prepare 2D technical drafts; conduct static, kinematic or dynamic simulations; and to ideate simple virtual prototypes.
In this case-study scenario, all course activities take place on-site. The condition "physical access to the institution" demands that students are not allowed on campus. A complete shift to online teaching is therefore recommended, affecting lectures, practice exercises, the student team assignment, consultation hours and examination. To achieve intended learning outcomes and satisfy student learning profiles, the applicant of the framework can incorporate methods and tools from the table of educational items. The process shall be demonstrated for lectures:

Table 2. Excerpt of the educational items table - Lecture type applicability

Educational Item	**Applicable to Lecture type**					
	Lectures	Exercises	Seminars	Projects	Laboratories	Excursions
Physical Prototypes	X	X	X	X	X	X
Gallery Method	X	X	X	X		
Classroom discussion	X	X	X	X	X	
AR-Visualisation	X	X	X	X	X	X

Table 3. Excerpt of the educational items table - Learning style applicability

Educational Item	**Applicable to Learning style (Kolb's Cycle)**			
	Concrete Experience	Reflective Observation	Abstract Conceptualisation	Active Experimentation
Physical Prototypes	X	X		X
Gallery Method	X	X	X	X
Classroom discussion		X	X	X
AR-Visualisation	X	X	X	X

Ex-cathedra lectures can be held online via videoconferencing tools or be supplemented with recorded lectures and live meetings to discuss the contents of the recording in a flipped classroom format. Lectures can be enriched with educational items such as physical prototypes, the gallery method, and augmented reality visualisation to address the concrete-experience learning style. Classroom discussions facilitate students with an active experimentation learning profile. Tables 2 and 3 depict educational items from the table and suggestions for practical implementation. Once the educator has implemented the course revision, student feedback and before/after comparison of the courses are needed. Through feedback, the educator can either verify course adaptations or reiterate the process.

4 DISCUSSIONS

The need for this type of research became visible during the COVID-19 crisis in the spring of 2020. Successive infectious waves for the past two years have shown that new rapid and region-specific adaptations will be again needed and experienced in the everyday and professional life of educators and students. To address this and other present and future crisis events, the paper presents a framework for the rapid adaptation of engineering product development courses. The example of the framework application demonstrates how educators in higher education can use the presented resources. Resources include the crisis conditions list to identify restrictions and to assist in determining the appropriate level of digitalisation, and the modern teaching objectives review in conjunction with the educational items table to enhance their courses with previously assessed methods and tools. The practice-oriented, crisis-resistant guidelines provide educators with a structured and tested approach for reacting to a crisis and adapting their course in alignment with the framework. This will not only lighten the burden on educators but also addresses the need for fast decision-making in a volatile environment. The goal from an educator's perspective has to be to maintain an excellent knowledge transfer and to keep all types of learners engaged in teaching activities.

The framework is currently being validated in product development courses conducted by the authors. It is the ambition of the authors to create a comprehensive platform for educators to exchange experiences from past and present crisis events, called the Knowledge Hub, and make the framework accessible in an interactive online form.

ONLINE APPENDIX

Please refer to our website www.cresdet.eu/framework/ to find the resources of the framework: Generic Crisis Conditions List, Review of Educational Objectives, Educational Items Table

ACKNOWLEDGEMENT

The authors disclosed receipt of the following financial support for the research, authorship, and publication of this article: European Commission Erasmus+ programme [Grant Agreement No.: 2020-1-AT01-KA226-HE-092617].

REFERENCES

[1] Lathan J. The Complete List of Teaching Methods. University of San Diego, Retrieved August 20, 2021, from *https://onlinedegrees.sandiego.edu/complete-list-teaching-methods/*.

[2] Anderson L. W., Krathwohl D. R. and Bloom B. S. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*, New York: Longman.

[3] Honey P. and Mumford A. (1986), *The Manual of Learning Styles*, Peter Honey Associates.

[4] Kolb D. A. (1984). *Experiential learning: Experience as the source of learning and development.* (Vol. 1). Englewood Cliffs, NJ: Prentice-Ha.

SKILLSLAB - PEER EDUCATION IN A RAPID CHANGING WORLD

Hilde VAN DYCK, Elke MESTDAGH, Kristof VAES and Alexis JACOBY
University of Antwerp, Belgium

ABSTRACT
In this fast evolving and changing world, design education is challenged to evolve and change at the same pace. The surrounding context, subject to continuous change, has a major impact on the university as an organization but also on the lecturer's role and the way students are prepared for their professional future. The necessary skills one needs to acquire in order to thrive in the context of the fourth industrial revolution [1] paves the way to re-evaluate what and how we teach bachelor and master students in product design & development and reveal new opportunities to experiment with new required knowledge, soft and hard skills, assignments, learning and interaction formats. New insights can be used as a baseline for future curriculum transformation.
This paper describes a pilot project at the department of Product Development of the Faculty of Design Sciences at the University of Antwerp, in which we designed and set up a SkillsLab in an extracurricular setting, where both bachelor and master students learn from each other with the lecturer as a coach [2]. SkillsLab focuses on the development of supporting skills for design students with the intention to make them grow as a person, and thus as a designer. Students are invited to propose subjects for a SkillsLab session that fits within one of 5 pillars: teamwork & leadership, creativity, self-management & well-being, communication and applying supporting tools & techniques. If needed, an expert from the work field is involved. SkillsLab sessions are organized as short and hands-on sessions. The cross-year interaction stimulates the students to learn from peers, with room for failure and a focus on a trial and learn attitude.
Throughout the pilot project, new insights are obtained on the way students can acquire and develop soft skills that provide an answer to the emerging needs and the complexity of their future professional context, but also on the way students can design, assess, and adjust their individual learning path. This pilot project, and the disruptive way in which it was implemented, is the first step in developing a generic script for best practices and an integrated approach for the product design & development programme and other programmes in the faculty in order to stimulate soft skills development, peer learning and multidisciplinary knowledge sharing.

Keywords: Peer learning, cross-year interaction, multidisciplinary knowledge sharing, community building, peer coaching

1 INTRODUCTION
One of the goals of higher design education is to provide students with a broad and suited set of hard and soft skills, to maximize their employability and to facilitate lifelong learning. This goal aligns with the first of ten TLRP principles of effective pedagogy (Table 1).
The professional design context reveals that designers are starting to play a larger and more substantial role in organizations, not only designing but also managing beyond the context of the design studio, broadening their activities across the different business units of an organization. Designers' responsibilities are expanding beyond the technical to include the organizational and the managerial [5].

Table 1. 10 TLRP principles of effective pedagogy

Principles
A. Educational values and purposes
1. Effective pedagogy equips learners for life in its broadest sense.
B. Curriculum, pedagogy and assessment

2. Effective pedagogy engages with valued forms of knowledge.
3. Effective pedagogy recognizes the importance of prior experience and learning.
4. Effective pedagogy requires learning to be scaffolded.
5. Effective pedagogy needs assessment to be congruent with learning.
C. Personal and social processes and relationships
6. Effective pedagogy promotes the active engagement of the learner.
7. Effective pedagogy fosters both individual and social processes and outcomes.
8. Effective pedagogy recognizes the significance of informal learning.
D. Teachers and policies
9. Effective pedagogy depends on the learning of all those who support the learning of others.
10. Effective pedagogy demands consistent policy frameworks with support for learning as their primary focus.

Design education, traditionally, focuses on the development of hard skills in a project-driven setting. The acquisition of soft skills is a side effect of this educational setting. The way in which students work together, develop communication skills and define their proper role as a designer evolves along the way. Although this approach has proven its merits in the past, the development of supporting soft skills deserves more attention. Not only because these skills are important in any given working environment, but also because it is important that students understand the explicit added value of supporting skills during their educational journey, enabling them to control the development of an individual skill set, adapted to their proper needs. Therefore, and as of 2019, the department of Product Development of the faculty of Design Sciences at the University of Antwerp, decided to focus more on the development of supporting soft skills and to actively involve students in this process of personal development and growth. By providing the opportunity of selecting, learning and practicing several supporting skills, students can enrich their learning path, enhance their educational output, and increase their employability. Doing so, SkillsLab also embraces the 4th and 8th TLRP principle of effective pedagogy (Table 1), providing the opportunity to learn in an informal and a scaffolded way.
SkillsLab wants to consciously activate the potential that lies in every individual, create a common language and act as a catalyst. Lifelong learning, interdisciplinary collaboration and sharing knowledge are central in this approach. On top of this, SkillsLab can be an appealing driver to attract new students for the product development programme.
Since a structural change in the curriculum requires time and effort, SkillsLab started with small experiments, organizing limited extracurricular workshops in which both bachelor and master students can participate voluntarily.
This paper firstly reveals how SkillsLab is conceived and implemented and concludes with the most essential learnings (advantages, pitfalls, and challenges) to take it to the next level.

2 THE PROJECT

2.1 Set-up

The main objective of SkillsLab is to teach and practice skills that support a designer in his development as a person and a designer, but also in his process of learning and in his daily tasks. Another primary objective is to bring together students of different years and education levels and have them learn from each other. Through peer learning and peer coaching, collaboration and debate are stimulated.
The secondary objectives of the project are community building and fostering a growth mindset in the students.
The SkillsLab sessions are organized as short and hands-on sessions during lunch break. One SkillsLab session takes 90 minutes and usually contains an introduction of 20 minutes, followed by interactive and practical exercises. The specific setup is adapted for each session. Groups of 6 to 8 students gather around a table to form a group, stimulating peer learning between students from the same and different cohorts. The interactive session on ‘giving and receiving feedback,’ for instance, was organized in a speed date setup where every participant could give and receive feedback on a design project they have

been working on in that period. During the 20 minutes introduction they got acquainted with the do's and don'ts of how to give and receive feedback.

One weekly session has a potential audience of about 400 students across three Bachelor and two Master years, with a maximum capacity of 25 students per workshop. In total, to date, 23 sessions with 235 participants (100 unique participants) have been organized over three semesters. In recent months, the Covid pandemic restricted the way we could organize real-life workshops and even if real-life workshops were organized the use of face masks and social distancing in some cases affected the interaction between students and the effectiveness in which objectives could be obtained.

Since we use a workshop format, we maximize interaction and stimulate debating. The cross-year interaction stimulates the students even more to learn from peers, with room for failure and a focus on a trial and learning attitude. A team of 2 lecturers are present and functions as a coach for the students. If needed, a supporting professional expert is involved. During the workshops students are reassured that there are no mistakes, no grading and a lot of room to grow skills.

Every SkillsLab topic is shortly introduced in a video that students have to watch prior to the session or a short introduction on the spot. This way, a basic background framework or step-by-step approach is provided on the topic, leaving plenty of time for practice.

2.2 Themes and programme

Initially, the SkillsLab programme was defined by the staff, looking for advanced topics that fit within one of 5 pillars: teamwork & leadership, creativity, self-management & well-being, communication and applying supporting tools & techniques. A suitable topic is extra-curricular and can be introduced in a 'SkillsLab setting, which means that the students should be able to experiment and learn after a short introduction. If relevant, we design a second SkillsLab session that builds further on prior sessions to dive deeper in a certain topic. The goal is that the specific learnings can be internalized by the students during their regular curricular project work.

Why these 5 pillars?

- **Teamwork & leadership**: In both educational and professional contexts, product designers encounter a lot of teamwork. They mostly learn it by experience. We noticed, however, that a lot of basic pitfalls could be prevented if we teach students the basics of teamwork and leadership in a SkillsLab session. In this experiment two workshops were organized on this subject: one explaining basic aspects, such as how to put together a suitable team, make team agreements, and other basic working agreements. A second workshop focused on dealing with conflicts and communicating feedback, both giving and receiving feedback.
- **Creativity**: Although every design project throughout the educational programme requires creativity, this creative mode doesn't always come easily or naturally. It is essential, however, that students develop their creative skills and explore supporting techniques and tools. In these sessions, specialized experts teach the participants how to enable a creative mindset and which creativity techniques to use in specific situations. As a result, the creative confidence is boosted based on scientific facts and hard practice.
- **Self-management & well-being**: Students entering the product design & development programme have to combine many projects and theoretical courses throughout the semester. The project-driven approach requires optimal planning throughout the entire academic year, and not only during the exam period. The workshop topics in this cluster included: focus management, planning, how to cope with stress and deadlines, providing essential learnings for them to deal with the context in a better way.
- **Communication**: Since the self-confidence of an 'idea-presenter' influences the judgment on the creativity and added value of an idea [5], several SkillsLab sessions focus on how to pitch an idea, how to communicate about a design concept and how to communicate in a connecting way during the creation process.
- **Applying supporting tools & techniques**: By offering SkillsLab sessions on specific digital and analogue techniques like laser cutting, 3D printing, drawing in Virtual Reality (VR), screen printing, etc., we motivate our students to explore and play [7],[8],[9] with tools and techniques. Although this cluster cannot be categorized as soft skill development, the underlying rationale is to support a 'create while doing' attitude and create a mindset on how to learn about design solutions by prototyping and making things. On top of that, learning about specific techniques is

also just fun. The value of augmenting the fun factor in an educational setting cannot be underestimated.

In a second phase, students could also propose additional topics for SkillsLab sessions as long as they would fit in one of the above-mentioned categories. Many of their proposals fitted with our targets, expressing their enthusiasm and involvement. Their ideas also provided valuable insights in the needs that students expressed on their personal development.

2.3 First observations and evaluation

As from the third semester, every participant was asked to evaluate each session anonymously, reporting if the workshops were clear and tailored to their needs, provided added value for them, delivered new insights that were useful and usable, and whether the right balance between theory and practice was applied. Figure 1 shows that the participating students (n=87) are very enthusiastic and consider SkillsLab as an added value with usable insights and skills for their own development. The workshops were evaluated as clear and tailored to the needs of the participants with a good balance between theory and practice. The average score on a ten-point scale is 9.05.

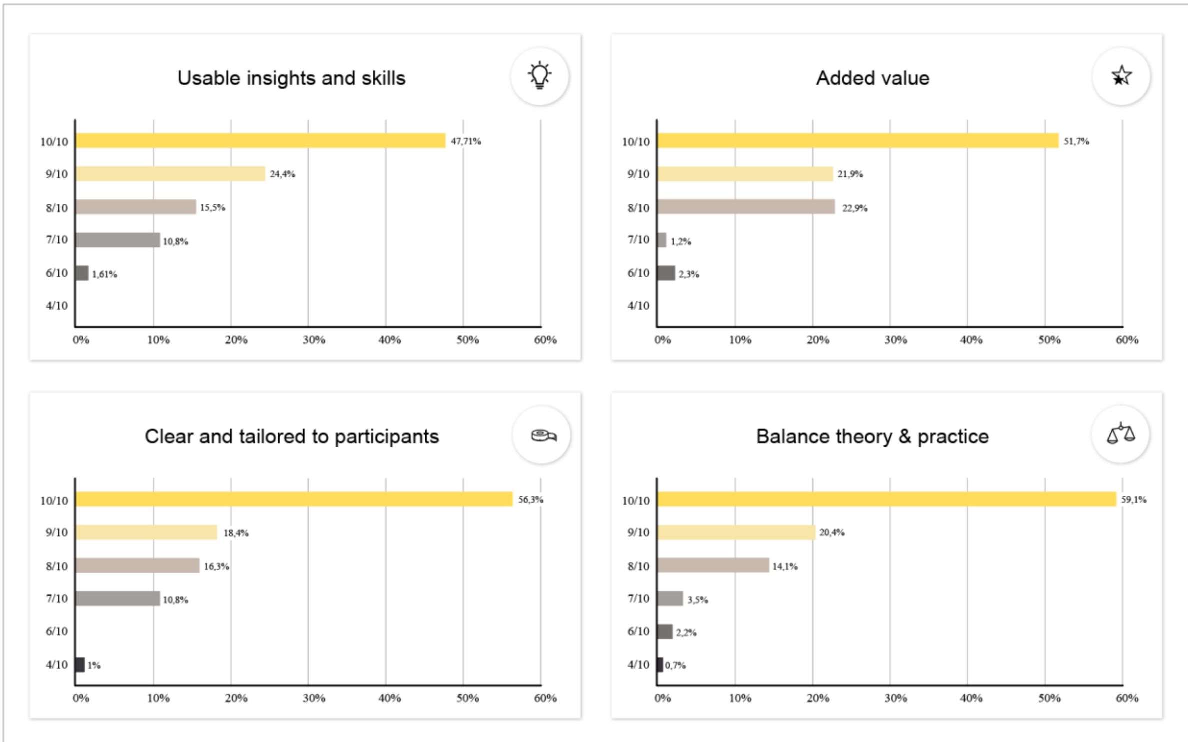


Figure 1. Evaluation and feedback on SkillsLab

In order to obtain more direct feedback from the students after a year of SkillsLab workshops, a student volunteer team was put together. In monthly meetings with the coaches, student topics were discussed and evaluated. In a next phase the SkillsLab team is looking for opportunities to organize workshops that tie in with design courses and projects, reviewing with them how we can further improve communication with the large student population of the Product Development programme at our university.

3 CONCLUSIONS

3.1 Learnings

After 3 semesters, we gathered valuable insights to improve the SkillsLab format and to better serve our students in the future. Some learnings we can share:

The 5 pillars we defined are well chosen and cover the main gaps and needs that we noticed in the existing curriculum. Although it is positive to offer extracurricular learning possibilities, it is also essential to define how skills development and peer learning can be built in the regular project-driven curriculum. A few SkillsLab sessions that we consider very useful, e.g., about stress and focus, did not reach a lot of students. We noticed that our jargon language on the topic did not resonate. This is a point of action for our future communication. Undoubtedly, our team of student volunteers will help us with this.

Since this is not a mandatory course, and participation is based solely on intrinsic motivation, we currently reach the more motivated students rather than those who may need it more. A possible pitfall is that the motivated and stronger students accelerate and the gap between them and the others can even grow bigger. To avoid this, we have decided to make three SkillsLab sessions mandatory for the second- and third-year bachelor students that start next academic year. By applying a pass rate based on their attendance, we are not undermining the safe trial and learning environment of the SkillsLab format. The workshop offerings will also be aligned with the ongoing projects and assignments in the specific bachelor programmes. In addition, we will provide supplementary workshops in all 5 categories, so students will have a wide range of options to choose from. Needless to say, that on top of the three mandatory workshops, we will encourage students to take up more workshops.

It is difficult to motivate first undergraduate students to participate in SkillsLab lunch sessions. They are new to the faculty and seem to be overwhelmed by the workload from the mandatory courses. Growing awareness among the other students might, in the long run, also have a positive effect on the engagement of first year students.

Similarly, students of the second master year are focused on their master thesis and rarely join a SkillsLab session. Further investigation is necessary to determine how we can motivate them to participate in the future as we feel they have an important role to play in the peer learning process.

In the current format, the workshops are organized during the students' lunch break. On top of a full learning programme, it is rather difficult to incentivize students to participate. This was mentioned explicitly by many students in the feedback forms. It was always the objective to integrate the development of supporting skills in the regular curriculum. It is a challenge for the upcoming years to embed SkillsLab sessions in the design project courses or to reorganize the courses in such a way that the sessions can obtain their proper place in the curriculum.

Although, up to now, only a limited number of students have participated in the SkillsLab sessions, we can state that the experiment is a success. Students participated with great enthusiasm and provided valuable evaluations and insights.

The fact that several students demand a more organizing (responsible) role and team up as volunteers is a positive sign. The meetings with the volunteers are always very inspiring and have a positive impact on the SkillsLab programme, subsequently increasing the awareness around SkillsLab among other students and improving the attendance rates of the workshops. As a result, SkillsLab also contributes to student cohesion and the community building across the different years, which was a secondary objective of this project.

Over the last semester several students also organized specific workshop for their peers, proving that they were motivated to share their own skills with others as well.

3.2 Positive side effects

SkillsLab clearly boosts cross-year community building among students within the department. Alongside other initiatives from the students and the staff, this project specifically supports the connection of students in a learning environment, which is quite new. It also opens other opportunities for cross-year collaboration within the context of design projects.

Furthermore, SkillsLab facilitates an improved student-life experience. The informal context of the sessions makes the coaches more accessible for the students to talk to, also about other education-related issues.

As the set-up is not bound to the formalities of the regular curriculum, SkillsLab can act as a living lab, opening opportunities for easy to organize learning experiments with students that we can enable in the future in order to anticipate on changes in our rapidly changing world.

3.3 Next steps

We are exploring new collaborations with our student and alumni association to boost this project even further in the next academic year and investigate if the sessions can also be opened for alumni. We are confronted with a growing need for specific skill development in the working field as well, since the future of design also lies in tackling larger, more complex, and often immaterial tasks [10]. Some

SkillsLab sessions may be suited for other departments or faculties. We will investigate this opportunity and see how we can build bridges and collaborations with other educational programmes.
To further support the self-development and growth component of SkillsLab, we want to explore (software) tools that can be used by the students and the coaches to monitor the individual competence development. The tool should support the student to be in control of the growth process and stimulate the necessary self-reflection and self-understanding in order to define the direction that best suits a particular student. This will be an important asset in constructing and further developing the SkillsLab workshop programme.

REFERENCES

[] Gray A. The 10 skills you need to thrive in the Fourth Industrial Revolution. Available: *https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/* [Accessed on 2022, 21 February], (2016) 19 January.

[2] Muratovski G. The making of an American Design school: lessons learned. In *She Ji*, Vol. 6, Glasgow, 2020, pp.67-82 (Elsevier, Amsterdam).

[3] James M. and Pollard A. TLRP's ten principles for effective pedagogy: rationale, development, evidence, argument and impact. Available: *https://discovery.ucl.ac.uk/id/eprint/1504912/1/James2011TLRP's275.pdf*

[4] Biesta G. Onderwijsonderzoek, een onorthodoxe introductie. Boom, 2022

[5] Meyer M. and Norman D. Changing Design Education for the 21st Century. In *She Ji*, Vol. 6, Glasgow, 2020, pp.13-49 (Elsevier, Amsterdam).

[6] Card deck of Vigor Innovation Research Group. Available: *https://vov.be/assets/files/news/vigor_kaarten_2.4.pdf*

[7] Brown S. Play: How it shapes the brain, opens the imagination, and invigorates the soul, *Penguin Books*, 2010.

[8] Bateson P. and Martin P. Play, Playfulness, Creativity and Innovation, *Cambridge University Press*, 2013.

[9] Reenders R., Spijker W. and van der Vlugt N. Spelend leren, lerend spelen, *Koninklijke Van Gorcum bv*, 1996.

[10] Swanson G. Educating the Designer of 2025. In *She Ji*, Vol. 6, Glasgow, 2020, pp.101-105 (Elsevier, Amsterdam)

REALISING THE POTENTIALS OF VIRTUAL REALITY AND BUILDING INFORMATION MODELS? CIVIL ENGINEERING STUDENTS' UTILISATION OF TECHNOLOGY IN A GROUP PROJECT

Ingri STRAND[1], Ernst Erik HEMPEL[1] and Eilif HJELSETH[2]
[1]Oslo Metropolitan University, Norway
[2]Norwegian University of Science and Technology, Norway

ABSTRACT
Collaboration between different actors is key to successful projects within the architecture, engineering, and construction (AEC) industry. Virtual Reality (VR) combined with Building Information Models (BIM) is an effective visualisation tool that may aid a team's communication and collaboration. Civil engineering students at Oslo Metropolitan University are encouraged to use such tools, available to them in a dedicated digital collaboration room dubbed the 'Little Big Room' (LBR) along with computers and large touchscreens. This paper explores how the tools in the LBR are utilised by three student groups working on a project and how the students view them, discussed through the theoretical lens of the technology acceptance model. The aim is to suggest how students' utilisation of the technology can be facilitated to improve their learning experiences in collaborative projects.
The students were satisfied with using the LBR. However, the full potential of VR was not utilised, such as the option to evaluate the size of the rooms and lighting conditions, something they only realised in hindsight, as not all students perceived VR as sufficiently useful for the tasks given. Changing the criteria of the task or increased focus on the students' first introduction to VR might facilitate increased utilisation of VR as a professional tool.

Keywords: Virtual reality, building information models, civil engineering education, visualisation

1 INTRODUCTION
Within the architecture, engineering and construction (AEC) industry, collaboration between actors with different specialties is key to effective and successful projects. As mistakes or inefficiencies can easily result in large costs and delays, it is important to continuously search for ways to improve communication and collaboration within groups. Although an emerging method in the industry, the use of immersive Virtual Reality (VR) in combination with Building Information Models (BIM) has proven to be an effective way to visualise a project and improve the actors' communication and understanding of the project [1, 2, 3]. 3D-representations can help participants discover errors and review the plans better than 2D plans [4], especially when viewed in VR [5]. However, studies show that VR still has an untapped potential [6, 7, 8]. This paper explores how civil engineering students utilise VR and other technology and their views on it, as part of a collaborative project. The aim is to suggest how increased utilisation of the technology can be facilitated to improve the learning experiences of students.

2 METHODS
This study combined qualitative, semi-structured interviews with quantitative timekeeping records. Descriptions of these methods follow a description of the scene of the study and participant sampling.

2.1 The scene of the study
This study took place in the Department of Civil Engineering and Energy Technology at Oslo Metropolitan University, more specifically in a dedicated digital collaboration room called the 'Little Big Room' (LBR). The LBR is a small version of the Big Rooms at construction sites, dedicated to collaboration between an entire project team [9]. The LBR is equipped with four sets of 65" touchscreens, computers, and Oculus Rift VR headsets.

In the 10 ECTS course *Introduction to Building Professions* in the first semester of the bachelor's degree programme in Civil Engineering, the students were divided into groups of 6 and asked to plan a semi-detached house. Each student in the group was given an area of responsibility, such as architect, contractor, project manager or specialised engineer. In addition to a written report, the groups made a BIM in Autodesk Revit. Lassen, Hjelseth, and Tollnes [10] have provided a more detailed description of this project in their work.

For a proper introduction to the LBR equipment and effective collaboration, the groups were encouraged to sign up for two voluntary Integrated Concurrent Engineering (ICE) meetings. The ICE-meetings were highly structured meetings assisted by a 3rd year student assistant, arranged in the LBR, lasting about 60 minutes each. The meetings observed in this study were held in September and October 2020. The first meeting was led by the student assistant, who guided them through a presentation of status reports and taught them how to use the large screens to show the BIM or draw on before instructing them on the use of the VR equipment with a walkthrough of a BIM. In the second meeting, the students themselves were in charge, with the student assistant present.

2.2 Sampling of participants

Three groups participated in the study. Groups A and B were sampled randomly, using convenience sampling. The first author participated in an ICE1-meeting to gain an understanding of the project. No data were gathered in this meeting, as this study examined how the students themselves utilised the room. An overview of the observed meetings is provided in Table 1. Groups A and B did not use VR in their ICE2-meetings but expressed an interest to view their finished models in VR. Prompted by the first author and the student assistant, a third meeting was scheduled. Group C was sampled strategically, as the authors heard that they planned to use VR in the ICE2-meeting. Including this group gave a broader image of how the room was utilised, perhaps more representative for the overall class.

Table 1. The ICE-meetings the first author participated in is marked with an X. The ICE1-meeting was used to gain familiarity with the project, while data from the other meetings are included in the study

	ICE1	ICE2	ICE3/VR
Group A	X	X	X
Group B		X	X
Group C		X	

The groups consisted of 5–6 students each, but not all students were present for all the meetings. One student did not wish to participate in the interview and left the room after the meeting. Thus, a total of 14 students participated in the observed meetings and 13 in the interviews.

2.3 Video observation with timekeeping records

Five meetings were observed in their entirety and recorded through a video camera placed in the corner of the room. The first author was positioned close to the camera, taking notes, attempting to observe the students' natural use of the room and affect their behaviour as little as possible, despite her presence.

The recordings were analysed through quantitative timekeeping records (Figures 2–4). The exact times of when the students started and stopped using (1) the large touchscreens, for viewing the models or drawing; (2) the VR-equipment; and (3) other items such as personal computers or pen and paper notebooks were entered into an Excel spreadsheet. This showed how much time the students spent using each of the tools, how they switched between them or used them simultaneously, and when they were used in the meeting.

2.4 Semi-structured interviews

Directly after the meetings, the students participated in semi-structured, qualitative group interviews resembling everyday conversations but following an interview guide with set themes. The students were asked about their shared experience from the meeting, their use of VR and the LBR in general, and the tools that had helped their collaboration. The interviews after the ICE2-meetings lasted 8–12 minutes and the interviews after the ICE3-meetings lasted 3–7 minutes.

The transcribed interviews were coded thematically. The interviews have been used for illustrating how the LBR was utilised and in answering how the students viewed the LBR.

2.5 The technology acceptance model (TAM) as an analytical tool

To understand the students' views on their use of the LBR, the observation and interview data are viewed through the theoretical lens of the TAM proposed by Venkatesh and Davis [11], visualised in Figure 1. Although originally designed for predicting technology use, it has been used in this paper to serve as a framework to discuss the students' initial experiences. Of particular interest are the following two constructs (1) *Perceived Usefulness*, the belief that using a specific technology will increase job performance and (2) *Perceived Ease of Use*, the degree to which the use of a specific technology is expected to be free of effort [12]. Together they influence the intention to use technology, which in turn influences its actual use. However, these are affected by *External Variables*, which in this study include factors like the students' prior knowledge of the technology, along with the tutoring and the tasks given. Discussing these constructs separately allows us to distinguish which variables can be changed to facilitate increased utilisation of the LBR and improve the students' learning experiences in collaborative projects.

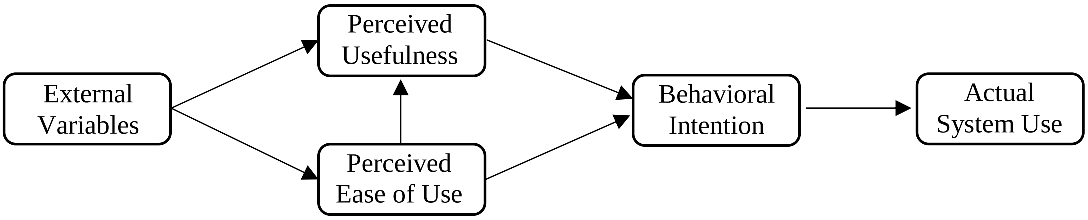


Figure 1. The technology acceptance model created by Venkatesh and Davis

3 RESULTS

3.1 Utilisation of the LBR in ICE 2

Groups A and B followed the ICE-structure learnt in the first meeting, where each group member presented what they had done since the last meeting. While talking, they showed relevant parts of the BIM from Revit on the large touchscreen. The option to draw on the screen was only utilised by the Contractor of Group A, who drew roads, barracks, etc. on a pdf showing the building site. During the presentations, one team member used their own laptop to make notes for the report. Their time spent using touchscreens and/or their personal computers is presented in Figure 2.

Figure 2. Utilization of the available technology in the ICE2-meeting by Groups A and B
Note: The dark segments of the top bar indicate drawing on the touchscreen. VR was not used at all

Group C utilised the LBR in a way different from Groups A and B. They switched between walkthroughs in VR and editing the model in Revit on the touchscreen, as shown in Figure 3. Immersion in VR was delegated to two of the students, while the rest of the group watched the walkthroughs on the screen. They used the walkthroughs to discover errors in the model, such as small holes in the floor or excessively narrow passages. The project manager made notes of errors using pen and paper, but some were also corrected directly. Group C stated in the interview that they had no need to spend time in the LBR presenting to each other, as they preferred updating each other through other channels.
Group C used VR for 25 minutes out of the 60 minutes, while Groups A and B did not use VR at all.

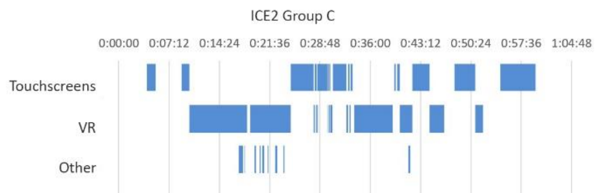


Figure 3. Group C's timekeeping record show switching between touchscreens and VR throughout the ICE2-meeting, spending about equal amounts of time on these two tools

3.2 Utilisation of the LBR in ICE3

In the ICE3-meeting, primarily set up so that Groups A and B could view their models in VR and take screenshots for the presentation, these two groups showed different approaches, as demonstrated in Figure 4. In Group B, the three participants that wished to try VR took walkthroughs lasting about 3–6 minutes each. After this, they spent the rest of the time working on the model in Revit, both correcting mistakes discovered in VR and taking screenshots, using both the large touchscreen and a private laptop. Group A's approach was similar to Group C's in the ICE2-meeting, where VR was used by all team members to discover errors in the model. These were subsequently corrected in Revit on the large screen. In addition to switching between Revit and VR views, one student worked in Revit while another student was viewing the model in VR. The student who used VR the most mentioned that communication was challenging, as the rest of the group was not necessarily viewing the same part of the model as he was. The duration of Group A's ICE3-meeting was about two hours, which was almost twice that of the other observed meetings. However, as they solved most of the issues with the model during the meeting, instead of taking notes for later work, this does not necessarily imply an inefficient meeting.

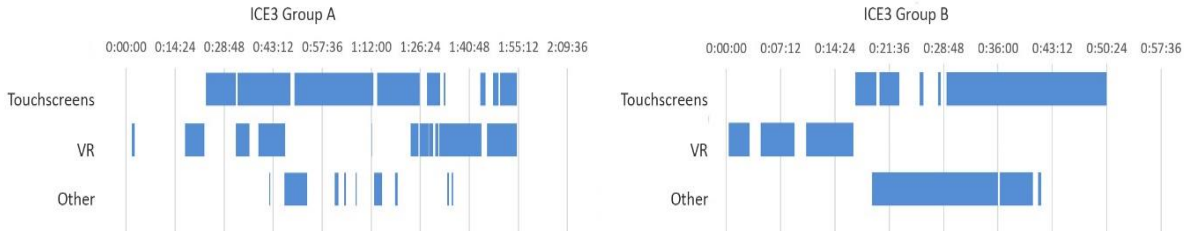


Figure 4. Utilization of LBR tools in ICE3-meetings by Groups A and B. Group A used VR throughout the meeting, while interested students in Group B took walkthroughs only at the start of the meeting

3.3 The students' views on using the LBR

After the ICE2-meeting, Groups A and B described it as a useful and efficient way to keep the entire group informed. Group B's Structural engineer said that he never collaborated with the Contractor of the group but appreciated to be informed and that he was able to contribute to that part of the project.

The large touchscreens were mentioned as very useful for the presentations. The Contractor in Group A, who drew on the touchscreens while talking, stated that the screens made it 'a lot easier to visualise'. When the rest of the group commented that the screens made it easier to follow the presentations too, the Contractor followed up by saying 'It's possible to ask questions; you easily can explain and clarify without too many explanations because you can show or point'. Group B attributed the discovery of a large mistake – a difference in the area between the two supposedly identical halves of the building – to viewing the model on the large screen. The Project manager commented that this probably would have been difficult to see on the small screen of a personal computer. The Structural engineer in Group A also commented that the large screens and switching between VR and working on the model in Revit facilitated a good workflow.

All groups talked about the ability to discover small and large errors as a big advantage with the use of the available technology, especially VR. Group C, who were well acquainted with each other's progress, mentioned this as the biggest advantage of using the LBR. In their model, a deep window frame had been placed in a flight of stairs, making the stairs too narrow. This was discovered during the VR-walkthrough, as it created a barrier impossible to pass and thus mentioned as an issue they could only discover in VR. Visible loadbearing beams in the ceiling was an issue discovered by both Groups A and B during the VR-walkthroughs. The Architect in Group B commented that in Revit, "you have the 3D-view, but you might not be inside the house then', which provides the necessary point of view.

Before viewing their own model, Groups A and B considered the use of VR primarily as something fun, something to try just for enjoyment. Both groups also mentioned viewing how the finished house had turned out and evaluating the lighting conditions. The Architect in Group A commented that it would be wiser to try VR earlier in the process. During the ICE2-meeting, they realised that the kitchen did not receive any natural light, something they regarded as a mistake. The Architect mentioned that they could have obtained a clearer feel for this issue by viewing the model in VR earlier, rather than just looking at drawings. However, most of the students in Groups A and B wished to wait with the VR walkthrough until the model was completed and fully furnished. The Project manager in group B stated that when they had finished everything they could 'do something that's not so educational and just play around with the model'.

After using VR in the ICE3-meeting, the students highlighted other positive aspects of the experience. The Architects in both groups commented that they realised the dimensions of the building and rooms by viewing the BIM in VR. In a discussion, the Architect and the Structural engineer in Group B agreed that one of the bedrooms had turned out to be a bit small and that they could have looked at it earlier and tried their hand with different sizes. Both groups also mentioned the satisfaction of seeing a result that could be interpreted as an actual finished building when viewed in VR. As the Project manager in Group B said, 'This is a project everyone in the group has been a part of. […] So, we are proud that, okay: at least we managed to create a finished building'.

4 DISCUSSIONS

4.1 Perceived usefulness

The access to the LBR was regarded as very useful by all groups to keep each other updated, to discover large or small errors, and as a dedicated room for collaboration. Groups A and B highlighted the usefulness of the large touchscreens for presenting and viewing the BIM, while Group C regarded the access to VR-equipment to search for errors in the model as the LBR's biggest advantage. After the ICE3-meetings, Groups A and B commented that VR would have been a useful tool in making design decisions. However, this potential was not utilised as they had regarded VR as a fun reward upon finishing the model rather than as a useful tool to improve the model.

4.2 Perceived ease of use

In the observed meetings, there were no signs of the students struggling to use the tools in the LBR. Most of the time, a student assistant was present to help them with unfamiliar tasks, but generally the tools appeared to be easy to use. The only remark on this came from a student in Group A who commented that the simple switching between VR-mode and editing in Revit offered a good workflow. At the end of Group A's ICE3-meeting, one student edited the model while another student was in VR, which made communication difficult as they did not know what the other was viewing and commenting on. This was mentioned as a challenge, although it could have been solved by using two screens.

4.3 External variables

The groups had two different approaches in the ICE2-meetings. Groups A and B followed the structure from the ICE1-meeting, presenting a status report while mainly showing the BIM on the large touchscreens, while Group C prioritised to use the VR-equipment. Group C's first ICE-meeting was not observed by the authors, but in the interview they said that they had viewed their own model in VR, while Group A, perhaps also Group B, viewed previous students' finished BIM. This suggests that the first ICE-meeting shapes how the students choose to utilise the LBR later in the project. The full potential of viewing their models in VR should therefore be demonstrated in the first meeting. Viewing an early draft of their model as part of this meeting could help them see how VR can be utilised in the process of making design decisions.

Despite their different approaches, the three groups were satisfied with their technology use. VR was not perceived as sufficiently useful, as they felt the assigned tasks could be completed successfully through viewing and editing their models on the large touchscreens and personal computers. To facilitate a better utilisation of the technology in the LBR, tasks more suitably solved with the use of VR should be added to the list of assignments. Included in this list could be tasks such as fault detection, window placement for maximum utilisation of natural light during specific hours, room layout, and perhaps furnishing. We also believe that students should be pushed to explore new ways of model-based teamwork, with a larger emphasis on the process rather than the product. Findings from a previous study on this course show that students spend considerable time on such projects, even though they regard the assessment 'Pass' as a disappointing reward for their hard work [10]. This suggests that there is a potential to nuance the focus towards exploration of new methods of collaboration in teamwork, without compromising their outcomes, and thus laying a solid foundation for the rest of their education.

5 CONCLUDING REMARKS

Considering the students were positive towards the technology and found it easy to use, there is potential for increased utilisation of the LBR. Not all students realised the potential of VR combined with BIM in time to implement it during their process. Small changes to the procedure of the ICE1-meeting and

the criteria in the task may contribute to shifting the students' perception of VR from a tool for detecting small errors or a reward for finishing a project to one of a valuable professional tool.
One complaint from the students was the difficulty of communicating while using VR, if the others were not seeing the same view. Technology has advanced in recent years to allow multiple actors to view the model in VR simultaneously while interacting, and one conclusion of this study should be to test the impact of such advances on the students' collaboration. The authors plan to do this in the fall of 2022.
Some of the advantages of using VR mentioned by the students such as gaining an understanding of the dimensions of the building lie beyond the scope of an engineer's responsibilities. However, in a world of increasing complexity that demands the ability to draw connections and to collaborate across disciplines, tools that aid in this will certainly add value. Familiarisation with such tools early in their educational curriculum may push students towards challenging the existing learning objectives.

5.1 Limitations and suggestions for further research

This study included a small sample of participants. Based upon the different approaches shown in this material, it is likely that including other or more groups would have given a different result. Doing a larger study, including more groups, would perhaps provide a more nuanced picture. A bigger task such as a shopping mall could encourage students to use VR to get a feel for the space while planning.
Effects of implementing the changes suggested in this paper, such as changing the list of criteria to pass or increased focus on the students' first introduction to VR, should be explored. Another suggestion for further research would be to investigate whether such lab-experiences will influence students to utilise such technology later in their education.

REFERENCES

[1] Asgari Z. and Rahimian F. P. Advanced Virtual Reality Applications and Intelligent Agents for Construction Process Optimisation and Defect Prevention. *Procedia Engineering*, 2017, 196, 1130-1137.

[2] Gyldendahl-Jensen C. Collaboration and Dialogue in Virtual Reality. *Journal of Problem Based Learning in Higher Education*, 2017, 5(1), 85-110.

[3] Sampaio A. Z. Education in Engineering: BIM and VR technologies improving collaborative projects. In *IV International Conference on Civil Engineering Education, EUCEET 2018*, Barcelona, September 2018, pp. 48-57 (International Centre for Numerical Methods in Engineering (CIMNE), Barcelona).

[4] Cárcamo J. G., Trefftz H., Acosta D. A. and Botero L. F. Collaborative design model review in the AEC industry. *International Journal on Interactive Design and Manufacturing,* 2017, 11(4), 931-947.

[5] Wood C. and Xavier P. Exploring applications of VR in civil engineering education. In *Realising Ambitions: Proceedings of the 6th Annual Symposium of the United Kingdom & Ireland Engineering Education Research Network*, Portsmouth, November 2018, pp. 168-179. (University of Portsmouth, Portsmouth).

[6] Liang L. M. Applied Research of VR Technology in Civil Engineering Teaching. In *2021 International Conference on Internet, Education and Information Technology (IEIT)*, Suzhou, April 2021, pp. 477-480 (IEEE Computer Society Conference Publishing Services (CPS))

[7] Delgado J. M. D., Oyedele L., Demian P. and Beach T. A Research Agenda for Augmented and Virtual Reality in Architecture, Engineering and Construction. *Advanced Engineering Informatics,* 45, August 2020.

[8] Sidani A. et al. Recent Tools and Techniques of BIM-Based Virtual Reality: A Systematic Review. *Archives of Computational Methods in Engineering,* 2019, 28, pp. 449-462.

[9] Ma Z., Zhang D. and Li J. A dedicated collaboration platform for Integrated Project Delivery. *Automation in Construction*, 2018, 86, 199-209.

[10] Lassen A.K., Hjelseth E. and Tollnes T. Enhancing learning outcomes by introducing BIM in civil engineering studies - experiences from a university college in Norway. *International Journal of Sustainable Development and Planning*, 2017, 13(1), 62-72.

[11] Venkatesh V. and Davis F. D. A model of the antecedents of perceived ease of use: Development and test. *Decision Sciences,* 1996, 27(3), 451-481.

[12] Davis F. D., Bagozzi R. P. and Warshaw P. R. User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, 35(8), 982-1003.

UTILISING MR TECHNOLOGIES FOR ESSENTIAL PROJECT-BASED LEARNING IN DESIGN EDUCATION

Santosh MAURYA[1], Yuval KAHLON[2], Takuya OKI[2], Jiang ZHU[2], Momoko NAKATANI[2], and Yufei LIU[2]
[1]Hitachi Ltd., Japan
[2]Tokyo Institute of Technology, Japan

ABSTRACT
The increasing use of digital platforms is bridging the distance between students and their instructors by augmenting student-instructor interactions. Yet when it comes to complex project-based and open-ended education content, the development of these platforms is far from complete. Especially seen in project-based learning environment, where multiple ways to teach, learn, and practice are required, real-world interactions are integral for encouraging exploration and implementation. Though recent works have shown the possibility of immersive technologies like AR/VR for teaching and hands-on experience, they are either strictly restricted to visualisation or require sophisticated equipment to be implemented as educational content. Here, a simplified and structured approach that can be directly used in the regular education environment, both in-house and remote, is needed. By taking a bottom-up approach through realistic use-case, this work demonstrates how to investigate and utilise/combine mixed-reality technologies for use in a PBL environment, targeting the values provided for education in general. Through a use case targeting design education activity in architecture, this work conducts a technological survey, evaluating available platforms/products and establishing PBL requirements, followed by mapping them to surveyed tech. The result of this work is a valuable MR Tech-PBL-education map, which can be used as a reference for designing interactive educational material.

Keywords: Future education technology, project-based learning, mixed reality, design education

1 INTRODUCTION
Recent technological advances with the unprecedented pandemic situation have catapulted the initiative of digitally transforming the education environment. Resultingly several remote digital platforms have emerged providing MOOC-like content, flexible in delivery to students and instructors communicating through web+video communication tools. Though such platforms have worked effectively for lecture-based education content, it has been hard to adapt them to *problem/project-based learning* (PBL) like content. For example, design education requires an experience-based approach regularly and requires a higher level of immersion in the education contents, making it difficult to adapt to current digital platforms for education. With the improvements and accessibility to immersive digital technology like human-computer interaction and mixed reality (MR), researchers have shown the possibility and effectiveness to improve the design [1], concept prototyping [2], evaluating [3], engineering design steps. Given the high immersion they provide, many of such works are specialised to achieve specific tasks like capturing the voice of customers [4] or design verifications through virtual prototyping [5] and require some level of expertise to create an immersive design platform. For example, though several use-cases of MR have been demonstrated for teaching and experiencing, they are either strictly restricted to visualisation or require sophisticated equipment for interactive learning. Also, a structured approach that can be directly used for design education for both in-house and remote environments require much work. In this work, we tried a bottom-up methodology to incorporate interactive and immersive tech like MR technologies within our design educational practices. By taking a bottom-up approach and utilising a real use-case, we demonstrate how to include MR in a project-based learning (PBL) environment to provide value for instructors, students, and education in general. In this study, we target PBL in design education in field of architecture.

2 BACKGROUNDS

2.1 Project-based learning in design education, requirements and reflections

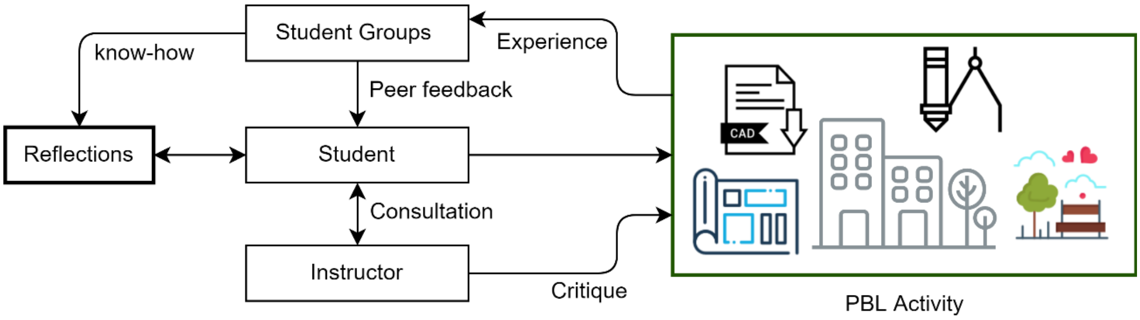


Figure 1. A generic PBL schematic

PBL is essential for students to create and learn independently, requiring students to learn a range of cognitive, thinking and technical skills to find and prototype their solutions. At the graduate level, like engineering or architecture, PBL is an essential part of the curriculum where students are expected to learn the concepts while creating something in real life. Students usually work in groups bringing their own experiences, abilities, learning styles and perspectives to the project [6]. A simplistic view of a PBL activity is represented through Figure 1, showing different interactions among students and instructors. In PBL activity, students continuously reflect on their experience constructing new knowledge. As a result, the PBL design activity/projects often resemble a complex system in which the participants create subjective reflections and values that are then interpreted, explored and standardised by the stakeholders involved in the activity [7], rather than simply measuring the objective outcomes of the design activity.

2.2 Immersive tech-based solutions in education and practice

The use of technology in design education or practice can be categorised primarily into two categories: design platforms or design tools. Design platforms, often seen in professional practice, can facilitate the complete design process from idea generation to final product and implement education frameworks like CDIO (conceive, design, iterate and operate) approach [8]. Design tools generally achieve a specific task and are relatively common for design visualisation, validation and concept prototyping [9, 10]. The application of such tools can be easily seen in the field of product design [11], spatial co-design [12], manufacturing [13], or STEAM education [14], to name a few. Some work on implementation frameworks like flowcharts has been proposed that (inexperienced) instructors can quickly develop AR experiences for higher education content [15]. In recent work, researchers showed the implementation [16] of an education system that uses Artificial Intelligence (AI) instead of instructors' direct instruction, indicating the digitalisation of educational practices in PBL activity.

2.3 Challenges

Students and instructors work in a studio in a traditional setting and often use a hands-on approach through rapid prototyping tools. In a studio environment, there is a possibility of working and getting feedback parallel to working with other students. When this setting is translated to the current online location, students and instructors work together through file-sharing or collaborating through a 3D environment and interact through video and audio. Concerning this online transition, a few challenges were observed considering the expected availability of such settings as non-verbal communication issues, variable instruction quality, varied motivation or stimuli for participants, difficulty to build team relations over hands-on activity, degree of collaboration etc. In conclusion, the contents and methods of the traditional approach cannot be transferred as it is to the digital space. The following sections present the process we followed to determine the suitability of MR tech for design education PBL in specific and discuss investigation results.

3 METHODOLOGIES FOLLOWED

To map out a reference framework to help educators create immersive and interactive PBL environments and education content, existing MR technologies and design education needs were surveyed. We focused on technologies and their feature that may suit specific requirements of a PBL concerning student and instructor activities. Resultingly, a relative mapping method focusing on `MR tech features` and `Target use-case criteria for PBL activity` was created, and then used as the evaluation criteria to judge the suitability of the surveyed tech with our project goals. Followed steps:

Part I: Survey MR tech in practice

- Surveyed the use of MR for education in various fields
- Highlighted common traits among them and identify their core contribution to education
- Defined a simple PBL activity performed in an architecture design course
- Extracted the MR features that would be required for PBL implementation

Part II: Mapping steps

- Established a generic student use case concerning course activity (architecture)
- Evaluated a list of available tools for relevance for use in PBL
- Mapped the extracted MR features to the tools based on required

4 ACTIVITY AND OBSERVATIONS

4.1 MR Survey Step Observations

First, a technological survey targeting immersion and engagement was conducted to understand and collect information on existing MR systems. Based on the surveyed tech, the following categories were observed: (1) headset-based solutions, (2) real-time simulation, (3) collaborative activity, (4) enhanced campus/laboratory experiences, (5) design Implementations like architectural design, and (6) physiological data-based user evaluations. A survey sample is shown in Table 1, showing special features of the surveyed tech and the categories they fall in.

Table 1. (Sample) Summary of surveyed MR tech in practice

Surveyed tech	Special features	Target
Spatial visualisation	Remote users can brainstorm and share content as if they were in the same room	Headset based solution, Collaborative activity
VSI HoloMedicine®	Streams lectures, procedures, and live surgeries directly into students' fields of vision	Headset, Real-time simulation
nextech AR - RALE	Creating AR experiences with live demos helps manage courses, Q&A, and Live sessions	Laboratory Experiences
SketchUp Viewer	Experience projects at a full 1:1 scale; teams can virtually inhabit a design	PBL, Implementation: Architectural Design
Verto Studio 3D	Able to convert about any format of the 3D model into a hologram	Headset, Implementation: Architectural Design
AR Spaceships by ARWAY	Captures unique feature points of the building by the camera, creates point cloud for later designs	Real-time 3D Measurement
Cardiolens	Potential for collecting feedback based on users' physiological behaviours	User Testing, behavioural data

4.2 MR contribution to PBL-educational activity among the surveyed solutions

We broadly identified the following attributes which make MR suitable for use in respective educational environments the capabilities and possibilities of MR technology in the field of education:

- Creating a more immersive experience - delivering immersive and interactive digital content)
- Enabling field observations/Exploratory expeditions: "virtual travel", untethered by the place
- Transforming to hands-on learning
- Promoting better collaborations and teamwork, and problem-solving - soft skills development
- Improving PBL activity thorough support for meetings, presentation, course prototypes (teaching), problem prototypes (student activity)
- Enhancing the knowledge understanding
- Recreation or simulation of past experiences for new learners
- Individualised learning and facilitation of self-directed learning - Course Management Platform

4.3 Selecting MR features required for facilitating the PBL activity

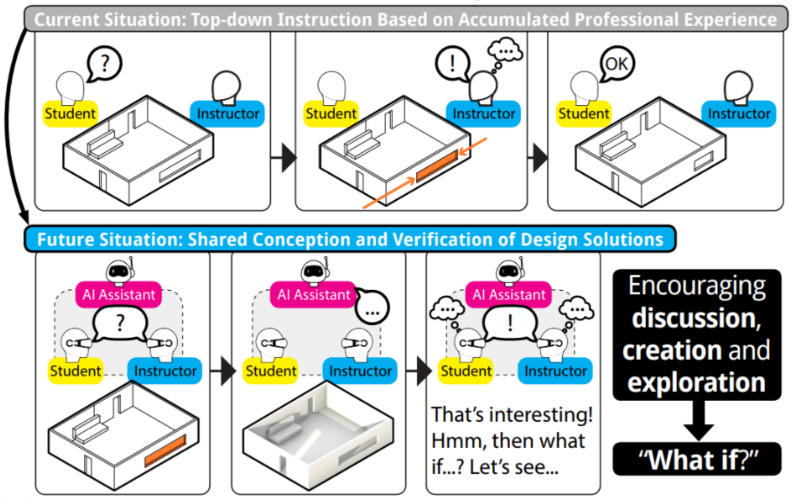


Figure 2. Explorative PBL project scenario: (top) traditional and (bottom) using digital tech

We considered a simple PBL activity for listing the *required features* in the solution system. It includes discussions and hands-on activities by the student, where students can work together, and the instructor can provide constructive feedback. A sample PBL scenario, where students design room considering furniture arrangement, lighting, position and size of windows and resulting shadows, is represented in Figure 2 as a traditional setup and future setup. Here traditional setup activity represents student and instructor simply discussing over a model (physical/digital). The Future setup activity, MR based setup, represents student and instructor individually supported through quick visualisations and smart checks. Based on the individual evaluation of the activities and support required for the mentioned PBL use case, we outlined the MR tech features that can be used to create an explorative educational environment that promotes discussion, mentioned in Table 2.

Table 2. Identified required-MR functionality suitable to PBL activity in Figure 2

	Definitions/explanations	**Req. features**
1	The ability to engage as a team remotely	remote collaboration
2	View and share models with others like HoloLens user/ mobile devices	visual sharing
3	Making notes or symbols by a gesture using 3D objects	tracking/ 3D marker
4	Multiple people interaction on the design, on-premises/remotely	multi-device support
5	Available for conference/meeting recording	Capture activity
6	Instantly turn speech into context for remote/ digital content	speech recognition
7	Search for information and visualise them in the surrounding space	Info. collection
8	Real-time speech recognition and translation	live translation
9	Change the conference environment or outside scenery	VR environment
10	Place holographic 3d model in any space at any angle, any scale	holographic mobility
11	Working with design in layers for easier handling	manipulate layers
12	Combine real space with a holographic model in 1x1 mode and experience the model from an inside viewpoint	immersive mode
13	The ability to duplicate, subdivide, smooth, extrude, rotate, scale, weld, apply textures in the 3D model by using gesture	3D modelling
14	View/interact with 3D tools like Grasshopper parameters in real-time	real-time edits
15	Simulate shadows and shadings resulting due to light simulations in the design environment that allows informed user decision and design	Scenario simulation
16	Ability to review structural MEP that can be referenced with PBL design activity assets, overlaying them onto the real world	3D model review

4.4 Mapping required PBL-related features to survey MR tech

Targeting student activity in a typical PBL exercise, we tried to identify the ability of surveyed MR tech (or lack of) to support the future PBL scenario from Figure 2. Here, the higher the support a given MR tech provides, the better it is for PBL in design education. A sample MR tech evaluation is shown in Figure 3 where the presence of required feature is checked if they are present in the surveyed MR tech. A summary of user scenario-based MR solutions evaluation is shown in Table 3, in which the presence is indicated by the feature number mentioned in the table taken from Table 2. A relative normalised value (RV) is calculated considering all the required features mentioned in Table 2 as the complete set for the PBL scenario, where all features are considered equally important. RV is shown as a percentage, indicating relative significance or Value for the PBL scenario.

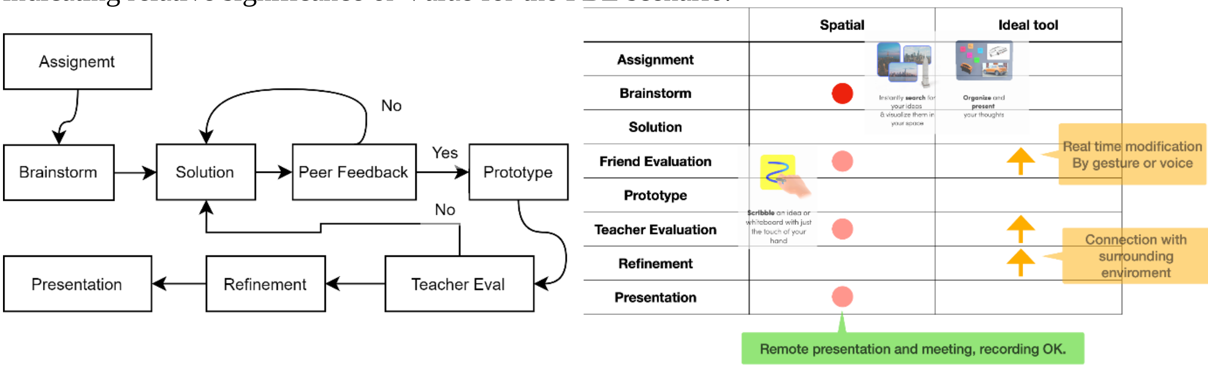


Figure 3. (left) typical student activity; (right) sample MR tech evaluation

Table 3. Potential for use in mentioned PBL Scenario: Sample set of surveyed MR tech

Surveyed tech	**Sketch up Viewer**	**Mr Builder**	**Fologram**	**Verto Studio VR**	**basics-model**	**Microsoft Mesh**
Available features	2,10,11,12	2,10,11,12	2,4,10,11,13,14	10,13	15	1,2,3,4,10
RV (%)	25.00	25.00	37.50	12.50	6.25	31.25
Surveyed tech	**Spatial**	**Whiteroom**	**Trimble XR**	**nextech AR-RALE**	**AltspaceVR**	**VSI Holo Medicine®**
Available features	1,2,3,4,5,7,8,9	1,2,3,4,5	2,16	1,2	1,2	2,10,16
RV (%)	50.00	31.25	12.50	12.50	12.50	18.75

5 DISCUSSIONS

The survey and evaluation activity are in its early phase, and its robustness is expected to increase with the increase in surveyed tech and application fields. With variations in the use-case scenario implementations, the created evaluations and *MR Tech-design Education map* can be directly used to identify the minimum MR tech required based on the features necessary to support a given PBL activity. Referring to this map, two or more MR tech can be combined to realise the whole required features for the target PBL activity. This map allows for customising MR implementations, which can be further improved by considering special requirements that can be different for students, instructors and education in general. The *value for the PBL scenario*, mentioned in Table 3, currently assumes all features have equal significance; here, the required features can be weighted based on the target scenario, where the weights would indicate the importance for students, instructors and education in general. Value for students can include features allowing quick prototyping, stimuli generation and peer discussion; value for the instructor can focus more on activity evaluations focusing more on the path followed by the students. Value for education can be treated as combined value for students and instructors. Still, it may include external factors like the availability of particular MR solutions, the cost of implementing it in a PBL classroom that can have multiple students, and finally, the difficulty of setting up or adapting to a specific PBL activity.

6 CONCLUSIONS

This research aims to create a structured methodology for positioning existing MR technologies within our future interactive educational practices. By taking a bottom-up approach and constructing realistic use-cases, we demonstrate how to include MR in PBL environments to provide value for instructors and their students. The result of this work is a valuable MR tech map, which can be used as a reference for designing interactive educational material towards the boundaries of MOOCs or online classes in PBL. We surveyed existing commercial MR systems and platforms used in practice in the real world. For example, MR tech usage in medical, civil/architectural, or educational activities, to name a few. We then designed generic use-cases representing typical in-person lectures and PBL activities, both instructors' and students' perspectives. By aligning these use-cases with the unique features identified in our survey, we formed a relational map that sheds light on the suitability of each platform/technology for PBL. The resulting map proposes clear insights into the relative importance of each technology for PBL, emphasising its potential value for instructors/students in a given educational use case. Future work would include improving the robustness and ease of use of the created map.

ACKNOWLEDGMENT

This research is supported by the Laboratory for Design of Social Innovation in Global Networks (DLab), Tokyo Institute of Technology, Japan.

REFERENCES

[1] Rahimian F. P. and Ibrahim R. Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design. *Design Studies*, 2011, 32,255-291.

[2] Maurya S., Mougenot C. and Takeda Y. Impact of mixed reality implementation on early-stage interactive product design process. *Journal of Engineering Design*, 2021, 32(1), 1-27.

[3] Johnston A., Candy L. and Edmonds E. Designing and evaluating virtual musical instruments: facilitating conversational user interaction. *Design Studies*, 2011, 29(6), 556-571.

[4] Carulli M., Bordegoni M. and Cugini U. An approach for capturing the voice of the customer based on virtual prototyping. *Journal of Intelligent Manufacturing*, 2013. 24(5), 887-903.

[5] Mejía-Gutiérrez R. and Carvajal-Arango R. Design verification through virtual prototyping techniques based on systems engineering. *Research in Engineering Design*,2017,28(4),477-494.

[6] CDIO. *Project-Based Learning in Engineering Education.* Available: http://www.cdio.org/knowledge-library/project-based-learning. [Accessed 14 March 2022].

[7] Wang T. A new paradigm for design studio education. *International Journal of Art & Design Education*, 2010, 29(2), 173-183.

[8] Maurya S. and Ammoun O. Implementing CDIO Approach in Integrated Digital Environment. In *14th International CDIO Conference*, Japan, June 2018.

[9] Maurya S., Takeda Y. and Mougenot C. Enabling designers to generate concepts of interactive product Behaviours: a mixed reality design approach. In *Proceedings of the Design Society: International Conference on Engineering Design, ICED19*, Vol 1(1), 2019, pp. 1933-1942.

[10] Bordegoni M., Ferrise F., Wendrich R. and Barone S. Virtual and mixed prototyping techniques and technologies for consumer product design within a blended learning design environment. In *DS 92: Proceedings of the DESIGN 2018*, 2018.

[11] Tang Y., Au K. and Leung Y. Comprehending products with mixed reality: Geometric relationships and creativity. *International Journal of Engineering Business Management*, 2018, 10, 1847979018809599.

[12] Maurya S., Arai K., Moriya K., Arrighi P.-A. and Mougenot C. A mixed reality tool for end-users participation in early creative design tasks. *International Journal on Interactive Design and Manufacturing*, 2019, 13(1), 163-182.

[13] Juraschek M., Büth L., Posselt G. and Herrmann C. Mixed reality in learning factories. *Procedia Manufacturing*, 2018, 23, 153-158.

[14] Birt J. and Cowling M. Toward Future 'Mixed Reality' Learning Spaces for STEAM Education. *International Journal of Innovation in Science and Mathematics Education*, 2017, 25(4).

[15] Chlebusch J., Köhler I. and Stechert C. Reasonable application of augmented reality in engineering education. In *Proceedings of the Design Society: DESIGN Conference*, 2020.

[16] Ito T., Tanaka M. S., Shin M. and Miyazaki K. The Online PBL (Project-Based Learning) Education System Using AI (Artificial Intelligence). In *Proceedings of the 23rd International Conference on Engineering and Product Design Education, E&PDE 2021*, Herning, 2021.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

AN INTERACTIVE SPATIAL ABILITY TRAINING APPROACH FOR STEM EDUCATION

Chi Hei NG, Leong Ying CHAN, Chun Yu CHIU, Yuen Suet LAI and Yi-Teng SHIH
School of Design, The Hong Kong Polytechnic University

ABSTRACT
While governments around the globe have been promoting science, technology, engineering, and mathematics (STEM) education for years, reports are pointing out the difficulties in learning for students. In response to the urge to improve the STEM education approach raised by society, numerous scholars proposed providing spatial ability training to students could be a possible solution. While spatial ability, especially mental rotation, has been proven by numerous researchers to be essential for success in STEM education, yet the implementation of spatial ability training in STEM education is still absent or insufficient. Our study focuses on proposing a spatial training approach with physical elements. This paper will discuss our attempts at converting the spatial training assignment into a physical educational toy. With our tests conducted in assessing the spatial ability before and after using our educational toy, we may conclude the success and limitation of the toy in improving a person's spatial ability. Thus, we propose conducting similar research with a larger sample size and try recreating a similar result to prove the success of our toy Turnit-In.

Keywords: Spatial ability, primary education, STEM, mental rotation learning of geometry

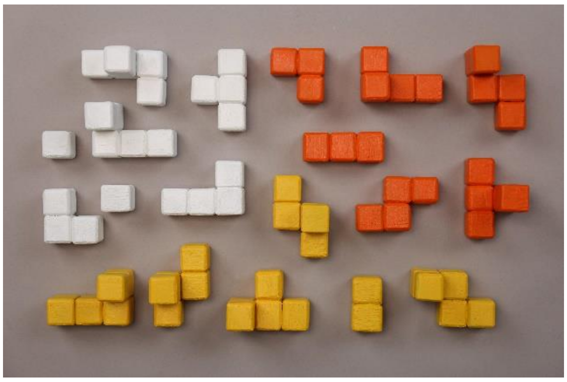


Figure 1. Turnit-In Final Design

1 INTRODUCTION
It is said that primary education is a crucial phase for a child's growth. During the primary education, different basic skills would be taught which are all essential for achieving comprehensive development in the future. Primary school learning goals should seek to perpetuate students' whole-person development, which includes improving students' language proficiency, strengthening their self-directed learning skills, developing their potential, and assisting them in adopting a healthy lifestyle. By going through all the levels of teaching, the child would become more independent and capable of handling their future study or personal development.
However, Hong Kong is widely recognized as an *exam-oriented place*, Hong Kong students are known for their lack of retention, creativity, life skills and communication. By receiving the cramming education, children are told to "recite" their learning material without thinking and understanding. They are not allowed to explore the outside world. Hindering other aspects of development can be destructive to children, children studying under the exam-oriented education system will result in low-stress tolerance and poor interpersonal relationships, further leading to stress, anxiety, and fear problems.

An interdisciplinary teaching approach named Science, Technology, Engineering and Mathematics (STEM) might be a cure to change this problematic situation. As a problem solving-based model, STEM requires the students to design and develop their knowledge, thus applying it to solve the real problem. Meanwhile, the academic ability is trained up and their mental strength as going through the trials and errors strategies that make them adapt to work with failures and mistakes and hence become more capable of working under pressure. The following chapter will discuss how STEM can apply better to the current situation.

2 OBJECT DESIGN

Research has already shown the significant benefits of spatial and mental rotation ability to STEM education, yet we believe the existing training methods are often test-orientated and not entertaining. Therefore, our study proposes an improved physical spatial ability training tool that appeals to children.

2.1 STEM educational tools

By inspecting the existing STEM educational tools in the market, we may understand the limitations of current STEM products in spatial ability training. To study the effectiveness and success of a STEM product, we propose six criteria in measuring: visual appeal, replay-ability, product complexity, problem difficulty, spatiality, and interaction between players. Through our market research, we discovered that existing STEM products lack interaction among players and generally have a lower spatiality level. In order the improve the spatial and mental rotation ability among primary one to three students, we believe we must enhance the spatiality aspect. With more opportunities for interaction among players in toy playing, students may also improve their spatial presentation skills.

Figure 2. STEM educational tools

2.2 Soma Cube

During our market research, we discovered Soma Cubes can be a foundation for our design to improve one's spatial and mental rotation ability. Piet Hein designed the Soma Cube in 1933. It is an irregular shape created by putting three or four identical cubes together on various faces. There are seven distinctive Soma Cubes, two of which are mirror images. It contains six tetracubes and one tricube, which can be put together in 240 distinct ways to form a 3x3x3 cube with a total of 27 unit-cubes.

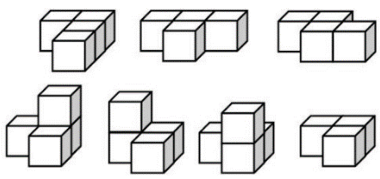
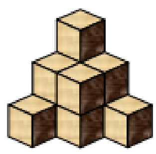



Figure 3. Seven distinct Soma Cubes (L); Figure 4. Example of Soma Cube combination (R)

Soma Cube has different combinations of building methods, for example, a sofa, a chair, a castle, a tunnel, a pyramid. A lot more combinations can be formed, in the process of variety, need to use spatial and mental rotation ability. For example, if only one can use three soma cubes to build the solid shape in figure 1, one needs to imagine the front, side, top views of the reference figure and find out three of the soma cubes can match, requires spatial and mental rotation ability.

2.3 Advance

To propose a toy to develop spatial and mental rotation ability for primary one to three students, the difficulty of basic Soma Cube set is easy to handle. In addition to the standard set of Soma Cubes, other combinations of Soma Cubes represent different difficulties. For example, using only four Soma Cubes in figure 2 can be combined into a 3x3x3 cube.

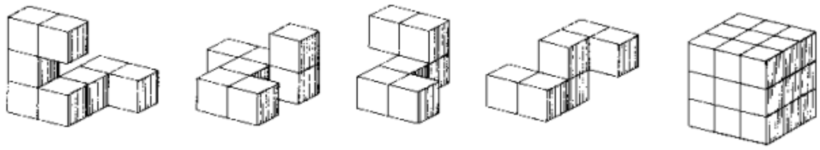


Figure 5. Example of 3x3x3 Soma Cubes advance combination.

However, different combinations of Soma Cubes in 3x3x3 cubes are not enough to develop into a toy; the final proposal of the combination is to change from 3x3x3 cubes to 5x5x5 cubes. Figure 3 is a 5x5x2 cubes combination.

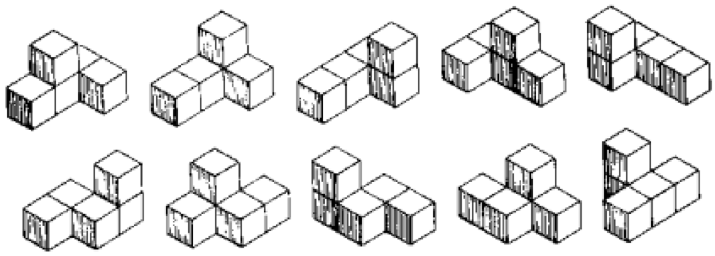


Figure 6. Example of 5x5x2 Soma Cubes advance combination.

We found inspirations from the Soma Cubes' form, thus elaborate its playstyle by enriching the spatial ability and balancing training content. We then modified the combinations of blocks to increase the complexity and playability. Our toy consisted of 2 sets of 5x5x2 cubes combination and 1 set of 5x5x1 cubes referenced from the basic Soma Cube set, in total 28 items of 3D objects, providing more possibilities for children to develop their combinations. To prove the effectiveness of our design, we conducted an experiment and compare the spatial and mental rotation ability of our participants before and after two weeks of the experiment.

3 METHODOLOGIES

3.1 Participants

We gathered 12 children to participate, ages from 7- to 10-year-olds, with 7 boys and 5 girls. The sample was predominantly Asian children in Hong Kong. All the participants are from primary one to primary three students. In that 12 children, 4 boys and 2 girls, have STEM school backgrounds, and the other 3 boys and 3 girls do not.

3.2 Material

The material of the experiment included a spatial and mental rotation ability training toy and two tests based on existing spatial and mental rotation ability questions as a task for participants to solve personally. To provide a tool to help participants learn spatial and mental rotation, a toy, Turnit-In, is designed by us to train the spatial and mental rotation ability. Turnit-In consisted of 28 items of 3D objects, one set of cards about the front, side, top of 3D objects. Two of the participants in one group play the Turnit-In. Before and after two weeks of training with Turnit-In, we would provide players with a spatial and mental rotation ability test for recording the data, mainly including the time-taken and the accuracy of the test. We used the mental rotation test proposed by Vandenberg and Kuse (1978) for the experiment. The test consists of 24 items of 3D objects (two sets of 12 each). Each item is made up of four target figures on the right and one reference Figure 4 on the left. The participants were instructed to find the two right choices that were identical to the reference figure on the left.

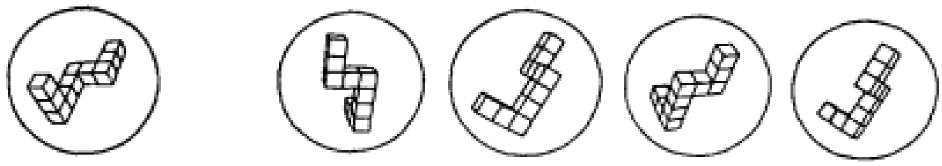


Figure 7. Example of mental rotation test sample items from Vandenberg and Kuse (1978).

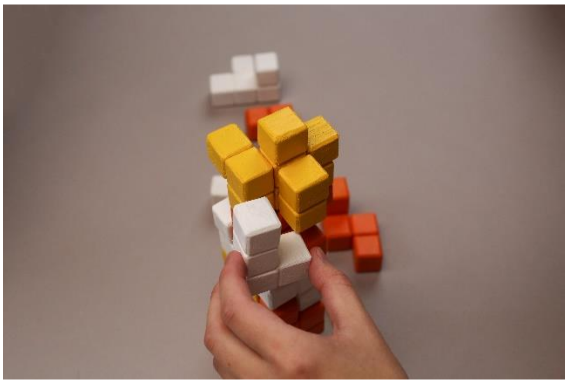
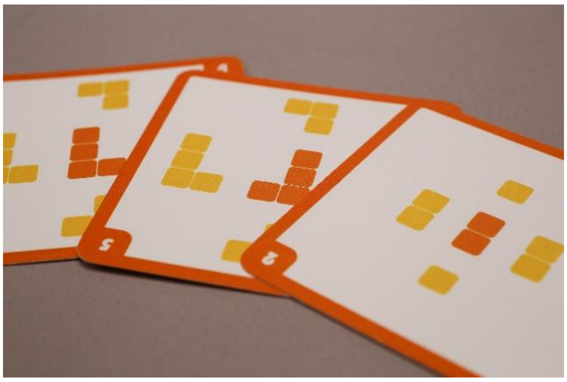



Figure 8. Game demonstration of Turnit-In (L); Figure 9. Cards of Turnit-In (R)

3.3 Testing

We provided the mental rotation test proposed by Vandenberg and Kuse to primary school students, and we discovered the difficulty of the test was challenging for primary one to three students in Hong Kong. To adjust the test's difficulty, we proposed that each item is made up of three target figures on the right and one reference figure on the left. The participants were instructed to find the one right choice identical to the reference figure on the left.

3.4 Procedure

Participants were asked to do the experiment in a studio. Children first received a spatial and mental rotation ability test provided individually. The test needed to count the time taken and the accuracy before playing Turnit-In. When the children finished the first test, they were separated into six groups, two in one group to play Turnit-In. Children were asked to draw a card randomly to get a front, side, top view of the parts. Recognize the part that matches the card and stack the parts up, from the base plate. Trying to balance and construct the taller blocks. The one whose blocks fall is considered a loser. The children would be asked to play three times per day, three days per week, Monday, Wednesday, and Friday, the toy given would let the children play two weeks in the studio. The children came after school and played with their partners. After two weeks of training with Turnit-In, the children were asked to do the spatial and mental rotation ability test again with different questions again. Collecting the data of the time taken and the accuracy again. Comparing the pre-test and post-test of playing Turnit-In data to analyse if there is any improvement of the children spatial and mental rotation ability.

4 DATA & ANALYSIS

In this study, 12 local students studying in primary school in the academic year 2021- 22 were selected in the age groups of seven to ten years old (P1 - P3) as the samples. Half of the students are from STEM approach school while the remaining half is from or non-STEM approach school. The accuracy and the time taken for both pre-test and post-test is recorded in Table 1. The description and analysis of the data will be included in section 4.1.

Table 1. Result of pre-test and post-test of 12 participants

STEM School	Pre-Test		Post-Test	
	Accuracy	Accuracy	Accuracy	Accuracy
P1	0	05:36	1	06:01
P1	1	06:41	1	06:13
P2	2	05:12	2	04:54
P2	3	04:03	2	03:58
P3	2	03:29	3	03:20
P3	4	04:10	4	03:58
Non-STEM School	Pre-Test		Post-Test	
	Accuracy	Accuracy	Accuracy	Accuracy
P1	0	06:35	0	06:28

P1	0	05:56	1	06:04
P2	1	03:57	0	02:45
P2	2	04:50	3	04:52
P3	3	04:16	3	03:51
P3	3	03:32	4	03:28

Table 2. Average accuracy rate and time for the mental rotation test

STEM School	Pre-Test		Post-Test	
	Accuracy rate (%)	Time taken (min)	Accuracy rate (%)	Time taken (min)
P1 average	12.5	06:08	25.0	06:07
P2 average	62.5	04:37	50.0	04:26
P3 average	75.0	03:49	87.5	03:39
Average	50.0	04:51	54.2	04:44
Non-STEM School	Pre-Test		Post-Test	
	Accuracy rate (%)	Time taken (min)	Accuracy rate (%)	Time taken (min)
P1	0.0	06:35	0	06:28
P2	37.5	05:56	1	06:04
P3	75.0	03:57	0	02:45
Non-STEM School Average	37.5	04:50	3	04:52
	Pre-Test		Post-Test	
Total average of both school	43.8	43.8	43.8	43.8

4.1 Task data analysis

In this test, we set the accuracy rate of the task as the measurement of spatial ability. The accuracy rate for the 4 questions from the mental rotation test proposed by Vandenberg and Kuse has raised moderately (4.2%) for the STEM approach school students, while it raised moderately (8.3%) for the non-STEM approach school students. For both test and school types, the accuracy rate is highest in P3 and lowest in P1. It is also found that STEM school students perform better than non-STEM school students. A notable effect could be observed, particularly in non-STEM schools, where the average correct answer increased from 1.5 to 1.83 within 4 questions. Performance of both P1 and P3 students has improved by 12.5%, noted that the accuracy rate of P1 raised significantly when there is no syllabus about three-dimension taught in school. This improvement in mental rotation ability can be considered as the effect of the toy.

4.2 Behavioural data analysis

Our findings revealed that the toy was in favour of children's response to mental rotation processing. The average time taken by P1 to P3 students in both STEM and non-STEM approach schools has slightly shortened, by 1.55% (from 4.51 minutes to 4.44 minutes) and 3.80% (from 4.51 minutes to 4.34 minutes) respectively. A significant improvement could be seen when comparing pre-test and post-test, especially for the P3 students. A similar effect in favour of P2 students was observed when comparing the average time taken to complete the tasks. This analysis indicated that the toy provides somewhat a stronger impact to P2 and P3 students on the response to mental rotation tasks than P1 students, even though both have medium effect sizes.

5 DISCUSSION & CONCLUSION

5.1 Result

This study was designed to investigate the effect of Turnit-In on mental rotation performance among participants. Firstly, the P3 students were found to score higher than the P1 students, followed by the P2 students. And the students studying in the STEM approach school perform better than those who study in the non-STEM approach school at the same level. We ascribe this to an increase in overall processing

speed and rotation rate with age. Another factor that is attributed will be their school programmes, notably STEM courses, which may significantly contribute to improving their visuospatial ability.
Secondly, we noted that the P1 students struggled during the test, even though the Vandenberg and Kuse mental rotation tests had been adjusted. A lack of fundamental information about space might be one of the reasons. We believe that further experimental investigation will be required to elucidate the situation, particularly for this group. However, the current findings suggest that the toy may be sufficient to increase mental rotation ability in P2 and P3 students in the near term. Besides, owing to the pandemic, this study will not be able to run a big group. One of the limitations of this study was the lack of a big group to analyse and compare the effectiveness of Turnit-In. Hence, it is uncertain whether the same findings will hold for a larger sample of students. Yet, our experiment confirms the toy can improve spatial abilities in terms of accuracy or responding time. The development of mental rotation ability with Turnit-In can be wielded throughout the school programme, regardless of a game or toy playing during recess time, and/or a teaching tool for assisting the school syllabus. It tests students' ingenuity and knowledge.

5.2 Conclusion

Our research analysed the existing STEM toys in the market by assessing their level of visual appeal, replay-ability, product complexity, problem difficulty, spatiality, and interaction between players. We then discover that the existing products lack spatiality train in their design. Our research finds that the Soma Cube is a well-designed spatiality training method; hence, we developed our Turnit-In with Soma Cube as one of our references.
To examine the successfulness of the spatial training capability of our design Turnit-In, we researched testing the player’s spatial ability before and after they play with our toy for a period. We invited six children from STEM schools and six from non-STEM schools to participate in the test. Our result shows that the players may improve their spatial ability after playing with our toy. Comparing the pre-test and post-test results, we discovered their accuracy rate has improved, and their time in completing the task has shortened. Therefore, we conclude that our toy Turnit-In may help players improve their spatial and mental rotation ability. We will conduct a similar experiment with a larger sample size in the future. We will then further prove the success if we can recreate the result.

REFERENCES

[1] Shriki A., Barkai R. and Patkin D. Developing mental rotation ability through engagement in assignments that involve solids of revolution. *The Mathematics Enthusiast*: Vol. 14: No. 1, Article 28. Available: https://scholarworks.umt.edu/tme/vol14/iss1/28 , (2017).

[2] Fernández-Méndez L., Contreras M. and Elosúa M. From What Age Is Mental Rotation Training Effective? Differences in Preschool-Age but Not in Sex. Front. Psychol. 9:753. Available: *DOI: 10.3389/fpsyg.2018.00753*, (2018) 16 May.

[3] Frick A., Hansen M. and Newcombe N. Development of mental rotation in 3- to 5-year-old children. Available: *https://doi.org/10.1016/j.cogdev.2013.06.002*, (2013).

[4] Lütke N. and Lange-Küttner C. Keeping It in Three Dimensions: Measuring the Development of Mental Rotation in Children with the Rotated Colour Cube Test (RCCT). *International Journal of Developmental Science*, vol. 9, no. 2, pp. 95-114. Available: DOI: 10.3233/DEV-14154, (2015).

[5] Geng J., Jong M. and Chai C. S. Hong Kong Teachers’ Self-efficacy and Concerns About STEM Education. The Asia-Pacific Education Researcher 28(1). Available: *DOI: 10.1007/s40299-018-0414-1*, (2018) October.

[6] Delavar M., Kolesnikova I., Rahimzade B., Ghahhari M., Mosapuor A. and Moradi A. Development of mental rotation ability at primary school level. World Scientific News 101 (2018) 77-88. Available: *https://www.researchgate.net/publication/342832766_Development_of_mental_rotation_ability_at_primary_school_level*, (2018) June.

[7] Vandenberg S. and Kuse A. Mental Rotations, a Group Test of Three-Dimensional Spatial Visualization. Sage Journals Vol 47, Issue 2. Available: *https://doi.org/10.2466/pms.1978.47.2.599*, (1978) 1 December.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

MULTI-GENERATIONAL LEARNING IN THE CONTEXT OF TOY DESIGN

Tse-Yen YEH and Yi-Teng SHIH
School of Design, The Hong Kong Polytechnic University

ABSTRACT
Education is a vital process for everyone, it helps people to think, feel, and behave, which contributes to their success. Education is important not just for children but also for the elderly. The increasing proportion of elderlies globally raises the importance of lifelong learning, specifically elder education. Furthermore, the significance of the grandparent-grandchildren relationship increased due to two factors: The number of grand families - the nuclear family living with the grandparents - increased globally by 7.3% (Beltran, 2019), and the average lifespan of people increased. Therefore, multi-generational learning, the learning derived from old and young generation interaction, takes an important role in families and society as a whole. Past studies show that multi-generational education benefits both age groups in various ways. For children, grandparents offer life wisdom, acceptance, love, and positive effects on a child's well-being, whereas for the elderly, having strong connections with the younger generation allows them to be exposed to new ideas and information, especially technology-related knowledge. Based on the research conducted, results show that over 70% of parents and grandparents find a lack in grandparent-grandchildren interaction, reducing the chances of multi-generational learning, whereas the majority of them find indoor toys a good tool to boost grandparents-grandchildren interaction. According to the criteria stated, a toy was specially designed for elders and children to enhance the training skills, boost the entertainment aspect of existing toys, and at the same time increase multi-generational learning and interaction. Based on the feedback from users, possible improvements were identified and modified for future development.

Keywords: Education, grand families, multi-generational learning, toy design

1 INTRODUCTION
Play is the highest form of research' - Albert Einstein. Learning is not and should never be purely sitting in the classroom with a transmissive teaching style. Learning can be derived through having fun, through conversations and interactions, and game/toy play. During play, learning is less regimented, this often leads to unexpected outcomes, allowing lateral thinking to happen. This applies to people at all ages, from children to the elderly. Hence, the idea of learning with multi-generational education through game play is established and developed in this paper, hoping to contribute to the education field uniquely.

2 BACKGROUNDS

2.1 Importance of education for children and elders
Education, the obtaining of knowledge and understanding a variety of subjects to be applied in daily life, takes an important role in a human’s life. It is vital because it provides stability in life, allowing individuals to achieve better possibilities in career and personal growth (Eugene, 2015).
Children’s education is very important because it provides them with the tools and mental characteristics required to excel in life (Anglia, 2020), which has the power to change lives, whether being the tool for breaking the cycle of poverty, supporting child survival, development and well-being; and minimizing the social inequality gap (UNICEF, 2014). Although children's education is important, elder education also plays a decisive position in society, but is often being forgotten by the public. As the saying goes: ‘It is never too old to learn’, elder education should be encouraged and attach importance to the society because it can benefit elderlies in various ways. For example, the opportunities for elders to pursue studies and participate in different social interactions can foster their physical and mental well-being (Elder academy, 2020).

2.2 Multi-generational education

Since children's education and elder education are both important to the individuals as well as to the society, 'multi-generational education' becomes an area worth exploring. Multi-generational education is a learning which stems from younger and older people interacting, whereas the older generation can offer the younger generation life wisdom, acceptance, love, stability to children, and having positive effects on child's well-being. For example, elders can teach the children how to react and continue with life setbacks. On the other hand, the older generation having connections with the younger generation can be exposed to different ideas, boost brain function, protect against depression, and even increase lifespan (The Waterford, 2017). For example, children can teach the elders how to use the technical devices. Most importantly, with the increasing interaction between elders and youngsters, multi-generational education can strengthen grandparent-grandchildren bonding, or family bonding, creating strong emotional ties with each other. Therefore, multi-generational education provides valuable insight which contributes to each family as well as the whole society.

In addition, according to the WHO, the proportion of the world's population over 60 years old will nearly double from 12% to 22% between 2015 and 2050 (WHO, 2021). With the increasing ageing population globally, it is essential that the different generations can have positive interactions and each group should acquire knowledge from one another. Furthermore, the aging population has brought attention to the generation gap created, which is the difference in values and attitudes between two generations because of the misunderstanding of each other from their different experiences, opinions, habits, and behaviours (Mendez, 2008). In order to reduce the generation gap, increasing generation interaction and multi-generational learning is considered a suitable way.

However, this is easier said than done. Multi-generational learning is difficult to achieve through the traditional education style, or in other words, providing them with the learning materials and asking them to read, write and speak. Another type of learning should be conducted, and this is through educational toys. 'Playing is the best way kids start to learn; playing is the best way elders come back to learn'. The benefits of playing games and toys for children is that it encourages them to enhance their senses, spark their imagination and boost their social skills, which help their intellectual and motor development (Skipy, 2020). Toys are often dismissed as 'just for fun' but playing is essential for children since it enables them to 'learn about and interact with their world, and gain the mental, physical and social skills necessary to succeed in their adult lives' (Lily, 2021).

Through multi-generational toy playing, children can engage in conversation with seniors, which can practice their listening skills, especially when elderlies often do not speak clearly. Children can also promote creative thinking using their imagination in play, and also help them express their thoughts and feelings more openly to their family members. The benefits of playing games and toys for elders is that it encourages them to communicate and interact with the children, letting them learn the ways to interact with the children to make them both comfortable and engaged. Mentally, it can train their working memory, the ability to temporarily store information in mind while working on other tasks, which is very critical to their lives as it helps elders recall important information that they may need at a particular moment. Physically, it can strengthen muscle control, while also increasing blood circulation. Therefore, linking the above to multi-generational education, if an interactive toy is being designed specifically for elders and children to play together, it will enhance multi-generational learning through various ways. The grandchildren, grandparents, parents, the whole family bonding will be strengthened through a simple toy design. Although the toy may not be the only factor bringing family members together, it surely will begin the generational interaction and bring a positive atmosphere within families.

3 DATA COLLECTION / METHODOLOGY

3.1 Collection method

Based on preliminary research, multi-generational education can be achieved through toy design. To further understand the necessary form and function of toys to be most effective for cross-generational education, primary research in the form of surveys and interviews were conducted via google forms and video calls (which could not be recorded due to privacy issues).

3.2 Online survey

To be specific, the surveys are mainly focused on participants aged between 15 to 55, given that they will be the targeted product initiators, i.e., they are the main groups who will buy the toy. Questions from different categories, such as types of toys and or games, ideal materials, playing environment etc., were made into multiple choice questions for easier and specified responses.

3.3 Online interview

6 interviews were conducted, ages ranging from 33 to 87, with 3 parents and 3 grandparents. The interview focused on the parents and grandparent's opinion. Grandparents were included in the interview part since they have the ability to speak out their ideas clearly. The interview questions are freer compared to the survey since allowing the users to express their ideas and opinion freely can stimulate innovative ideas which were not thought of during the survey.

4 DATA ANALYSIS

4.1 Survey results

Over a period of 1½ months, there were a total of 131 survey participants, Figure 1. A majority of participants (~80%) preferred board games and puzzle games as they consider these to be the easiest game to understand and play. 77% of the respondents preferred indoor toys, one of the main reasons being the impact of COVID-19, most people work from home and stay home for most of the time. Regarding the toy colour combination preference, 41.3% of the respondents chose Red & Blue because the two colours are commonly considered as competitive colours, increasing tension between players. Finally, when asking participants how the grandparent-grandchildren can be improved, 38.9% believe more interactions will benefit the most, with 32.2% of the participants considering playing toys and games together can improve the relationship.

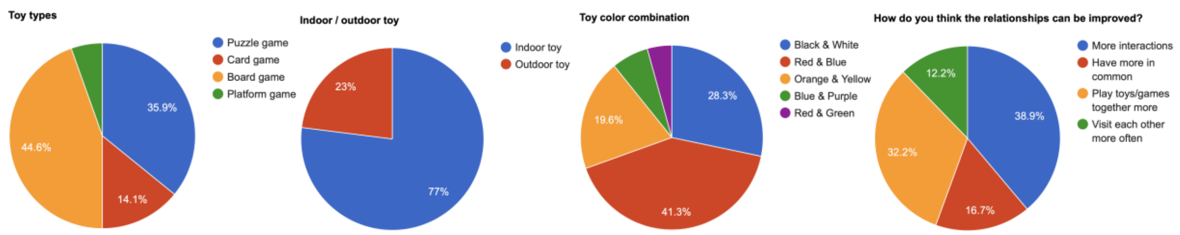


Figure 1. Pie chart survey results

4.2 Interview results

Statistics about multi-generational learning were collected from 6 interviews and 131 surveys. The results show that over 70% of parents and grandparents find a lack in grandparent-grandchildren interaction, reducing the chances of multi-generational learning, in which the majority of them find indoor toys a good tool to boost grandparents and grandchildren interaction. In addition, a large number of parents agreed that toys should comprise the 'education' aspects, which for the elderly is the working memory, and for children is the eye-hand coordination.

5 MARKET RESEARCH

To further develop the design criteria in which the concept toy will follow, brief market research was conducted to find what current products are lacking, or areas with rooms for improvement that can be included, Figure 2. Toys designed specifically for children and the elderly with specific skill training features were being studied with comments reviewed. The purpose of this is to learn the similarities and differences between children's toys and elderly toys and combine the features into an integrated toy design. For children's toy research, many of the current toys which involve 'eye-hand coordination' skills were being studied. Results show that most toys use both hands and are mostly 2 players since the unpredictable movement of opponents enhances the children's eye-hand coordination. For elder's toy research, toys incorporating 'working memory' were being studied. Many of the current elder toys involve the use of balls, with different sizes, softness, and purpose. The common factors of children and elders' toys are muscle strength and muscle control. Most toys train the player's ability to hold, grip, move, or balance, enhancing their muscle control, which benefits the body as it activates blood circulation and also increases muscle strength and endurance. However, when reviewing the comments and feedback from customers of current toys, it was found that some of the skill training toys often lack entertainment due to repetitive movements. Many children's toys made for tackling coordination problems are often considered too childish for older children. Many of the elder's toys are considered more of a tool rather than a toy. Therefore, improvements were being made in later toy design.

Figure 2. Children and elder toy marketing research

6 DESIGN CRITERIA

Design criteria are created for the toy design. The toy aims to enhance multi-generational learning with improved skills of eye-hand coordination, working memory, and muscle control. In addition, grandparent-grandchildren relationships can also be boosted. The game type of the toy is a combination of puzzle game and board game, which is the most voted game mode and the most suitable for both children and elders. The material of the toy should be plastic as it is the most cost-effective, safe, and easily cleaned material. The colour combination is red and blue according to the survey results. Furthermore, since many of the grandchildren and grandparents do not live together regularly, it is vital to make the toy small and portable.

7 FINAL TOY DESIGN

7.1 Toy design introduction

A toy named 'G2G' is designed, which means Grandparent to Grandchildren with 2 players, was designed according to the design criteria, as shown in figure 3.

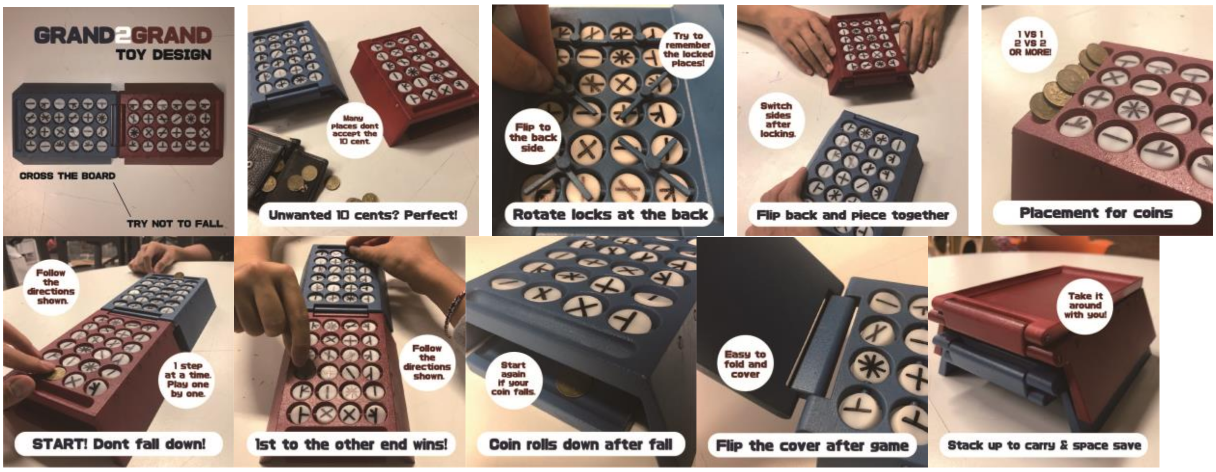


Figure 3. Images of toy & how to play

The toy consists of two separate boards, with 24 rotatable circles on it. The total 48 rotatable circles contain different directions on both sides, indicating the directions the players can move each time. On the back of the board is the locking mechanism. Before the gameplay, players can rotate the locks to their desired places. The 'piece' to play with is a 10 cent Hong Kong dollar. The reason is that the 10 cent Hong Kong dollar is only worth ~0.01 US dollars, and many of the places do not accept the 10 cent coins, leaving a waste of unusable coins. Some people even discard these coins. Therefore, this game uses the 10 cents as the piece to cross the boards, hoping to reduce non-essential waste and bring positive influence on society. The main goal of this game is to cross the board with the piece without falling into the traps. The players go one at a time, following the directions indicated. The first to cross to the other end wins. If the piece falls from the trap, it will roll down back and the player needs to start all over again.

7.2 Benefits of toy

Through ‘G2G’, multi-generational learning can be achieved. During gameplay, grandparents and grandchildren will communicate frequently, which might lead to deep and meaningful conversations. The grandchildren might be impatient and frustrated when the piece keeps on falling. This is when the grandparents can appease them and teach them how patience is important in life. Or at times the grandchildren might be a sore loser, which the grandparents can teach them that ‘you win some, you lose some, you cannot win them all, and that ‘there does not exist an eternal loser, nor an eternal winner’, just like life. On the other hand, the grandchildren might also lead the conversation to similar online games as the G2G, telling grandparents the types of games children at their age are playing nowadays, leading to technological conversations, the field where grandparents are not familiar with and should learn about. Hence, multi-generational learning through game conversations and interactions benefits both groups.

Since the toy is small and portable, the grandchildren can bring it to their grandparent’s house easily if they live separately. In addition, the game requires players to pick up the pieces and move them around the board, and also rotate the locks at the back. It trains their ability to perform movements with hands while being guided by their eyes, enhancing eye-hand coordination, while also improving their muscle strength and muscle control. The players also need to remember the traps the opponent and themselves made, and prevent stepping on them, sharpening their working memory. Therefore, G2G also boosts their physical and mental skills, which is vital for both groups. Overall, G2G allows multi-generational education to be achieved through toy playing, providing impact and insight to the new education system. Most importantly, it increases interaction between grandparents and grandchildren, which strengthens the grandparent-grandchildren relationship, benefiting grand families and society as a whole.

7.3 Further development and improvements

The game uses 10 cents Hong Kong dollars to play, which is limited to the Hong Kong region only. If considering the global market, a piece of a similar size and weight will be included in the toy set. In addition, the 10 cent coins might be contaminated and dirty, especially during the COVID-19 pandemic. Therefore, providing a coin-like piece for the toy set might be a more suitable way. Furthermore, storage for the pieces should also be attached to the board to prevent piece loss.

8 CONCLUSIONS

In conclusion, multi-generational education has become increasingly important these days, which can be achieved through game playing. The designed toy - G2G is anticipated to enhance multi-generational learning through grand to grand interactions, building a mutually beneficial relationship. This type of learning is very much different from traditional in-class learning, in which the students are forced to acquire knowledge. The learning model for this is more towards learning autonomy, whereas children and the elderly gain knowledge through listening, sharing, and observing. G2G is concept-based, modifications will be needed for further development. Although the research was on a small scale with limited time, hopefully, the final results are meaningful in certain perspectives, and that some parts of the findings and design may contribute to the education field and the society.

REFERENCES

[1] Anglia N. (n.d.). *Why is education important?* Why is Education Important? | Nord Anglia. Retrieved December 21, 2021, from https://www.nordangliaeducation.com/news/2020/03/06/why-is-education-important.

[2] *Child development & education*. UNICEF Canada : For Every Child. (n.d.). Retrieved December 21, 2021, from https://www.unicef.ca/en/discover/education.

[3] *Children’s family structure-2021 - bgsu.edu*. (n.d.). Retrieved December 21, 2021, from https://www.bgsu.edu/content/dam/BGSU/college-of-arts-and-sciences/NCFMR/documents/FP/westrick-payne-wiborg-childrens-family-structure-2021-fp-21-26.pdf.

[4] *Education is the key to success by Jasmeane - April 2015 scholarship essay*. Private Tutoring. (n.d.). Retrieved December 21, 2021, from https://www.varsitytutors.com/scholarship_entries/jasmeane-5617.

[5] *Generation Gap | SpringerLink - link.springer.com*. (n.d.). Retrieved December 21, 2021, from https://link.springer.com/referenceworkentry/10.1007/978-0-387-33754-8_195?view=modern&page=5.

[6] *How dementia patients can benefit from physical therapy exercises*. Foothills Sports Medicine Physical Therapy. (2021, March 11). Retrieved December 21, 2021, from https://foothillsrehab.com/blog/dementia-physical-therapy/.

[7] Laron C., Seiden A. and Knudsen A. (1984). *Electronics basics*. Amazon. Retrieved December 21, 2021, from https://www.amazon.com/electronics-store/b?node=172282.

[8] Mayo Foundation for Medical Education and Research. (2021, March 10). *Memory loss: 7 tips to improve your memory*. Mayo Clinic. Retrieved December 21, 2021, from https://www.mayoclinic.org/healthy-lifestyle/healthy-aging/in-depth/memory-loss/art-20046518.

[9] *Occupational therapy townsville: Allied Health: Apricus Health*. Occupational Therapy Townsville | Allied Health | Apricus Health. (n.d.). Retrieved December 21, 2021, from https://www.accesstherapyservices.com.au/the-role-of-hand-eye-coordination-toys-in-occupational-therapy/.

[10] Tuxworth, N. (2015). *Toys*. Amazon. Retrieved December 21, 2021, from https://www.amazon.com/toys/b?node=165793011.

[11] The Waterford. (2017, October 4). *What is multi-generational learning?* The Waterford. Retrieved December 21, 2021, from https://thewaterford.net/2017/10/04/multi-generational-learning/.

[12] *Why are educational activity toys important for your kids?* Skipy Blog. (2020, January 28). Retrieved December 21, 2021, from https://www.playskipy.com/blog/educational-activity-toys/.

[13] *Why is education important: All the reasons to stay in school*. University of the People. (2021, December 9). Retrieved December 21, 2021, from https://www.uopeople.edu/blog/10-reasons-why-is-education-important/.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

A STUDY OF CONSIDERATIONS TO THE DESIGN CRITERIA FOR PARKINSON'S DISEASE TOYS

Douglas MAN and Yi-Teng SHIH
The Hong Kong Polytechnic University, Hong Kong

ABSTRACT
Parkinson's Disease (PD) is considered to be a common disease globally, being diagnosed in elderlies regardless of hereditary and or environmental factors. Though gadgets are more widely utilised to aid PD patients, toys can provide a more enjoyable, educational and or interactive approach in improving their user's everyday lifestyle. The current market for PD is relatively limited and can quickly bore the users physically and mentally. Hence this paper aims to recognise and propose a set of considerations to the design criteria for Parkinson's Disease toys, as well as put forth a conceptual product that encompasses and analyses the findings.

Keywords: Parkinson's disease, toy, design criteria, suggestion, design research

1 INTRODUCTION
There are three major points in designing a toy for Parkinson's Disease: Firstly, it is globally the second most common neurodegenerative disease, whilst locally affecting approximately 4% of Hong Kong (HK) elderlies aged 80+ [1]. Given the nature of this disease, there is no permanent cure once diagnosed; only the prevention and extending the progression of worsening symptoms. Although many do suggest that Parkinson's is partially a hereditary disease, it is also argued that environmental factors are one of the major contributors to activating Parkinson's, implying everyone will have relatively equal chances of being diagnosed in senior years. Second, given that aging is inevitable, designing for elderlies will benefit both current and future societies. Lastly, toy products have the potential to be multi-issue solutions - being both educational and enjoyable - therefore being a relevant PD symptom-alleviating tool by being able to potentially maintain and or retrain the cognitive and motor skills lost due to degeneration, whilst improving mentality. Due to the lack of specialized toys for PD, this paper aims to highlight considerations to the design criteria for Parkinson's Disease toys through research and user feedback on physical prototypes.

1.1 Understanding Parkinson's Disease
Understanding the issue will be crucial to devising the considerations to the design criteria. In short, Parkinson's Disease (Parkinson's or PD for short) refers to the loss of functionality in the Substantia Nigra region of the brain; the main producer of dopamine - of which affects motor control and mood [2]. The degeneration of abilities is exponential and are commonly rated with the Hoehn and Yahr scale (of which has often been criticised for only gauging movement impairment progression, thus neglecting mental instability).

2 RESEARCH METHODOLOGY
Research can be split into 2 main categories: User research that covered a questionnaire, interviews and additional secondary research, and conceptual prototype feedback. User research was used to formulate the design criteria, whilst the prototype feedback allowed confirmation on the effectiveness of said criteria. In further detail, the questionnaire focuses on the relationships between youthful participants aging 15 to 25, and their grandparents to have a general understanding of inter-generational relationships specifically in HK. The interviews were not consisted of formulated questions, but rather freely discussed, focusing on the PD patient's family members and helpers (if applicable) to get insight on first-hand experience with taking care of the PD patient. Lastly the secondary research consists of brief findings to partially compensate for the low quantitative primary data.

Prototyping feedback will be done with one neighbouring family taking care of an elderly with PD. This is mainly due to the current pandemic worsening locally, discouraging face-to-face contact; hence data collection will be following the style of designing for one user, before adapting for more. Note that said participant is stage 5 PD, therefore the prototype feedback will be from the extreme spectrum.

3 RESULTS AND DISCUSSIONS

3.1 Questionnaire

A total of 84 participant responses were recorded within a one-month period. The results show that approximately 90% of participants lived in separate residences from their grandparents and would visit them between long periods of time. This is due to the participant's lack of time and quality of communication. For confirmation, the 2017 HK Family Survey [3] has also stated that an estimated 85% of HK families did not live with the elderly yet maintained good relationships (as was found from the questionnaire). From this, one consideration to be made is that the PD users are living separate from the nuclear family, hence increased attention on allowing the toy to be used independently (includes interactive dexterity and mobility).

3.2 Interview

Short interviews which lasted approximately 20 - 30 minutes were conducted during questionnaire response collection, and can be summarised as shown in Figure 1:

Family A *Diagnosed period: ~3 years, Current*	**Family B** *Diagnosed period: ~5 Years, [Passed]*	**Family C** *Diagnosed period: ~10 years, Current*

- Large family living together with grandparents
- Condition worsened exponentially during past year
  - Recently hired a part time helper to tend to their needs
- Practice stretching exercises every morning and afternoon
- Positive attitude to keep hopes up
- Daily interactions in late afternoon: games, snacks and tea
- Difficulty in constantly motivating affected family member (AFM) into
	- Meets 2 time year, calls once a month
	- Hired helper and ate medicine
	- Loss of movement each time they saw her
	- After 2 years of diagnosis cannot walk; required to use a wheelchair; was very active prior
	  - Mental degeneration seems to occur after 3rd year diagnosed
	- Easy to lose temper, attitude and personality changed a lot
	- Singing seems to help
	- AFM did farming as a hobby, raising chickens and vegetables
		- Daughter has doctor degree, peers have access to newer methods of re-stimulating muscles
		- Very open to solutions
		- AFM participated in electrotherapy
		- Constant and consistent exercise
		- Had to begin in early stages (stage 2.5 and beyond is difficult to manage)

Figure 1. Interviews with families - summarised responses

Through interviews, the necessity for the consideration of mental stability is suggested, most notably with families A and B. Results also suggest that it takes approximately 2 to 3 years after diagnosis for symptoms to worsen until stage 5 unless diligent action has been taken immediately after diagnosis (as implied with family C). One major observation that can be deduced is the PD user's lack of motivation to maintain their abilities, of which can be a consideration (though secondary, as entertainment is already a primary purpose of toys) - further supported by the user's rapid decline in positivity; spontaneous pessimism or fits. By comparing the three, we can see that at the later stages of Parkinson's, familial and friend support plays a vital role in keeping morale - as conveyed in family A's frequent visits and activities together, family B's singing to elevate mood, and family C's encouragement to take action early. When taken into account, this can be a combination of motivation and independence.

3.3 Additional Secondary Research

Medication also becomes a necessity in the daily lifestyle of PD users in late stages, with the tendency to rely on dopamine supplements (Levodopa) or inhibitors that prevent enzymes from breaking down nerve cells to function relatively normally [4]. Its significance is highlighted through the consideration that the toy should be easily picked up and placed down conveniently, not just for meals but also after short bursts as the PD user gets tired. Natural remedies include enhancing wellbeing via exercising, the ability to have quality sleep, frequent exposure to sunlight and dieting [5]. Studies concluded that there was a positive correlation between exercising and levels of dopamine, though the level of effect was not consistent with each participant. Additionally, Tsai et al further confirms that participants who were

frequently exposed to sunlight also produced the highest density of dopamine receptors [6] - though these were based on healthy participants, the studies suggest that outdoor activities are beneficial to PD users and so can be linked to environmental considerations.
Case study wise, Michael J. Fox, of whom has lived with Parkinson's for 30+ years has attributed his ability to cope with PD for such an extended period of time to enforcing positive mentalities. Though he admits pessimistic mentality is inevitable, it was ultimately the support and understanding from his inner social circle and family that enabled him to accept and live with PD [7]. Three product types - PD gadgets, toys and elderly toys / forms of entertainment - were compared in order to better understand the current market, as well as it's areas that can be improved, Figure 2.

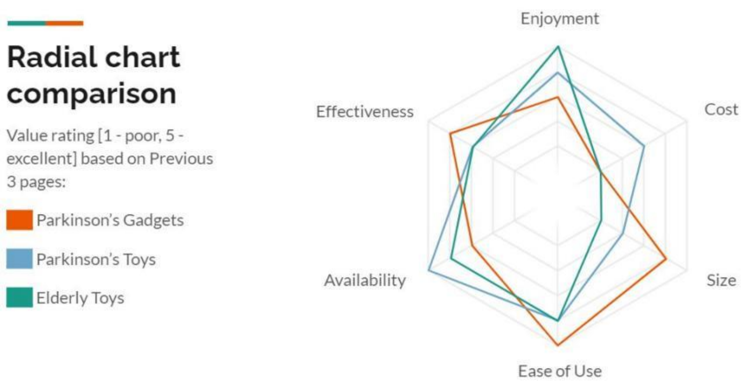


Figure 2. Comparison of current market products

To summarize, the findings indicate that there is limited to no specialized toys for PD; many of which are simplistic in functionality, i.e., weighted blankets and puzzles suitable for developing children are marketed as toys for PD. Relative to section 3.2, family A bought and tested a variety of said PD toys yet found that these solutions were unsuccessful in the long term (given the user lost interest after several months). In terms of training or ability maintenance, gadgets are solely used to counteract physical symptoms such as tremors, although it is arguable that this in turn reduces the negative mentality by dampening frustrations from low dexterity. Elderly toys were also analysed as a reference to what the PD users used play pre-diagnosis, which could affect the usability and acceptability of new toy concepts. Locally, this refers to games such as mah-jong or Chinese chess, of which requires both finger dexterity and cognitive processes (hence the inability to play can be an incentive to use a specialized PD toy).

4 DESIGN CRITERIA, CONCEPTS AND FEEDBACK

In response to the findings and considerations noted, there are several routes in which a product can follow when being designed for Parkinson's disease:

- A toy that focuses on training mental capabilities and motor skills, similar functionality to puzzles.
- Improving the target user's standard of life; making a social toy that makes them feel "normal" when by themselves and with others.
- Focusing on ensuring or cultivating an optimistic mindset; a toy that counteracts or reduces mental instability
- A product that enables increased quality time between the nuclear family and the grandparents, PD patients

Note that it is crucial to differentiate a toy from a gadget: A toy should first and foremost be used for active entertainment rather than passive interactions.

4.1 Initial Criteria and Considerations

Given the time restraints to produce and test the concepts, the criteria and considerations are updated throughout the conceptual stage, rather than being fixed in the beginning. Simplified criteria can be referred to below:

1. User - Designed for extreme spectrum of elderly (assume reduced capabilities such as strength or range of movement); currently for one PD user.
2. Function - Be able to train or maintain the user's skills and abilities, whilst being able to encourage a positive mentality for extended periods of time (independent use).

3. Size - Portable, medium sized (compensate for low dexterity and reduced strength); easily accessible for independent users in sitting and standing positions.
4. Aesthetics - Simple shapes (suitable for holding and grabbing), sharper colours and textures (visual identification, subjective to user preference), recognizable forms (either for nostalgic value or ease of acceptance and continued use).
5. Environmental - Primarily indoors use, able to be used or brought outdoors (reliant on functionality), placed on user or elevated surfaces (tabletops, chairs etc.).

Note that the costs and manufacturing criteria are negligible, as this project aims to find the effectiveness of proposed criteria and consideration, rather than its commercial value. Current criteria can be comparable to designing for elderlies with considerations of reduced capabilities, however level of simplicity should be subtle to allow ease of use without negatively lowering their self-assessment of competency (i.e., reduce the chances of frustration due to feeling they are unable to do anything “normally” anymore; avoid potential stigmatization of capabilities).

4.2 Initial Concept

Two main concepts were formulated, the first being a 3D, multi layered puzzle that is designed for independent play called the Matryoshka Puzzle, whilst the second being an interactive electronic plush with digital interfaces aiming to make messaging more enjoyable (Figure 3). After consulting with the target user and their family, the latter concept was preferred and thus continued.

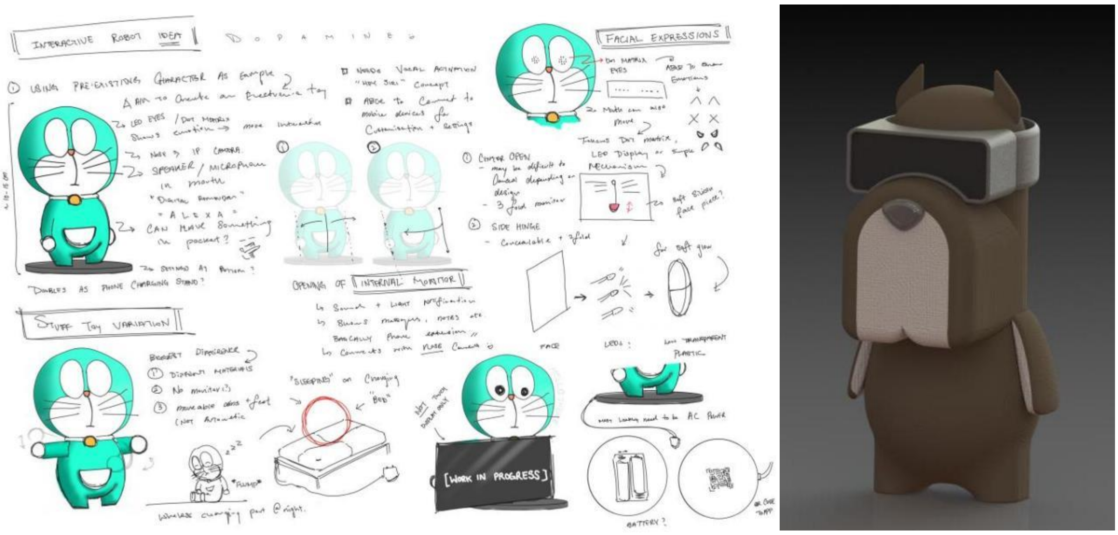


Figure 3. Electronic plush concept

Gordon (rendering on the right) is a portable toy that the user can keep on them through multiple environments. It is approximately 15cm tall and 8cm wide. The initial concept uses well known cartoon characters (in this case Doraemon) as the external form for easier recognition and gimmick value, however due to legal reasons will only be used as an example to explain the features. The body and outer layer of the head will be made of soft materials (e.g., fabrics or elastic plastics) for comfortability and easier gripping. Its secondary purpose is to partially protect the internals components inside an endoskeletal structure (of which also allows the toy to sit on its own when placed on surfaces). Early concepts for this include a built-in screen for easier text visibility, in a way similar to an enlarged kindle, although this was removed in later development due to it over complicating the functionality.

There is a total of 4 main features for this concept: 1. Interface Goggles to display messages, information or different eyes that react accordingly to different user inputs. 2. Microphone and speaker components for direct communication between the users and Gordon. 3. The ability to connect with the user’s phone via Bluetooth or NFC connections and 4. A mini projector built into the nose to display images or screens onto wider surfaces such as walls and ceilings. Features 2 and 4 will be placed in the mouth or body portion of the toy, of which will be decided after the first few prototypes. It is also possible for Gordon have customisable heads - i.e., different types of animals - and possible accessories for personal preferences. By theory, this would be categorized as a specialized PD toy, given the educational aspect from the functionality combined with entertainment from form, whilst having an appropriate level of maturity.

4.3 Initial Prototyping and Brief User Feedback

Majorly due to time restraints, a dimensional prototype (Figure 4.) was made and given to the target user for feedback. This was done by leaving Gordon with said user for a day (10am to 5pm) and collecting their thoughts. In addition, the user's caretaker was also asked to observe the user's mood throughout the day and how they would interact with Gordon. Overall, the user had a very good first impression of Gordon, specifically how the shape and overall cartoon style look made it very appealing. Several areas for improvements pointed out included how the overall dimensions felt smaller than expected, leading to occasional fumbling when handling Gordon. From the caretaker's perspective, the user had a positive attitude throughout the day and held on to Gordon frequently. Besides concerns similar to the user's feedback, they also suggested for the goggle size to be larger when the interface was included, as they stated the user would hold Gordon close to their face when looking at the goggle and face.

Figure 4. Dimensional prototype

Criteria 3 (size) and 1 (user) will need to specifically include considerations for both physical and digital interface dimensions, given that the original concept of smaller dimensions requires less dexterity was incorrect.

4.4 Modifications to Form

An updated variation, named Gordon Jr., was made through CAD software to mainly address the size constraints, and secondarily improve the overall form, as shown in Figure 5.

Figure 5. Gordon Jr. CAD renderings

Its overall dimensions have scaled up by 1.33x, whereas the goggle interface is now 12cm wide. Additional details were made on the legs (for a sitting position) and battery pack (indicated as the red backpack). The CAD model has been shown to the testing user for further thoughts and opinions on the aesthetics, resulting in the added newsprint colour theme.

Function wise, the mini projector feature has been removed due to the enlarged goggle interface, and to simply the toy; currently contains too many features. Details on the contents of the interface has also shifted from being a smart device to a vocal training device focusing on training and maintaining the user's ability to speak clearly (aims to reduce slurred speech). As of April 2022, the digital interface as well as physical prototype is a work in progress and will aim to be completed by summer.

5 LIMITATIONS OF STUDY

Research limitations include the quality and quantity of participants in the primary research stages. This study was done during a serious pandemic wave, and thus prevented the option of both interviews and face-to-face discussions or feedback. Nevertheless, this prompted a different path of conceptual designing, where the target group would be first narrowed down to a singular target user, perfecting the design, then followed by adjustments to suit a wider range of users (relatively fortunate the target user was at late stages of PD, allowing the design to be made for the extreme percentile, thus reducing the difficulty for adjustments). Note that the research period was within an annual quarterly, and significantly based on findings in HK (e.g., family as a value in Chinese culture, or distance between relatives being relatively close), hence affecting the quality and reliability of the considerations if applied to other countries. As such, it is recommended that the universal considerations be limited to having physically reduced capabilities and encouragement of positive attitudes.

Prototyping limitations include the lack of resources and time to create a functional prototype, of which affects the weight and interaction feedback. Participants in the prototyping feedback stage will need to be increased to be made in order to fully test the reliability of these considerations. As such, this study should be taken as a starting point for considerations to the design criteria for PD toys rather than a checklist, having room for improvements and confirmation in the future.

6 CONCLUSIONS

To conclude, when designing a toy specifically for Parkinson's Disease, the criteria should somewhat resemble one for elderlies in general, with additional considerations for the reduced capabilities. Main considerations should include the lack of mobility, low finger dexterity, decreased focus (or increased irritability), and most importantly how the toy can improve the user's mood. It is also important to clearly differentiate toys with gadgets and ensure the level of maturity perceived in both functions and aesthetics are suitable for adult usages.

REFERENCES

[1] Health Tips - Parkinson's Disease. Available: *https://www.hklife.com.hk/hklifeweb/web/others/others_health_detail.jsp?lang=eng&id=45* [Accessed on 2021, 21 October], (2007).

[2] Parkinson's Disease. Available: *https://www.mayoclinic.org/diseases-conditions/parkinsons-disease/symptoms-causes/syc-20376055* [Accessed on 2021, 17 October], (2021).

[3] Family Survey 2017. Available: *https://www.familycouncil.gov.hk/en/files/research/family_survey_2017.pdf* [Accessed on 2022, 14 April], (2019) March.

[4] Treatment - Parkinson's Disease. Available: *https://www.nhs.uk/conditions/parkinsons-disease/treatment/* [Accessed on 2021, 22 October], (2019) 19 April.

[5] Julson E. 10 Best Ways to Increase Dopamine Levels Naturally. Available: *https://www.healthline.com/nutrition/how-to-increase-dopamine* [Accessed on 2021, 20 October], (2018) 10 May.

[6] Tsai H. Y. et al. Progress in Neuro-Psychopharmacology and Biological Psychiatry. Sunshine-exposure variation of human striatal dopamine D2/D3 receptor availability in healthy volunteers, 2011, 35(1), 107-110.

[7] Dogan S. E. Parkinson's Life. Michael J. Fox opens up about living with Parkinson's Disease. Available: *https://parkinsonslife.eu/michael-j-fox-living-with-parkinsons-disease/* [Accessed on 2021, 23 October], (2020) 19 November.

TOY DESIGN: IMPROVING LEARNING EFFECTIVENESS FOR ADHD STUDENTS

Mei Yee LUI, Lok Yiu WONG, Ho Yin MAK and Yi-Teng SHIH
School of Design, The Hong Kong Polytechnic University

ABSTRACT
With the rapid development of medical knowledge, more young generations are confirmed to suffer from attention deficit hyperactivity disorder, abbreviated as ADHD. Inattentive, hyperactive and impulsivity symptoms are three categories that are signs of ADHD. Fidgeting, interrupting, losing homework, daydreaming are all common signs of ADHD. It affects student learning performance and classroom order. The most effective ADHD treatment is a combination of medication and behavioural therapy. However, there are many side effects of ADHD medication use. Thus, fidget toys, therapeutic devices, and other solutions that make use unconscious repetitive actions to increase their concentration. In this solution, feedback is considered as a helpful tool to let ADHD students concentrate on class and improve their learning effectiveness. Nevertheless, in some cases, other students are attracted to the attention by fidget toys and lose focus on class. Therefore, students are forbidden to bring fidget toys back to school. How to take a good balance between regulations of school and student needs was the problem that we were concerned about. This study aims to help ADHD students to reduce their concentration disorders and anxiety problems and use them with school at the same time. Finally, there was testing to let ADHD patients try the model in reality to evaluate the performance. The experimental results show the effectiveness of our proposed method.

Keywords: ADHD, attention deficit hyperactivity disorder, learning effectiveness, fidget toy

1 INTRODUCTION
Students with attention deficit hyperactivity disorder (ADHD) face greater challenges than the ordinary student on their way to success. Inability to pay attention, trouble sitting still, and difficulty managing impulses are all signs of ADHD, and they can make it difficult for children with this diagnosis to achieve well in school [4]. Therefore, therapies, school support and fidget toys are able to help the ADHD students improve their learning experience. Concerning treatment, combination of medication and behavioural therapy is the most effective ADHD treatment. However, there are many side effects of long-term ADHD medication use such as stunting or slow growth. Besides, many people do not like the idea of taking medicine for ADHD if not a serious case. [1] [7]. Concerning school support, Individualized education plans (IEP) and section 504 plans are two possible school services for students with special education needs. For example, provide technology-assisted tasks and changes to the classroom to limit distraction. Nevertheless, some cases are hard to control like talking out of turn or moving around the room to draw attention. Their behaviours take time away from instruction and disrupt the whole class.[15][5]. Concerning fidget toys, it can help ADHD students to reduce their concentration disorders or anxiety problems, so that they can concentrate and settle. Minor repetitive movements can improve the nerve function of the brain and improve concentration when children have to perform long and tedious tasks such as listening to a teacher or reading, playing fidget toys may improve performance [11]. Unfortunately, some schools banned fidget toys both in class and at recess. Feedback is considered distracting other students in some classes [6]. Thus, the aim of this study is to find an effective and safe method to reduce ADHD students' concentration disorders and anxiety problems in classes. How to take a good balance between regulations of school and student needs was the problem that was concerned.

2 ADHD X STATIONERY FOR ADHD
Providing tools to help children develop the sensory processing skills, emotional regulation skills, and social skills needed. Fidget toys are an example of a “self-regulation toolbox” and come to use them

without others' help. Thus, as time goes on, they could improve self-regulation skills [14]. For children with ADHD, the toys can offer a movement outlet that allows the child to focus and concentrate better. Some people with anxiety also benefit from using fidget tools [13]. By keeping their hands engaged in basic, repetitive motor actions that help people concentrate and pay attention by allowing the brain to filter out extraneous sensory information. It allows them to self-soothe in peaceful, predictable, and repetitive motor patterns [14]. Holding, pulling, pushing and sliding are common hand actions used in the fidget toys for children with ADHD [12]. Based on the children's stance, there is no doubt that toys are attractive things in their daily life. Compared with those treatments, education plans and school support, using fidget tools is better. Fidget toys are not only tools for self-regulation that let ADHD students reduce their disorders and anxiety problems but also could effectively decrease the times of disrupting classes and others.

Increased focus and concentration, create movement for stimulating the brain stem, provide fun mental occupation and reduce stress and anxiety are the main benefits that are found in fidget toys [8]. Some studies proved that fidget toys improved scholastic achievement, especially students with ADHD [8][11]. However, some educators do not agree. They say the toys have become a major distraction to teachers and students. In some cases, fidget toys, especially fidget spinners, are forbidden to bring back to school. Some school administrators find that the toys distract students, or worse [17]. Putty, stress balls, and other therapeutic fidget products can be used for the same purpose as fidget spinners, but more classroom-friendly and less distracting. Visual attention is the main concern [9]. Referring to the current fidget tools market, all products look like toys and easily attract other students' attention. In order to help ADHD students, relieve some of the fidgeting symptoms in class and use the product with school permits. The design should not only be functional but also need to reduce the attention of others. Therefore, stationery is a good choice to combine with the fidget tools since all students need to bring stationery to school.

3 METHODOLOGIES

Throughout the project, we interviewed three people through the introduction of teachers and friends. During the interview, we learned about the daily life of ADHD adults and young people, their needs and requirements for fidget toys, also how parents face the impact of ADHD on their children and how they treat fidget toys. The first interviewee is a 35-year-old male instructor in the design department. He was diagnosed with ADHD when he was 12 years old. The following are the key points learned in the entire interview. When he was a child, he lived in Brazil and under the Western education system in primary school, there was not much pressure caused by homework and tests, life was very pleasant and cheerful.

Moreover, Western children are more talkative and actively participating. As an ADHD, he is no different from other children. Until high school, with more and more homework and exams, he found that his ability to concentrate was very poor, and he couldn't patiently listen to the teacher in class. With the increase in pressure, he began to feel low self-esteem during his middle school life. After knowing that he had ADHD, he became less self-confident, afraid that he was different from others. The symptoms of ADHD have even accompanied him until now. He pointed out that sometimes he cannot be fully engaged and focused on work. The problem of concentration gives rise to the problem of poor memory. Due to insufficient concentration and uncareful listening, it is easy for him to forget things in class and work. In his childhood, there was no fidget toy, but there was Lego. He liked Lego’s creativity, size and touch feel, which could stimulate his concentration. After touching Lego with his fingers, the bumpy design can make him feel familiar and comfortable and can quickly merge and build.

The second respondent is a 15-year-old male secondary school student who was diagnosed with ADHD when he was in primary school. The following are the key points obtained in the interview. When he was in primary school, he was often scolded by the teacher because he was very active and talked a lot during class. In addition to the behavioural problems in the school, the teachers and social workers also found that he also had difficulties in making friends with his peers, such as often interrupting and not talking. Also, he didn’t know how to cooperate with others, it was obvious that he could not adapt to the school environment, so he was designated by the school to do the test of ADHD, so that the school's educational psychologist could make further evaluation. In the end, he was confirmed to suffer from distracted attention and excessive activity. In school, he knew he liked to talk and interrupted. He liked to sing and climb. He often walked out of position during class. Not only was he unable to concentrate on class, but he also affected other people in class. Teachers often stopped the class progress because of him. This led to his poor interpersonal relationship in primary school, and not many classmates were willing to play with him.

Until secondary school, he began to receive different support channels, such as medication, to improve behaviour problems through the room, so that he could concentrate more easily and reduce their activity. In addition, there are behaviour therapies, which use reward programmes and social skills training to improve his behaviour and relationships with other people. Without taking medicine, it is difficult for him to listen to the teacher intently. It is difficult to maintain concentration when doing homework, and it is easy to be distracted by external interference, so his grades can only be maintained at the middle level.

The third respondent is a 42-year-old mother, and the mother of the second respondent. The following are the highlights of the entire interview, summarizing the choices and feelings of parents facing their children's ADHD. Her child was confirmed to have ADHD in primary school. But at that time, she just thought that the child was too active and was too young to concentrate, so she was unwilling to give the child medication and did not take any behavioural treatment. It was only when she was about to take the secondary school examination that she realized that the situation was more serious than she imagined, and the child could not concentrate on studying. She began to accept the doctor's advice to give the child medication. After taking it for a period of time, she found that the child's appetite was poor. For a child of developmental age, he was weaker and shorter than the child of the same year.

Therefore, she started to choose to take medicine only during the exam phase, hoping that it would not affect his physical development. She also tried to buy some fidget toys for her child to play with. They did make him suddenly quiet when he was active. It didn’t matter if he was playing with fidget toys while watching TV or reading a book. On the contrary, his body could be distracted by a fidget toy. A big problem is that these fidget toys can't be taken to school. If fidget toys can be taken, they can improve his concentration in class.

4 DESIGN OVERVIEW

4.1 Concept

In the stance of ADHD students, fidget tools are a good helper to reduce their concentration disorders and anxiety problems in classes. Therefore, the product should be accompanied with their school life. The outer case of the pen is decided to develop because it could be long lasting use. Besides, this design encourages students to replace the new ink cartridge with no ink rather than buy a new pen. It could be more environmentally friendly. The pen is designed not only for writing, but also as a fidget tool of ADHD. Referring to the movements on the fidget toys, extended design is used in the structure of the pen. In order to write smoothly, the extended part would design on the upper part of the shell. After extending the pen, the user needs to rotate the upper cover to lock the structure.

When the user unlocks and push it back, it could save space in your pencil case. Pull and push with simple movements that are able to let ADHD students unconsciously repeat the actions during class. To improve their concentration in class and have a better learning performance at school. Concerning material, Polylactic acid (PLA) is the material that is considered to be used. Since it is a biodegradable thermoplastic polymer obtained from resources like corn starch, or sugarcane which is made from renewable raw materials. Compared with fossil-based plastics, PLA has a reduced carbon footprint [3]. Besides, it is classroom and children friendly because PLA is a nontoxic corn-based, biodegradable material and is considered safe to use in classrooms. Moreover, it is a good part of stiffness, since PLA will maintain its form up until its breaking point which is important in applications [10]. The pen would keep a tough structure and be supposed to long lasting use.

4.2 Style

Because of the fidget toys with nice appearance, some students are attracted to the attention by the toys and lose focus on class. Therefore, a simple look is the style that is considered. In the design concept, making good use of pattern, repetition and variation could make an interesting design for many different effects. Unified composition and stability are shown by pattern and repetition. For example, when repeating the shapes, the intervals between each repetition might give people a sensation of rhythm and movement. It is the five types of visual rhythm. Also, variation of the pattern adds interest to the design [16][2]. Rhombus pattern is used on the appearance of structure. Since it is a simple and suitable shape in a seamless pattern that combines to form a whole in order to enhance the aesthetic appeal [16]. In order to look simple and clean, only one colour would be used in each pen (Please refer to Figure 1~4).

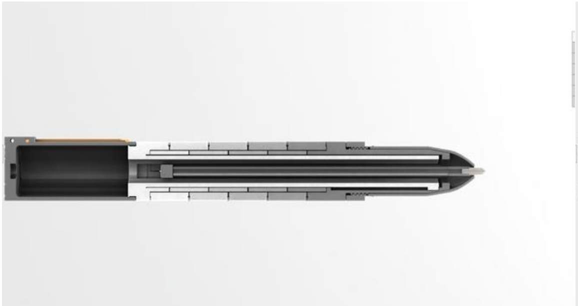


Figure 1. Section view with pen structure

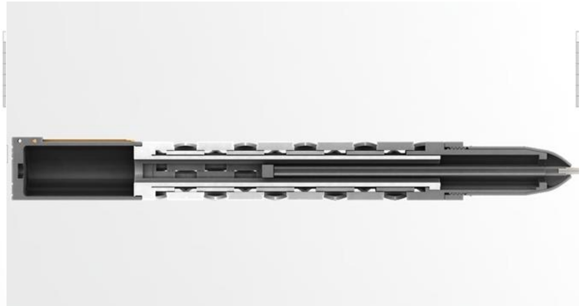


Figure 2. Section view with extended pen structure

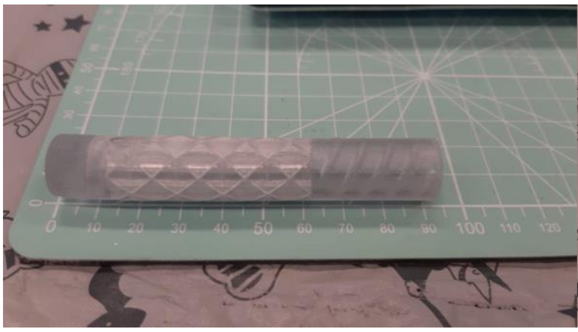


Figure 3. Functional test - Length record (Before extending)

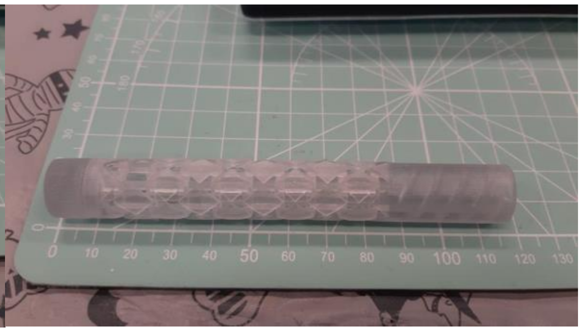


Figure 4. Functional test - Length record (Extended)

4.3 User test

After the structure with the rhombus pattern extended successfully, users tests would be prepared. 6 students were invited that included 1 ADHD student and 5 other students that aged 11 to 17. This user test aimed to prove the design is effective or not and observe the behaviour of the user and other students. Each of them started to finish their homework. The test lasted an hour. Without informing other students, our team offered the mock up to the ADHD student. During the testing process, other students were still able to concentrate on their work, and the user kept pulling and pushing the pen shell when he was stuck in his work. Thus, he did not show signs of anxiety in the test. By touching the raised patterns, the repeated rubbing between the fingertips and the pen can make ADHD students settle down, reduce anxiety, and achieve a little soothing effect. Coupled with the stretching and twisting, ADHD students kept doing the slight but repetitive hand movements by twisting the pen. It can improve concentration without being taken away by the pen, helping the user to focus on the appropriate place more easily, and reduce excessive movement due to insufficient concentration. The pen effectively reduces the negative effects of ADHD and helps study and work (Please refer to Figure 5 & 6) .

Through user feedback, we hope to have more different pattern designs and have provided more choices of stationery. This was testing to let ADHD patients try the model in reality to evaluate the performance. The experimental results show the effectiveness of our proposed method.

Figure 5. Mock-up (1)

Figure 6. Mock-up (2)

5 CONCLUSIONS

The purpose of this study is to find a suitable plan for young people with ADHD to relieve some of their fidgeting symptoms during class to improve their learning performance. At the same time, it can be used without affecting the classroom and other students, which can effectively maintain the order of the class and make the teacher's teaching process smoother. Therefore, the design should be not only functional but also concealed to reduce the attention of others. Through the analysis of the research, it can be inferred that fidget toys can be "invisible" in the classroom. For example, a simple appearance and playing method can reduce the vision attraction problem.

In order to improve practicality and concealment, a combination design of fidget toys and stationery is an option since students need to bring their stationery to school. The product should be accompanied with their school life. The outer case of the pen was decided to develop because it could be long lasting use. To let ADHD students unconsciously repeat the actions during class, pull and push with simple movements are applied in the design. The testing to let ADHD patients try the model in reality to evaluate the performance. The experimental results show the effectiveness of our proposed method. It is believed that this design can improve the class performance of ADHD students and relieve the inattention. At the same time, the entire classroom process will not be interrupted, and the learning performance can also be improved.

REFERENCES

[1] ADDUCE Consortium, Neurological and psychiatric adverse effects of long-term methylphenidate treatment in ADHD: A map of the current evidence. *Neuroscience & Biobehavioural Reviews*, 2019, Volume 107, 945-968.

[2] Araujo and Ana. Repetition, pattern and the domestic: notes on the relationship between pattern and home-making. *Textile: The Journal of Cloth and Culture*, 2010, 8 (2), 180-201.

[3] Barrett A. Advantages and Disadvantages of PLA, 2020, 9 June (BioplasticsNews).

[4] Evans S., Owens J. and Bunford N. Evidence-based psychosocial treatments for children and adolescents with attention-deficit/hyperactivity disorder. *Journal of Clinical Child & Adolescent Psychology* 2014, 43(4), 527-551.

[5] Gaastra G. F., Groen Y., Tucha L. and Tucha O. The Effects of Classroom Interventions on Off-Task and Disruptive Classroom Behaviour in Children with Symptoms of Attention-Deficit/Hyperactivity Disorder: A Meta-Analytic Review, 2016, 11(2), e0148841. *https://doi.org/10.1371/journal.pone.0148841*.

[6] Hartanto T. A., Krafft C. E., Losif A. M. and Schweitzer J. B. A trial-by-trial analysis reveals more intense physical activity is associated with better cognitive control performance in attention-deficit/hyperactivity disorder. *Child Neuropsychology*, 2016, 22(5), 618-26.

[7] Hasan S. ADHD Medicines, Available: *https://kidshealth.org/en/teens/ritalin.html* [Accessed on 2021, 10 December], (2018) March.

[8] Isbister K. Fidget toys aren’t just hype, Available: *https://theconversation.com/fidget-toys-arent-just-hype-77456* [Accessed on 2021, 11 December], (2021) 7 May.

[9] Kriescher S. L. The Effects of Fidgets on Attention and Learning of College Students, 2020, 91-106.

[10] MakerBot Industries, EVERYTHING YOU NEED TO KNOW ABOUT PLA 3D PRINTING, Available: *https://www.makerbot.com/stories/engineering/everything-you-need-to-know-about-pla-3d-printing/* [Accessed on 2021, 11 December].

[11] PACER, Children's Mental Health and Emotional or Behavioral Disorders Project How “Fidget Toys” Are Helping Kids With ADHD, Available: *https://www.pacer.org/cmh/learning-center/parenting/support-adhd/fidget-toys.asp* [Accessed on 2021, 10 December].

[12] Performance Health, 15 Fidget Tools (Not Toys) for Your Classroom, Available: *https://www.performancehealth.com/articles/15-fidget-tools-not-toys-for-your-classroom* [Accessed on 2021, 11 December].

[13] Rohrberger A. The Efficacy of Fidget Toys in a School Setting for Children with Attention Difficulties and Hyperactivity. *Ithaca College Theses*. 330. 2011, 3-18.

[14] Sarver, Dustin E., Mark D. R., Michael J. K., Joseph S. R. and Lauren M. F. Hyperactivity in Attention-Deficit/Hyperactivity Disorder (ADHD): Impairing Deficit or Compensatory Behaviour?, 2015.

[15] SingleCare Team, ADHD statistics 2021, Available: *https://www.singlecare.com/blog/news/adhd-statistics/* [Accessed on 2021, 10 December], (2021) 21 January.

[16] Soegaard M. Repetition, Pattern, and Rhythm, Available: *https://www.interaction-design.org/literature/article/repetition-pattern-and-rhythm* [Accessed on 2021, 11 December] (2020).

[17] Thayer K. Schools ban fidget toys as classroom distraction, 2017, 2 May (CHICAGO TRIBUNE).

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

INTERVENTIONS REQUIRED TO SUPPORT JAPANESE HIGH SCHOOL TEACHERS TO FACILITATE DESIGN-BASED PROJECTS

Leon LOH, Noriko TAKANO, Moe SHIMOMURA and Yanfang ZHANG
Kyushu University, Faculty of Design, Japan

ABSTRACT
This study aims to clarify the necessary interventions to support Japanese high school teachers in facilitating problem identification and ideation in design-based learning. The SDGs Challenge Project in Fukosho High School was studied as a case study. This study analysed teachers' feedback before programme implementation and post-lesson surveys. The findings suggested that professional development for teachers before implementing the programme is necessary. Such professional development should focus on developing pedagogical competencies required to lead the design process, abilities to provide students with just-in-time knowledge and skills, and a good understanding of the nature of the design process.

Keywords: Design education, design process, problem identification, ideation, teacher training

1 INTRODUCTION
The Course of Study (curriculum guidelines) is revised in a recent educational reform in Japan to focus on competencies-based education. Competencies are defined by the “holistic qualities and abilities that include not only knowledge but skills and attitudes.” [1]. The qualities and abilities, anchored mainly by National Institute for Educational Policy Research’s 21st century competencies (21CC) framework, are (i) independence and autonomous action, (ii) relationship-building ability, (iii) problem-solving skills, (iv) the ability to utilize information technology, (v) the quality/ability to live with globalization, and (iv) the practical ability to act for a sustainable society.

Design education as a form of general education can develop 21CC in students [2]. At the moment, design education is not available in the curriculum of Japanese high schools. In 2021, the SDGs Design School in Kyushu University, Faculty of Design, and Fukusho High School collaborated to develop and implement a school-wide design-based learning programme, the *SDGs Challenge Project*, for all 3rd grade students. The aim was to develop students in 21CC, social-emotional learning and increase SDGs (Sustainable Development Goals) awareness through design activities. In order to integrate the *SDGs Challenge Project* into the school curriculum, lesson time for the *Period for Inquiry-Based Cross-Disciplinary Study* was used to adopt the project.

The *Period for Inquiry-Based Cross-Disciplinary Study* is an inquiry-based subject in Japanese high school curriculum where each school can set its objective, learning outcomes, and content. According to the Course of Study, the subject should provide cross-disciplinary and integrative learning opportunities. The overarching objectives of the subject are,

- acquire knowledge and skills necessary to solve real-world problems and propose appropriate solutions to the problems
- develop independent and cooperative learning
- develop the attitude to create new values and a better society

The overarching objectives of *Period for Inquiry-Based Cross-Disciplinary Study* make it an ideal platform to adopt the *SDGs Challenge Project* into the school curriculum. Lessons for the *Period for Inquiry-Based Cross-Disciplinary Study* occur in the school timetable once a week—the curriculum time for each lesson is 100 minutes. The *SDGs Challenge Project* was designed as an 18-week programme that spans from 13 April 2021 to 26 October 2021. During the 18 weeks, students would go through the design process to identify authentic problems, generate appropriate ideas to solve the problems, present their solutions and write a report.

The current study is part of extensive research to find out how design-based learning may be introduced and implemented in the school curriculum of Japanese high schools through the *Period for Inquiry-Based Cross-Disciplinary Study*. Using the *SDGs Challenge Project* as a case study, this study aims to clarify the necessary interventions to support Japanese high school teachers to facilitate the process of problem identification and ideation in design-based learning. In an education landscape where design education is not available, the value of this study will provide crucial insights for Japanese high schools to explore how design education may be introduced and implemented as a school-wide programme.

2 LEARNING THROUGH DESIGN: A LITERATURE REVIEW

Based on the concepts of "designerly ways of knowing", design education can be delivered as a form of general education [3]. As a form of general education, design education is non-vocational, and it focuses on developing a) abilities to solve real-world problems which are ill-defined, b) thinking skills, and c) non-verbal thought and communication abilities. Design as general education can be articulated in the form of subjects in the school curriculum, or design may be used as a general strategy for teaching and learning of subject knowledge and content [4][5].

Design education as general education can be articulated in the form of a school subject, such as Design and Technology (D&T) or Technology (TE), in the school curriculum in Europe, America, Oceania and Asia. In D&T and TE, students often learn through design projects. In design projects, students used the iterative nature of the design process to identify the needs or opportunities for change, conduct research and investigation, ideas generation, development and refine ideas, engage in critique, and experimentation through model making and prototyping [6][7][8].

As an educational pedagogy for classroom teaching and learning, design methods and pedagogy of design education are used in design-based learning to teach content knowledge and thinking skills in schools [9]. In design-based learning, students are engaged in the process of inquiry and reasoning to generate innovative solutions to solve real-world problems [10]. For example, design-based learning can be found in programmes to foster science concept learning in elementary, junior high (secondary), and high (senior secondary) schools. Some prominent programmes are such as Learning by Design (LBD) [11] and Design-Based Science (DBS) [12]. Some of the common characteristics of LBD and DBS are that students are given meaningful and authentic design challenges that motivate students to learn science concepts and use the design process to provide key learning experiences. Based on the literature reviews, design-based learning in this study adopts the definition that the design process is used to engage students in solving real-world problems to develop new content knowledge and skills and make connections between different subject areas.

3 RESEARCH METHODOLOGY

To clarify the necessary interventions required, the key research question is as follows.

- What challenges do high school teachers face when facilitating the problem identification and idea generation phase of the design-based learning activities?

The current study employed a qualitative research approach to build a case study around the *SDGs Challenge Project* implemented in the *Period for Inquiry-Based Cross-Disciplinary Study* in Fukusho High School. In this study, research strategies from quantitative and qualitative methods are being used. The participants for this study were 27 Fukusho High School teachers who were deployed to teach the *Period for Inquiry-Based Cross-Disciplinary Study* for 3rd grade students in 2021. These 27 teachers deployed were mainly of different teaching subject backgrounds, and none were trained in facilitating design-based learning. Refer to Table 1. To create opportunities for cross-disciplinary learning, two or three teachers from different teaching subjects were teamed together to facilitate a class.

Table 1. Distribution of subject teachers facilitating the SDGs challenge project

Subject Area	Japanese Language	Mathematics	English Language	Social Studies	Science	Health and Physical Education	Art	Home Economics
Number of Teachers	5	2	4	5	4	4	1	2

All 3rd grade high school students, about 314 students, participated in the *SDGs Challenge Project*. The 314 students were divided into 13 classes based on their interest in issues related to SDGs. Each class consists of about 20 to 30 students. In each class, students worked in groups of 4 to 6 members. All the participating students had little or no experience in design-based learning activities.

Before implementing the project, all teachers received a set of instructional materials which they could use to prepare each lesson. The instructional material contains lesson plans, simple explanatory notes, and student worksheets for each student activity. To further support teachers' preparation and facilitation of the activities during the lessons, a resource webpage was created to contain materials such as videos explaining the design process, problem identification, brainstorming methods, and idea generation. After each lesson, the programme coordinator would clarify teachers' inquiries and concerns by posting his advice on the resource webpage.

The study objects came from questionnaire surveys done by the teachers. A pre-commencement survey and post-lesson surveys for Lessons 1 to 7, which involved problem identification and idea generation processes, were conducted. Refer to Table 2. The questionnaires consisted of 5-point Likert items and open-ended questions. Descriptive statistic method is used to analyse the Likert items. The open-ended questions are analysed by first doing an initial immersion into the data to read and review the data. Then, the responses are categorized and interpreted to look for patterns or links in teachers' perceptions.

Table 2. The schedule of programme and questionnaire survey implementation

Date	Key Program Schedule & Outline	Survey Implementation
6 April 2021	Program Meeting with Teachers • Briefing of lesson schedule by program coordinator in Fukusho High School • Addressing key concerns before commencement of program	Pre-Commencement questionnaire survey conducted using google form
6 April 2021	• Program resource website created by program coordinator released to teachers	
13 April 2021 Lesson 1	• Program briefing for all 314 students • All 314 students moved into their respective groups of 5-6 students • Exploration of problems and sharing of problems	Post-Lesson 1 questionnaire survey conducted using google form
20 April 2021 Lesson 2	• Selection of problem and refine the articulation of problem	Post-Lesson 2 questionnaire survey conducted using google form
27 April 2021 Lesson 3	• Research on selected problem	Post-Lesson 3 questionnaire survey conducted using google form
18 May 2021 Lesson 4	• Sharing on research findings • Identification of target users and stakeholders related to the problem	Post-Lesson 4 questionnaire survey conducted using google form
8 June 2021 Lesson 5	• Research on existing solutions	Post-Lesson 5 questionnaire survey conducted using google form
15 June 2021 Lesson 6	• Idea generation	Post-Lesson 6 questionnaire survey conducted using google form
22 June 2021 Lesson 7	• Selection of ideas • Production of concept poster	Post-Lesson 7 questionnaire survey conducted using google form

4 FINDINGS & DISCUSSIONS

4.1 Pre-commencement survey

In the pre-commencement survey, 10 questions were structured to clarify five key areas: a) teachers' experience in teaching content areas outside their teaching subjects, b) teachers' experience in conducting problem solving and group work related lessons, c) teachers' level of understanding on SDGs and design, d) usefulness of instructional materials created for this programme, and e) other concerns. Responses from questions with Likert Items (Not at all=1 to extremely high=5) are presented in Figure 1. Responses from open-ended questions (Q8 and Q10) are presented in Tables 3 and 4, respectively.

Most teachers were not very experienced in conducting problem-solving and group work lessons. Teachers' in-experience may explain the low confidence perceived by most teachers in facilitating group work. The majority of the teachers expressed a lack of content knowledge in SDGs, reflecting their in-experience in teaching SDGs related lessons. In addition, most teachers had very little understanding of design thinking, and most of them had no experience in any form of teaching related to design. In terms of support, most teachers found the instructional materials provided easy to understand.

Question 8 in the questionnaire clarified teachers' current perceptions of design by asking teachers to provide three keywords that may describe design. Refer to Table 3. Most keywords provided by the teachers were relevant and can be grouped into four areas shown. Teachers’ understanding of design relates mainly to design specialization and design abilities based on Question 8.

Students' engagement in learning may be influenced by five key factors: pedagogical competencies, creating meaningful learning experiences, content knowledge, assessment for learning, and setting the tone of the environment [13]. Pedagogical competencies may be related to using strategies to manage instructions to help students learn and understand concepts and content and develop skills. Creating meaningful learning experiences involves helping students acquire a deep understanding of what they learn and develop as self-directed learners. Content knowledge is related to the content that students will learn. Assessment for learning is the ability to determine students' level of mastery in their learning and provide timely feedback to improve students' learning. Setting the tone of the environment involves creating the environment to allow students to make decisions, express themselves, promote cooperative learning and develop active learning. When analysing teachers' concerns in Question 10 in the questionnaire, their concerns can be associated with the five key factors mentioned above. Refer to Table 4.

Figure 1. Responses of teachers for Likert items questions

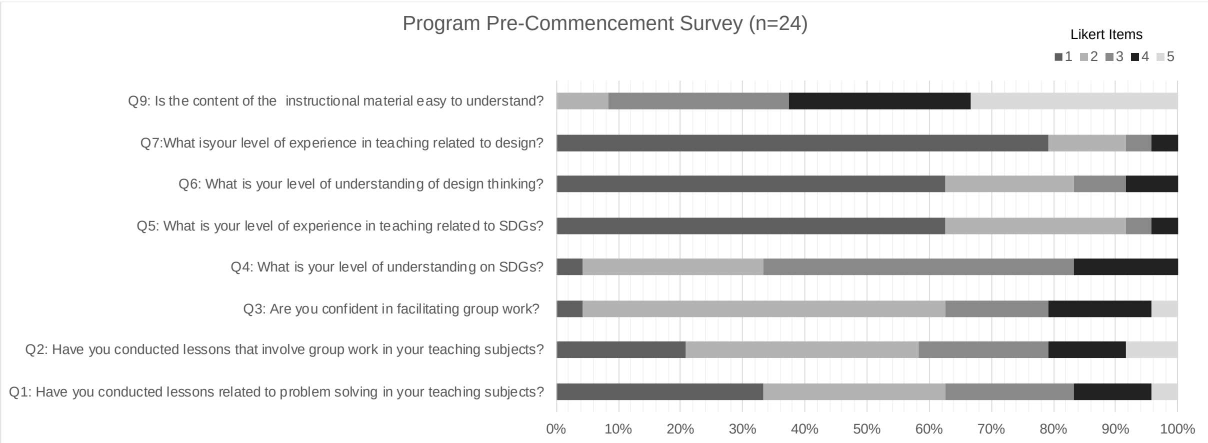


Table 3. Teacher's perception of design

Table 4. Teacher's key concerns in conducting the programme

Q10: Please provide any concerns you may have about the conducting the SDGs Challenge Project. (n = 24)					
Key Concerns from Teachers (✓ will be indicated in those key factors that may be associated to the teachers' concerns)	Teachers' concerns may be associated to the factors below:				
	pedagogical competencies	creating meaningful learning experience	content knowledge	providing assessment for learning	setting the tone of environment
not experience in group work and lacking in understanding on SDGs and design thinking	✓		✓		✓
in-experience in design-based projects	✓				
the extent of teachers' involvement during the facilitation, and how to monitor students' progress	✓	✓		✓	✓
lacking knowledge in implementing the lessons and anxious about conducting the lessons	✓	✓	✓	✓	✓
not used to facilitating group work in class and conducting discussions to guide students, and fear of interfering too much into students' work	✓	✓		✓	✓
students may not be able to manage their learning and complete their tasks		✓			
inability to set meaningful topics		✓			
lacking content knowledge on SDGs which may result in the inability to provide good advice			✓	✓	
managing students' progress				✓	
Inability to draw out students' interest		✓			

4.2 Post-lesson surveys

In all the post-lesson surveys from Lesson 1 to 7, three key questions were used to elicit teachers' responses to instructional materials and their challenges during problem identification and idea generation. Using 5-point Likert items (strongly disagree=1 to strongly agree=5) for the questions, refer to Figure 2, teachers were optimistic about the instructional materials provided.

When asked about challenges faced during lessons through an open-ended question, refer to Table 5; teachers generally face difficulties in providing advice to students when facilitating the problem identification and the idea generation processes. They also face challenges in managing the progress and motivations of different groups of students. Other challenges that may need to be addressed as a priority were as follow. In the problem identification process, teachers lacked sufficient understanding of the problem identification process. They were facing challenges in guiding students to break down the larger aspect of the problem into specific problems. In addition, teachers found that students lacked the research skills to understand the problems through research. For example, students found difficulties determining the target users and stakeholders related to the problems. During idea generation, teachers faced challenges guiding students to generate creative solutions. Some may also have provided too much advice to students instead of directing them toward the solutions. Teachers were also not familiar with creating concept posters for selected design solutions.

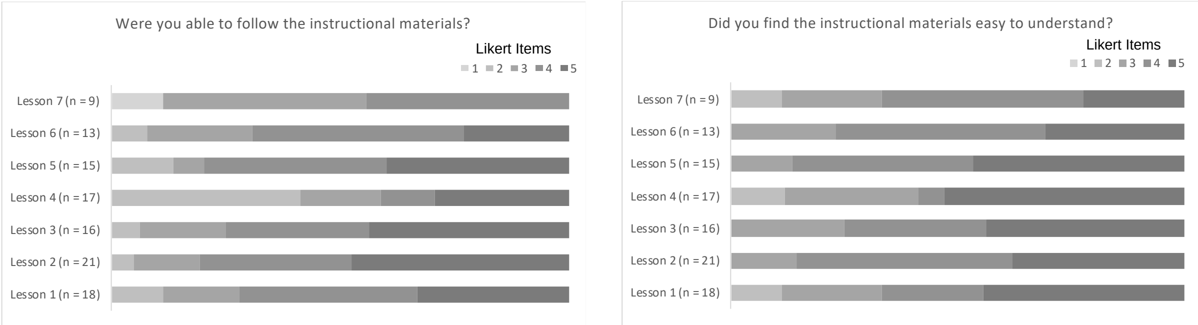


Figure 2. Teachers' feedback on instructional materials

Table 5. Challenges faced by teachers from Lesson 1 to 7

	Please describe any difficulties you have had in teaching.	
Design Process	Lessons	Key issues
Problem Identification Process	Lesson 1: Exploration of problems and sharing of problems (n= 18)	• Teachers unaware of the pre-program preparations done by students • Students were not active in group work and collaboration skills • Students were not able to group their concepts about the problems even though they were taught
	Lesson 2: Selection of problem and refine the articulation of problem (n = 21)	• Need of teacher's guidebooks with model answers • Lacking in facilitation skills • Lacking competencies in information communication technology • Lacking in the understanding of problem identification process • Students were not active in group work and collaboration skills • Some students were lacking in motivation • Students find difficulties in connecting concepts • Unclear instructions in the instructional materials provided
	Lesson 3: Research on selected problem (n = 16)	• Interest level of students varies • Students lacking in research skills • Difficulties in monitoring progress of students • Some students were not engaged
	Lesson 4: Sharing on research findings; Identification of target users and stakeholders related to the problem (n = 17)	• Difficulties in determining the user targets and stakeholders • Difficulties in providing advice • Students were not active in group work and collaboration skills • Some students were lacking in motivation • Students lacking critical thinking skills
Idea Generation Process	Lesson 5: Research on existing solutions (n = 15)	• Students lacking in research skills
	Lesson 6: Idea generation (n = 13)	• Ideas were too abstract and lacking in detail • Teachers provided too much advice • Different progress among different groups • Students did not know about their objectives
	Lesson 7: Selection of ideas; Production of concept poster (n = 9)	• Ideas generated were too similar to existing solutions • Unclear how to create the concept poster of the solution

4.3 Implications on interventions required

Based on the pre-commencement survey and the post-lesson surveys, several implications for necessary interventions may be presented. Although providing instructional materials and support via the resource webpage may be helpful for teachers during the implementation of the project, professional development before starting the project may prepare the teachers better to lead and facilitate the design process. In professional development, teachers should be prepared in the following aspect. Firstly, developing teachers' pedagogical competencies in teaching and facilitating the design process is necessary to guide students navigate the design process. In addition, strategies such as questioning techniques would be helpful for teachers to guide students to ask meaningful questions so that students can be self-directed to find relevant answers and make meaningful decisions in the design process. Secondly, while teachers may feel that they lack content knowledge, it should be noted that in the design process, different groups of students will require a different set of knowledge and skills to engage the design problems. Thus, teachers' ability to provide just-in-time knowledge and skills to students is essential. Just-in-time knowledge and skills refer to knowledge and skills that students require to complete the tasks required in particular design problems or solutions. Thirdly, a good understanding of the design process will be crucial. The reason is that teachers will then be able to guide students through the iterative nature of the design process. Knowing the nature of the design process will allow teachers to understand that design problems are ill-defined and solutions are not limited to one. As such, teachers may be able to monitor students' progress, and give timely feedback and provide scaffolds to direct students through the design thinking processes in design-based learning.

5 CONCLUSIONS

This study aims to clarify the necessary interventions required to support Japanese high school teachers to facilitate the process of problem identification and ideation in design-based learning. In a context where none of the teachers were trained to facilitate design-based learning activities, it can be suggested that professional development of teachers before the commencement of design-based learning is necessary. The following aspects should be considered as part of the professional development. Firstly, teachers should be developed with pedagogical competencies to lead and facilitate the design process. Secondly, teachers are required to possess the ability to provide just-in-time knowledge and skills during the design process. Lastly, a good understanding of the nature of the design process is necessary to monitor students' progress and provide timely feedback and scaffolds for students during design-based learning activities.

ACKNOWLEDGEMENTS

The authors would like to extend their appreciation to the principal and teachers of Fukusho High School for this study. This work was supported by JSPS KAKENHI Grant Number JP21K02527.

REFERENCES

[1] Kimura D. and Tatsuno M. (2017). *Advancing 21st century competencies in Japan*. Asia Society. Retrieved March 13, 2022, from https://asiasociety.org/files/21st-century-competencies-japan.pdf

[2] De Vries M. (2018). Technology Education: An international history. In M. J. de Vries (eds.). *Handbook of Technology Education* (pp.73-84). Springer international handbooks of education.

[3] Cross N. (1982). Designerly ways of knowing. *Design Studies*, 3(4), 221-227.

[4] Davies M. and Littlejohn D. (2017). The culture of practice: Design-based teaching and learning. In S. Goldman & Z. Kabayadondo (Eds.), *Taking Design Thinking to Schools* (pp. 20-36). New York: Routledge.

[5] Kangas K. and Seitamaa-Hakkarainen P. (2018). Collaborative Design Work in Technology Education. In M. J. de Vries (eds.). *Handbook of Technology Education* (pp.597-609). Springer international handbooks of education.

[6] Adams E. (2013). Design education Projects. In K. Baynes & E. Norman (Eds.), *Design Education: A Vision for the Future* (pp. 87-95). UK: Loughborough Design Press Ltd.

[7] Williams A., Cowdroy R. and Wallis L. (2012). Design. In P. J. Williams (Eds.), *Technology Education for Teachers* (pp. 93-114). The Netherlands: Sense Publishers.

[8] Morley J. (2002). How can we meet the challenges posed by a new model of practical scholarship? In S. Suyers, J. Morley & B. Barnes (Eds.), *Issues in Design and Technology Teaching* (pp. 13-26). London: RoutledgeFalmer.

[9] Davies M. and Littlejohn D. (2017), 20-26.

[10] Gómez Puente S. M., van Eijck M. and Jochems W. (2013). A sampled literature review of design-based learning approaches: a search for key characteristics. *International Journal Technology and Design Education*, 23, 717–732. https://doi.org/10.1007/s10798-012-9212-x

[11] Kolodner J. L., Camp P. J., Crismond D., Fasse B., Gray J., Holbrook J. et al. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design™ into practice. *Journal of the Learning Sciences*, 12(4), 495–547.

[12] Fortus D., Dershimer R. C., Krajcik J., Marx R. W. and Mamlok-Naaman R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching*, 41(10), 1081–1110.

[13] Ministry of Education. (2007). *The PETALS™ primer*. Singapore: Ministry of Education and Association for Supervision and Curriculum Development (Singapore).

A DIDACTIC LOOK ON THE INTRODUCTION OF E-PORTFOLIOS IN A PRODUCT DESIGN COURSE

Maria TYROLLER, Michael S. J. WALTER, Charlotte KAETZEL and Christian RIESS
University of Applied Sciences Ansbach, Germany

ABSTRACT
While e-portfolios are well established in several countries (57 % of U.S. colleges use e-portfolios), they are rarely found at German universities in courses on product design. Consequently, the use and applications of e-portfolios are new and unknown for students and lecturers alike. Fear about contacts with new technology, scepticism, inhibition thresholds, and technical as well as organisational barriers are therefore inevitable. In this paper, we dedicate ourselves to the fundamental analysis of the existing initial e-portfolio situation. This is done using a course on project-based product design for engineers at our university. In addition to the opinions of students and lecturers, the analysis also considers the perspective of administrative departments. Based on this, didactic strategies for the introduction of e-portfolios in the product design course will be developed. These strategies refer to the following three phases: preparation, implementation, and evaluation. The following factors have emerged as crucial for the successful implementation of e-portfolios: a comprehensive personal introduction, extensive information material that can be accessed at any time, continuous guidance, a clear structure and work instructions, room for flexibility and creativity to foster learners' individual strengths, and exchange and feedback between learners and teachers.

Keywords: E-portfolio, product design education, didactic strategies, communication, survey

1 INTRODUCTION
The manifold competencies that students acquire in courses on engineering design and product design cannot be meaningfully evaluated by questions in exams. According to Bloom's established taxonomy, ‘design’ activities are considered cognitively highly demanding and valuable [1]. Since design competencies are both cognitive and motivational/social in nature, study diaries or portfolios (or their digital form, e-portfolios) are suitable for evaluating students’ skills. E-portfolios, with their functional versatility, are ‘a tool for the structured collection, storage, and presentation of both the “path” (process, progress) and the “goal” (increase in knowledge, development of technical, methodological, or social skills) by means of digital information objects’ [2]. While e-portfolios are well established in several countries (57 % of U.S. colleges use e-portfolios) [3], they are rarely found at German universities [4]. So far, research on administrative issues related to the introduction of e-portfolios or on their suitability as an assessment tool has dominated. Less often, the perspective of students and how e-portfolios must be introduced didactically to bring real benefits to the target group has been considered [5]. Field research in the German-speaking area that refers to this topic so far comes mainly from two fields: teacher education (e.g., [6], [7]) and foreign language teaching (e.g., [8]). Research contributions from other disciplines can therefore offer new perspectives on the topic.
This paper deals with a perspective that has hardly been researched so far: the didactic introduction of e-portfolios in engineering science in the context of a product design course that is geared towards practical work. At our university, we have started to explore how to implement e-portfolios with the software Mahara in a course on project-based product design in the bachelor's degree programme for ‘Sustainable Engineering’. It is the only course focusing on product design in the curriculum of the bachelor programme. The students face the challenge to design and build a wooden product for children. In addition, each student must devise a 90-minute workshop, in which the product can be designed or built by the children themselves. Normally around 20 students take part at the course. One lecturer teaches the theoretical part that provides the content on relevant aspects of project management and product design (each week 90 minutes over 14 weeks). The practical part takes place in the lab and is accompanied by the lecturer and a lab engineer (also each week 90 minutes). Previously, students had

to demonstrate the skills that they gained through a seminar paper. In March 2022, when the next seminar starts, we plan to implement e-portfolios as a tool for the documentation, reflection, presentation, and proof of the acquired skills. The first step was the analysis of the initial situation. Students, lecturers, and an associate of the student service have been surveyed to formulate the needs of participants and identify the advantages and challenges of using e-portfolios in teaching. Based on this, didactic strategies for the implementation of e-portfolio work have been developed. A brief description of our research method follows. In the main part of the paper, our didactic strategies are described. We divided the relevant aspects of our didactic strategies into three stages: preparation, which takes place before our seminar and portfolio work start; implementation, which involves communicating requirements during our seminar; and evaluation, which takes place after the seminar, when the stakeholders will be able to provide a final evaluation of their experiences. Given the limited scope of this paper, we will not address the evaluation phase here. Nevertheless, it is an equally important part of our didactic approach and will be discussed in more detail elsewhere.

2 RESEARCH METHOD

To develop a concept that is appropriate for the social reality of our university, we chose the method of qualitative empirical research [9]. By conducting expert interviews with three students, two lecturers, and one administrative staff member, we gained important information about their respective perspectives and needs. In individual interviews based on semi-structured guidelines, we talked with engineering students who had participated in the course on project-based product design in the summer of 2020 about their personal experiences with the examination method (a seminar paper) at the time. To avoid influencing the interviewees, we asked open questions without mentioning e-portfolios as an alternative examination method at the beginning of the interview. At the end of the interview, we asked the stakeholders about the associations they have with e-portfolios and introduced them to the concept of e-portfolios. The assessment of the material gained has been done using typological analysis, as suggested by Misoch [10].

3 DIDACTIC STRATEGIES

The interviews showed that for all students, one lecturer, and the administrative associate, e-portfolios are an unknown tool so far. None of the students could associate anything with the word ‘e-portfolio’. Therefore, a good communication strategy is very important to making e-portfolios known and accessible to stakeholders. In the following, we outline some key points for the integration of e-portfolios into assessment practices and for the use of e-portfolios as working tools using the example of our course on project-based product design for engineers.

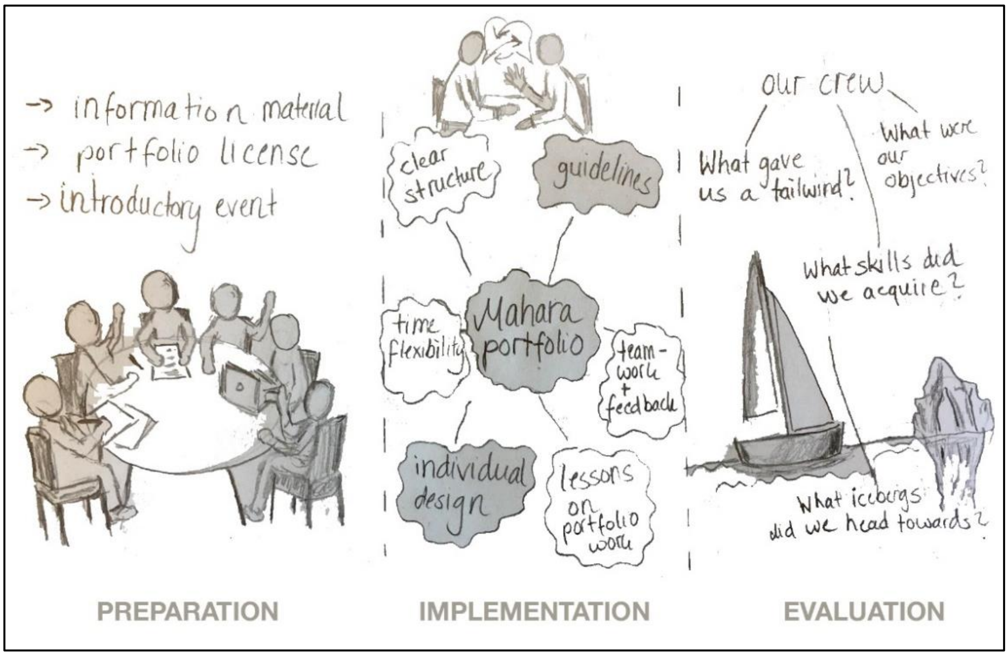


Figure 1. Stages 1–3 of the didactic strategies

3.1 Preparation: Requirements for a starter kit

The analysis of our interviews showed that it is important to create a well-structured introduction to e-portfolios to allow students to use them successfully. All students mentioned that clear expectations in the form of guidelines are very helpful.

Problems and demotivation emerge when the order is not clearly defined, or students have the sensation that they have not been well informed. One of the students interviewed, for example, described the problems he had in developing a workshop for children without being able to judge the target group: 'What was difficult was to really put myself in another head. I might have needed a bit of a framework.'

To encourage a high level of motivation in students, it is important to provide comprehensive and well-structured information about a new topic or working tool.

The channels in which the introduction takes place are also relevant. Apart from multimedia information material that students can use while exploring the functions of e-portfolios, there should also be an information event for real interaction with tutors, as well as a Moodle course that students can use by themselves to acquire the skills required for the use of e-portfolios.

3.1.1 Introduction by interaction

As e-portfolios were nearly unknown to most of the interviewees, an ice breaker is needed. Experiences from everyday university life show that using introductory events to present new concepts works. We suggest a two-hour information event during which tutors explain the concept and functions of e-portfolios on Mahara to the students directly. To make it as interactive as possible, the participants should bring their own laptops to try out e-portfolios together with the tutors.

The experiences of the interviewed lecturer who had already worked with e-portfolios suggest that the demonstration of a best-practice portfolio could be a good start; this would show students what a good portfolio should look like. To directly experience e-portfolio work on Mahara, the students then register and create their own profiles. After this, they receive a first invitation to a shared project from the tutors, namely the user manual, which was created for the special needs of our university. By giving the students a user manual in form of a portfolio, the basic functions of Mahara can be explained.

After this, the participants could try to start their own first project on an easily accessible topic, like planning an upcoming weekend trip. Due to the low complexity of this challenge, the students can focus on both the challenge itself and the procedure of integrating their work progress and results in Mahara. As all interviews showed, it is very important for the stakeholders to know what is expected from them. Therefore, they receive guidelines with a description of all requested content and assessment criteria for the project 'weekend trip'. While planning this simple project, they can always access the user manual portfolio when they have questions about Mahara functions.

3.1.2 Information material

Information material should be available independent of the information event to all interested participants. Weber's research work points to the importance of guidelines that support students by providing them with the terms and functions of Mahara from the beginning [7].

To reach different types of learners, it can be helpful to have a printed version and a digital version. As briefly described before, the material should consist of four parts: a best-practice portfolio demonstration in form of a video/ pictures; a user manual for Mahara with all important functions and terms, which is supplemented by short learning videos/ pictures; guidelines containing the requested contents for the product design course and the contact information of the tutors, as well as the office hours for questions about portfolio work; and a description of the assessment criteria.

3.1.3 Portfolio license

To motivate students to really work with Mahara, a short course (with a workload of 3 hours) on Moodle that they can go through by themselves is a good additional resource. The course contains different tasks that, step by step, enable the users to use Mahara comprehensively. They become familiar with its structure, all possible functions, interactions with users, and how to upload videos, pictures, and documents on Mahara. They demonstrate their acquired skills at the end of the course by completing a multiple-choice test. Experiences from our human resources department show that e-learning courses, which employees can complete independently, make a good contribution to knowledge acquisition. Participation in the Mahara course will be a prerequisite for registering for our product design course.

The instructor of the course could also imagine a more extensively designed Mahara course that could be used to obtain elective credit points (2 ECTS) and a document which could be called a 'portfolio license'. The license, in turn, would offer the students the opportunity to work as portfolio tutors.

3.2 Implementation

After this comprehensive introduction, the instructor can start incorporating e-portfolio work into his project-based product design course. As the e-portfolio is a new working tool, it is very important that e-portfolio work is continuously accompanied by the lecturer and the tutors. The analysis of the interviews with stakeholders produced the following critical points to be considered for good working results: a structure that includes clear instructions and working methods and space for flexibility and creativity, and the promotion of autonomous learning and feedback loops. All of these aspects will be explained below.

3.2.1 Clear instructions and working methods

For product design, the systematic approach of Pahl and Beitz will be used due to its simplicity and effectiveness. Pahl and Beitz define four crucial steps: task classification, conceptual design, embodiment design, and detail design [11]. These steps will also give the basic structure to our portfolio template on Mahara. Every step contains different tasks one can manage using project management methods like writing a project diary, designing a mind map, etc.

The specification of methods on product design and on project management is necessary due to the strong need of all surveyed persons for clearly defined structures, tasks, and time frames. The interviewees found it very helpful to learn classic project management methods and to directly realise them while planning and documenting their own practical work step by step: '[…] write down tasks that you can then work through in a structured way, so I think that's very helpful in a project like that.' A clear framework also helps the teacher to limit the portfolio work so that it does not require any additional work compared to the previous form of examination.

One of the students feared that e-portfolio work could lead to an unauthentic way of working if a method is chosen because of its external effect and not because the learner really prefers to work with it. The danger that there is no real reflection on what has been learned, but that the portfolio work is reduced to self-marketing, is also addressed by Arnold et al. [12]. To avoid this risk, it is very important to clearly communicate that the design of the portfolio will not be assessed and that students can make mistakes. What is important is how they handle these mistakes and if they can reflect on and react to feedback.

3.2.2 Flexibility and room for creativity

Another important aspect that the interviewees pointed to was the ability to work in a creative, flexible way and to show one's own strengths through e-portfolio work. The challenge is to satisfy both needs: the need for safety can be met by a clear structure, but there is also a desire for autonomous, creative, and flexible learning. Gebhard defines this challenge in the following way: 'In general, instructors and learners must find their optimum middle way between a lax laissez-faire attitude and rigid requirements' [13].

One of the interviewed lecturers suggested balancing these opposed needs by providing plenty of structure but communicating simultaneously that students can always leave the given path. Weber recommends in her research work to use an open-adaptive concept to satisfy both the demand for a clear structure and the wish for liberty and creativity. This can, for example, be realised by providing a clear framework and best practices during orientation and then letting students independently develop the topics they want to work on [7].

For the product design course, we would therefore suggest a clearly structured portfolio template and list of requirements combined with giving the students the freedom to decide which project management tools are used when and in what way material is presented on Mahara. One interviewee, for example, told us about his preference for visual content: 'For example, the one point where I explain how I took the measurements for the tractor. I see the picture and know, ah, this is happening in this paragraph.' Others do not like typing on the computer and would rather take a picture of their handwritten scripts to load them into their e-portfolios. Thus, along with concrete instructions, students concurrently have space to explore their own ideas and strengths.

One of the interviewees objects that some students, especially students of engineering, could feel unsettled if design is made an important element of their portfolios: 'Especially among the technicians, the visual skills are perhaps not quite as pronounced. Maybe some of them would have a massive advantage. Others, they might not have it at all.' This shows again how important it is not to assess design aspects themselves, but only to assess if the presentation is vivid and understandable. If a student is not a graphic design student, artistic aspects of the portfolio should not be evaluated.

One aspect of the product design course that students also mentioned very positively was the flexibility they had in writing their seminar papers. In contrast to exams, where the 60 minutes of the examination are decisive for the assessment of students' overall performance, students can work on their papers over a long period of time. This same flexibility can be a part of e-portfolio work.

Positive mention was also made of a possible experimental, autocorrective approach to errors: 'So you make a first version of something, then you see how it looks. Does it work at all and then you make another version until it works. And then there's the error analysis, which of course also counts.'

All these aspects coincide with the findings of Gebhard, who found that e-portfolio work is very motivating for students, as it allows them to demonstrate their individual skills in a flexible, creative way and under little pressure [8].

3.2.3 Reflective, autonomous learning and feedback

In accordance with the guiding principle of competence-oriented teaching and self-responsible learning of the European and German Qualifications Framework, e-portfolio work supports the individual acquisition of competences [12]. This is achieved through the independent documentation and reflection of learning processes and the exchange of information with others [12]. In particular, exchanges between fellow learners and teachers concerning the learning content can be implemented very well via Mahara through the group chat and comment functions. In contrast to this, in a classic seminar paper, as one of the interviewees complained, the performance aspect of teamwork is difficult to depict.

To guarantee that all students are motivated to work autonomously with Mahara and to interact with others, e-portfolio work must be learned and practiced by the students together in the compulsory course. One of the interviewed lecturers observed that many students do not learn to work independently and to reflect on their own learning process in high school. Autonomous learning can therefore by no means be taken for granted as an ability; it must be learned by many students at the university level. Furthermore, experts recommend clear guidelines for social interaction so that everyone feels comfortable participating [14].

Our course consists of 14 weeks x 180 minutes of weekly classes. Each week, 120 minutes are reserved for product design itself and the acquisition of the methods. The course mainly takes place as a workshop, and lectures are given on demand. Sixty minutes each week should be spent on the topic of e-portfolio work (weeks 1 to 4). Of these 60 minutes, 30 minutes are used to try out certain functions together and the other 30 minutes are reserved for individual work with the portfolio.

One important function, for example, is sharing projects with others and commenting on each other's content. Teachers should set feedback rules to help learners formulate their feedback in a constructive way. In addition, it must be clearly defined to what extent exchanges among the students are included in the assessment of portfolio performance. More reserved learners should not be disadvantaged compared to extroverts who love to be in constant communication with other students. Rather, the assessment should be about encouraging students to interact with each other in the first place.

The following framework could make this aspect implementable: All students receive a tandem partner by lot, and they and their partner give each other feedback on a work result four times during the seminar via the comment function. In addition, each student attends the tutor's portfolio consultation hour at least once. The assessment is only based on whether the student has completed all five feedback interactions, not on the content of the feedback. For weeks 5–14, we can assume that the Mahara functions have been fundamentally mastered and therefore we can shorten the joint portfolio work during lessons to 30 minutes per week. As there are always lectures on demand, students still have the ability to discuss further questions about Mahara during the course.

Research shows that for portfolio work to be accepted and successful, beginners must be continuously assisted, and they must have the ability to exchange information about questions that arise [7]. To ensure this support, e-portfolio tutors should be available to students on a regular basis during weekly consultation hours, in addition to the portfolio units in the course.

4 CONCLUSION AND OUTLOOK

In this paper, we showed approaches to implementing e-portfolios via the Mahara software in a course on project-based product design for engineers. The analysis of our interviews with different stakeholders led to the following five important aspects that should be considered in the development of didactic strategies: First, e-portfolios are an unknown tool for most of the interviewees at this point; therefore, a comprehensive introduction is an important prerequisite of their success. Second, for the realisation of e-portfolio work, students need a clear, well-defined framework and guidelines. Third, to enable students to use Mahara autonomously and creatively at the same time, they have to be instructed in its functions through weekly tutorials as part of a compulsory course. Fourth, design aspects may not be assessed. Fifth, mutual exchange, feedback, and teamwork, as important parts of autonomous learning, should be promoted by tandem partnerships and regular consultation hours.

To continue to keep students' perspectives in mind, we will also conduct interviews with learners during the implementation phase. Finally, a comprehensive evaluation of the project by students and teachers will contribute to the improvement and further development of e-portfolio work in the department of engineering and to the general increase of knowledge in the field of e-learning.

ACKNOWLEDGEMENTS

We thank the *Stiftung Innovation in der Hochschullehre* for funding our research project '3-Klang' (putting e-portfolios into practice – a triad of theory, communication, and utilisation).

REFERENCES

[1] Bailey R. and Szabó Z. Assessing engineering design process knowledge. *International Journal of Engineering Education*, 2006, 22(3), 508–518.

[2] Hilzensauer M.W. and Hornung-Prähauser M.V. *ePortfolio – Methode und Werkzeug für kompetenzbasiertes Lernen* (Salzburg Research). Available: https://eportfoliowick.jimdofree.com/literatur/salzburg-research-forschungsgesellschaft/ [Accessed on 2022, 23 February] (2006).

[3] Eynon B. and Gambino L. M. *High-impact ePortfolio Practice: A Catalyst for Student, Faculty, and Institutional Learning,* 2017 (Stylus, Sterling, Virginia).

[4] Schütz-Pitan J., Seidl T. and Hense J. Wirksamkeit eines fächer- und modulübergreifenden ePortfolio-Einsatzes in der Hochschullehre. Einflussfaktoren auf den Kompetenzerwerb. *Die Hochschullehre Interdisziplinäre Zeitschrift für Studium und Lehre*, 5, 2019, pp. 769–796.

[5] Himpsl-Gutermann K. *E-Portfolios in der universitären Weiterbildung. Studierende im Spannungsfeld von Reflexivem Lernen und Digital Career Identity,* 2012 (VWH Verl. Hülsbusch, Boizenburg).

[6] Rachbauer T. *E-Portfolios als Instrument für Selbstreflexionsprozesse in der Lehrerinnen- und Lehrerbildung. Eine empirische Untersuchung zur Implementierung von E-Portfolios in der universitären Lehrerinnen- und Lehrerbildung*, 2019 (Dissertation: LIT Verlag, Münster).

[7] Weber N. *Reflexionsmedium ePortfolio. Strukturierung von digitaler Portfolioarbeit im Lehramtsstudium*, 2021 (Dissertation: Verlag Julius Klinkhardt, Bad Heilbrunn). Available: https://elibrary.utb.de/doi/book/10.35468/9783781558854 [Accessed on 2022, 1 February].

[8] Gebhard C. Das Lernportfolio als Leistungsnachweis im Chinesischunterricht. *CHUN*, 35, 2020, pp. 86–102.

[9] Mayer H.O. *Interview und schriftliche Befragung. Entwicklung Durchführung und Auswertung*, 4th edition, 2008 (Oldenbourg, München [u.a.]).

[10] Misoch S. *Qualitative Interviews*, 2, pp. 119–128, 2019 (De Gruyter Oldenbourg, Berlin, Boston).

[11] Bender B., Gericke K. and Pahl G. *Pahl/Beitz Konstruktionslehre. Methoden und Anwendung erfolgreicher Produktentwicklung,* 9, 2021 (Springer Vieweg, Berlin).

[12] Arnold P., Kilian L., Thillosen A.M. and Zimmer G.M. *Handbuch E-Learning. Lehren und Lernen mit digitalen Medien*, 5, 2018 (W. Bertelsmann Verlag, Bielefeld).

[13] Gebhard C. Portfolios as performance records in a reflective approach in teaching Chinese as a foreign language. In *Business Meets Technology 2. Proceedings of the 2nd International Conference of the University of Applied Sciences*, Ansbach, July 2020, pp. 22–25.

[14] Spielmann D. *E-Portfolio in der Schreibberatungsausbildung. Cognitive Apprenticeship und reflexive Praxis, Volume 2*, 2017 (wbv, Bielefeld).

DEMOCRATIC MANUFACTURING: A STUDENT MANUFACTURED & OPERATED 3D PRINTER FARM

Francesco Luke SIENA[1], Christopher FORBES[2] and Kerry TRUMAN[2]
[1]Product Design Department, School of Architecture Design & The Built Environment, Nottingham Trent University
[2]Technical Team, School of Architecture Design & The Built Environment, Nottingham Trent University

ABSTRACT
The DIY movement goes back to the late 60's and started the trend of shared tools as a reaction to the lack of skills and education on how things are made; this resulted in an increased awareness of democratic manufacturing resources and facilities, especially makerspaces and hackspaces, innovation labs, 3D printer farms etc. At Nottingham Trent University (NTU), we have observed an increase in students choosing to study Product Design thus increasing pressure on workshop/manufacturing spaces, especially automated manufacturing resources such as 3D Printers. Subsequently, the maker experiences students have been experiencing within the workshop environment temporarily lessened to ensure the needs of our rapidly increasing student cohorts are catered for. This paper explores how democratic technologies and manufacturing tools have overcome this issue by enabling designers, makers, and hobbyists to increase their access to facilities within the Product Design Department at NTU. This paper explores/reflects on the initial development of a 3D printer farm located in a product design studio where a group of sixty-nine students manufactured/assembled eighteen Creality CR-10S 3D printers. The success of the initial student led democratic manufacturing project resulted in ADBE developing a second 3D printer farm in a second product design studio consisting of a further eight Creality CR-10S V3 3D printers. The 3D printer farms are now complimented by a blended induction allowing for student independent use of the resource. Student feedback is also presented regarding the blended induction to ascertain knowledge acquisition and confidence on using the resources independently.

Keywords: 3D printing, blended learning inductions, democratic manufacturing, product design education, technology literacy

1 INTRODUCTION
As a reaction to the increased capacity issues, demand for teaching and learning on modern manufacturing methods and student enthusiasm to learn about modern manufacturing methods, the democratic manufacturing project within The School of Architecture Design and Built Environment (ADBE) at Nottingham Trent University was created. This paper focuses on a student manufactured, operated, and maintained 3D printer farm. Within ADBE, the aspiration is to constantly improve facilities and student engagement with hands on experience, especially in workshops and studio spaces, which in recent years has been limited due to capacity/footprint restrictions, cohort sizes, national lockdowns etc. The democratic manufacturing project focused on providing students the opportunity to assemble/manufacture, operate and maintain a 3D printer farm within their product design studio.

A 3D printer farm is a large collection of 3D printers situated in one location; an example is the Monkeyfab Prime 3D printers shelved in one location at The Department of Automotive and Machine Tools at the Warsaw University of Technology [1]. 3D printer farms can be framed in two contexts i.e., integrated production, and consumer production. Integrated production 3D printer farms provide the possibility of dramatically influencing the supply chain through automation [2]. 3D printer farms also offer automated manufacturing possibilities i.e., Prusa Pro AFS Automated Farm System [3]. 3D printer libraries have been trialled, providing a point of access/support for 3D printing for students/faculty across disciplines beyond engineering and technology [4]. There are many benefits of using 3D printing in engineering education, offering learning opportunities across computer aided design (CAD), digital manufacturing, software skills, amongst others [5]. 3D printing is used in various teaching settings ranging from schools through to higher education and across multiple subjects ranging from engineering, product design, amongst others [6]. 3D printing used in combination with eLearning tools for design education offers many opportunities; eMaking can help bring together the virtual and the physical worlds in the design studio [7]. There are many learning challenges within product design that encompass physical/digital making; bridging the learning gap from the studio environment to labs or digital manufacturing laboratories is essential to embed learning through technology use whilst still being considerate of critical making [8]. This extends beyond typical design studios, fabrication laboratories or makerspaces; 3D printing services are offered in academic library environments too [9]. This paper explores/reflects on the initial development of a 3D printer farm located in one of the product design studios at NTU where a group of sixty-nine students manufactured/assembled eighteen Creality CR-10S 3D printers completing a four-week 3D printing project. The success of the initial student led democratic manufacturing project has seen ADBE invest further and develop a second 3D printer farm in a second product design studio consisting of a further eight Creality CR-10S V3 3D printers. Both 3D printing farms are now 100% student operated, accessible seven days a week, with no staff supervision required. Students require a one hour thirty-minute blended learning 3D Printer farm induction developed to give students a quick hands-on learning experience that enables them to gain confidence in using the 3D printers when inducting themselves. This step-by-step induction resource allows students to follow along learning how to use the 3D printers and the supporting software. Feedback on the induction process has been collected, demonstrating the successes of the project. Overall, over the past two academic years, over 300 students have self-inducted themselves into the 3D printing farms resulting in a dramatic increase in awareness of democratic manufacturing resources.

2 BUILDING THE 3D PRINTER FARM

The initial democratic manufacturing project was set to a group of sixty-seven BSc (Hons) Product Design first year students in the 2019/20 academic year. Students selected their pairings which were later collated into groups of four/five. Each student group was provided with a DIY kit for a Creality CR-10S 3D printer and were tasked to construct, calibrate, and produce test prints together (Figure 1). Each student group was provided with a set of simple instructions and a standard user manual provided with the printers to aid the initial constructions and assembly. Students could however use additional video tutorials and content available online or seek support from the tutors. The students were also tasked with documenting their construction process as part of the project, they were expected to produce a more detailed and informative user manual which could be shared with future student groups who would learn how operate the 3D printers when fully installed and located in the 3D printer farm location.

Figure 1. BSc Product Design Year 1 Students Building Creality CR-10S 3D Printers

Alongside the construction of the 3D printers, the students were tasked with designing a board game within their groups, all components beyond the board game boards had to be 3D printed (Figure 2). This forced each student to interact with the 3D printers and produce accurate components on a small scale. Students were also aware that between the sixty-seven of them, there were only eighteen 3D printers, therefore they were required to work in a democratic manner by sharing resources. Feedback from students highlighted the positive impact of the initial democratic manufacturing project with students suggesting that they enjoyed the hands-on approach to building a machine and then utilizing this machine in practice to produce usable components. Feedback collected identified that for many students this was their first experience being hands on with manufacturing technologies not ordinarily accessible to them. The construction/assembly of the 3D printers also gave them a sense of ownership and pride in not only utilizing the resource but maintaining it too:

> *"I like how the module got more hands on (i.e., the construction of the 3D printers) this allowed us to utilize our skills learned from other sessions (i.e., Solidworks 3D CAD sessions). It feels like I am practicing and comprehending my skills and knowledge together. I also like that the 3D printing lectures provide up to date industry knowledge". [Anonymous]*

> *"I liked how creative I had to get… I have enjoyed research about new and interesting concepts. Learning how to independently 3D print anyway was the aspect of the teaching I valued the most". [Anonymous]*

Figure 2. Board Games & 3D Printed Components – Credit: B.Green, B.Holmes & D.Kapoor

Following the success of the initial democratic manufacturing project and the rapid increase in demand for 3D printing across the product design cohorts, but also the sudden change to working practices due to COVID-19 social distancing, this resulted in two priorities being identified. Firstly, a second smaller 3D printing farm for a second product design studio to help facilitate other product design cohorts democratic and digital manufacturing needs was required. Secondly there was also a need for an induction process to be created that could be delivered in a blended teaching and learning environment, whilst being socially distanced, thus helping to reduce the reliance on one-to-one staff demonstrations.

3 DEVELOPING THE BLENDED LEARNING 3D PRINTER INDUCTION

With the dramatic increase in demand for 3D printing, it was decided that a one hour thirty-minute blended learning 3D Printer farm induction was necessary to allow individuals to induct themselves onto the 3D printers through the demonstration of the successful printing of a small component. The induction requires the students to gain a fundamental understanding on how to operate the 3D printers whilst also demonstrating successful manual leveling of the build plate, successful loading of material, appropriate setup of files within a slicer program (in most cases this was Ultimaker Cura or Creality 1.2.3 slicer) and successful 3D printing of a sample part. To conform to NTU's teaching and learning principles, we aim to offer videos in several segments each of which are no longer than ten minutes in length. A step-by-step induction resource developed (Figures 3 & 4) allows students to follow along learning how to use the 3D printers and the supporting software via a VLE learning room setup for 3D printer inductions.

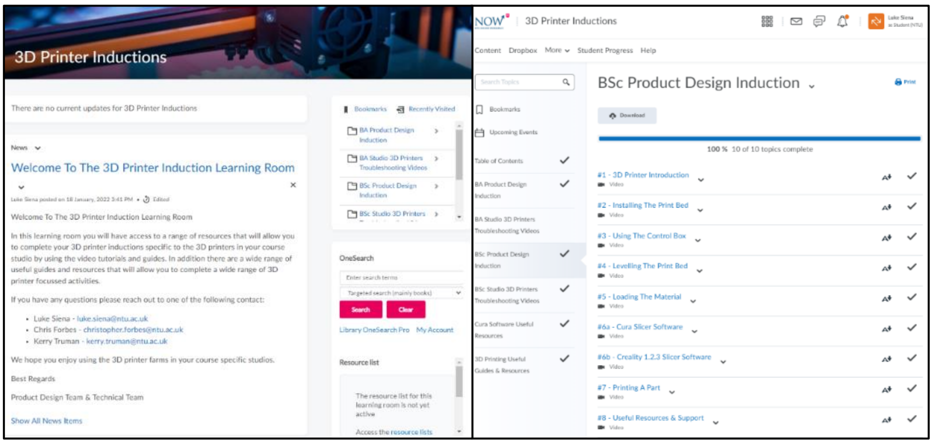


Figure 3. 3D Printer Inductions NOW Learning Room

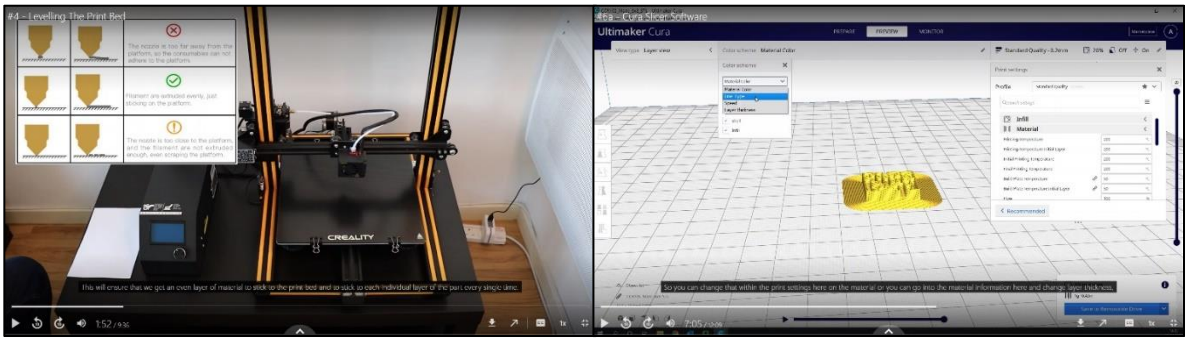


Figure 4. Video Resources Recorded to Support The Blended 3D Printer Farm Induction

We identified that the students needed to learn several new skills whilst understanding new software and terminology. We therefore aimed to make the learning experience quick and hands-on, enabling students to gain confidence in using the 3D printers and induct themselves into the facilities. It was necessary for the students to have a recourse to refer to at any time, as the demands of different courses would dictate frequency of access required. Students who used the 3D printers less frequently could therefore recap any knowledge forgotten after a period of none use. Eight videos were necessary to complete the induction, these covered topics including, a general 3D printing introduction, an overview on how to install/change a print bed, how to operate the control box safely, how to level the printer bed, how to load/unload material, how to operate a compatible slicer software depending on the device being used, how to print a part and finally how to access additional useful resources and support.

Due to the diverse range of students with varying needs, especially students with physical disabilities (e.g., hearing loss) or specific learning difficulties (SpLD's), several key principles were adhered to for accessibility compliance. Content was methodically delivered at a pace which allowed students with information processing conditions the time needed to digest/apply the information. All videos have fully embedded captions and are accessible on all devices. The videos are hosted on NTU's NOW (Nottingham Online Workspace) VLE and delivered via Panopto. This ensures all students, irrespective of their financial status and IT literacy can complete the induction regardless of the device used.

To facilitate the clarity of information, all videos were video edited in Adobe Premiere Pro to allow information to be overlayed/embedded (Figure 4) where simple video shots were not sufficient in communicating the desired information by themselves. To support knowledge acquisition on 3D printing, a series of 3D printing lectures and activities have been produced to support design for manufacture and assembly (DFMA). These videos explore Ultimaker Cura's features and provide detailed insights into how to produce functional components. Each 3D printer farm also has a material bank available to the students. Each 3D printer has been given an individual name to allow for easy reporting of faults to the relevant technical personnel. QR code posters are also placed in each 3D printing farm space to help students navigate to online resources. The QR codes also directly link to the 3D printer induction booking system that links to academic's calendars regarding availability.

4 LEARNER PERSPECTIVES & REFLECTIONS

Over the past twelve months, feedback has been collected from forty-nine students across BA (Hons) Product Design and BSc (Hons) Product Design courses whereby they completed an anonymous online survey so insight could be gained on the blended inductions. Eighteen participants were "not at all familiar" with 3D printing compared to thirteen that were "slightly familiar", twelve that were "moderately familiar", four that were "very familiar" and two that were "extremely familiar". Twenty-two participants found the induction videos "extremely useful", twenty-four found the videos "very useful", one participant found the videos "moderately useful" and two found the videos "slightly useful". Significantly, forty-seven of the participants found the members of staff supporting the blended inductions "very helpful" with two participants finding the members of staff "somewhat helpful".

After completing the blended induction, fifteen students were "extremely confident" using the 3D printers, with twenty-seven "quite confident" and seven participants "somewhat confident"; no participants identified that they were "not confident at all". In summary, across the forty-nine students who completed the survey, the average rating for the blended induction was 4.8/5.0 for their overall cumulative experience. From the open-ended questions provided for further comments, students provided further feedback with the below quotes demonstrating the positive experiences encountered:

"Methodical videos which were clear in breaking down the use steps. This allowed me to easily play the videos in parallel to using the 3D printers. Didn't feel overloaded with information". (P3)

"The step-by-step videos (were most useful) because they allowed everyone to go at their own pace depending on their personal familiarity with 3D printers". (P31)

(useful aspects included) "gaining basic understanding of how to use 3D printers, how to set up 3D printers and just being able to see one working in action". (P46)

Some of the student feedback that suggested areas for improvement focused on areas such as the online booking system for the inductions, the frequency and time-period of the automated reminder emails from the booking system not being frequent enough and also identifying challenges some of them faced during the induction when things went wrong; requests for more visuals or supporting videos were made:

"It would have been useful to know the day before that we needed laptop as not everyone checks there emails daily (to check the booking system reminders)" (P5)

(The videos) "didn't really mention what to do if something goes wrong with your print, and how to fix it". (P9)

"I found it challenging to set up the correct height (when levelling the print bed) for the base, as using the paper technique to see if there is friction isn't the most accurate" (P15).

Following feedback, additional useful resources and helpful hints videos have been recorded for each type of 3D printer. These focus on the unloading/changing of material, Z-Axis adjustment to allow for improved material loading/unloading, as well as supporting videos on more complex design considerations related to DFMA for 3D printing for functional prototypes. Student feedback included:

"Perhaps making students aware of common pitfalls that they can encounter when 3d printing in general" (P3).

"There wasn't a video for the unloading of material from the printer, this could be useful for those who don't have the background knowledge." (P42)

The 3D printer induction learning room on the VLE environment and provision of 3D printing resources has had a significant impact on student education over the past twelve months with over 200+ unique users engaging with the online induction resources. When considering NTU's success for all agenda, the 3D printer farm and material hub has provided all students with equal opportunities to learn about democratic manufacturing tools without having to worry about the associated costs to them:

Having access to materials and resources we need is also very helpful allowing me to get on with projects without having to worry about trying to find materials suitable for the machines such as the 3D printers. [Anonymous]

5 CONCLUSIONS

The development of the 3D printer farms at NTU has seen a dramatic increase in student DFMA proficiency within design projects. More notably, student confidence with democratic manufacturing machines/tools is at an all-time high, with students at key times during the academic year manufacturing models utilizing the 3D printers for 1st/2nd year project work in addition to the production of working prototypes for final year commercial and self-directed projects. The overall workflow for 3D printing has been drastically improved, with the student experience significantly improving (Figure 5). The rapid increase in digital manufacturing tools within the portfolio of product design courses at NTU continues to add value to the student experience. We are now exploring methods of increasing democratic manufacturing opportunities in the form of "Pop Up Workshop" initiatives which can be supported by a blended learning induction. These inductions can provide students with relevant health and safety knowledge, but also the confidence to utilize democratic manufacturing resources in the product design studios. We are also looking to expand the use of the blended learning inductions to cover other digital design and manufacturing resources, especially for other types of 3D printing/3D scanning.

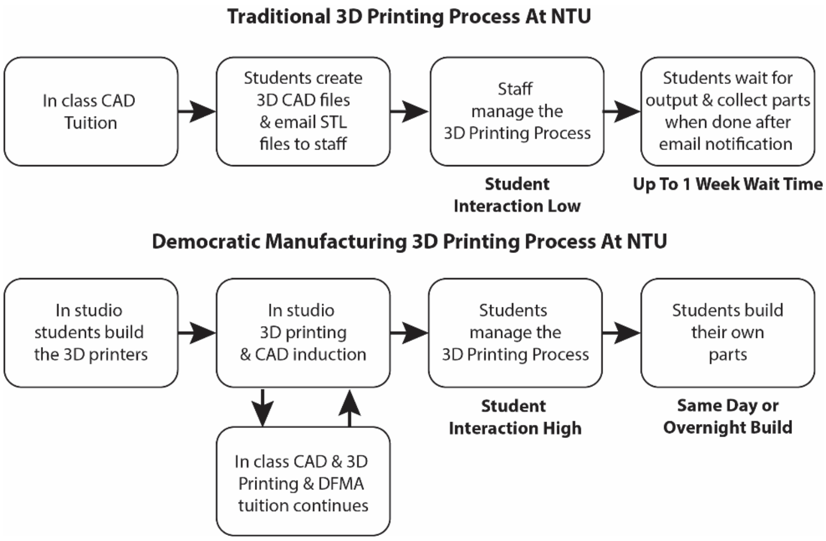


Figure 5. Comparison of 3D Printing Workflows

Due to student confidence with democratic manufacturing resources, especially the 3D printer farms, NTU is looking to expand the technical expertise retained by employing 1st year students as bank staff to help maintain the 3D printer farms. We are looking to train/deploy students into other areas of the workshops/studios especially as student numbers continue to grow whilst expanding the 3D printing farms by offering other low-cost machines with varied capabilities. As the online resources/inductions have proven popular and reduced the reliance on the technical specialists at NTU, we are looking to expand the online induction resource pool by offering bite sized videos on key topics. Although segmented, all videos are typically below 10 minutes in length, allowing students to access key resources quickly and get direct answers to queries. As we continue to expand our resources, the use of digital manufacturing for other hardware such as 3D scanners, virtual reality headsets etc., will aim to also improve the digital design workflow for our students and improve their technical proficiency thus having a positive impact on their employability in the years to come. The use of digital workflow systems such as booking systems for the blended inductions has also allowed for improved effective planning and delivery. Although challenging to setup, the student facing interface is straightforward for students to use/book their inductions. Due to our international/diverse student pool, initial interactions with democratic manufacturing tools and workshops experiences must be embedded in the students first year of study to give them the autonomy and confidence to become skilled product designers and industrialist.

REFERENCES

[1] Skawiński P. and Siemiński P. The 3D Printer Farm–function and technology requirements and didactic use, *Mechanik*, 2017, 90(8-9), 796-800.
[2] Kylau U. Goerlich K. and Mitchell RL. 6 Ways 3D Printing Will Disrupt Manufacturing in the Next 5 Years–and Beyond, *SAP Center for Business Insight*, 6.
[3] Průša J. The Future of Manufacturing in Dubai: The first look at our Automated Farm System - Prusa Printers. [online] Prusa Printers. Available at: https://blog.prusaprinters.org/the-future-of-manufacturing-by-prusa-research_55993/ [Accessed 8 March 2022]. (2021) 1 October.
[4] Van Epps A. Huston D. Sherrill J. Alvar A. and Bowen A. How 3D printers support teaching in engineering, technology and beyond. *Bulletin of the Association for Information Science and Technology*, 2015, 42(1), 16-20.
[5] Jaksic NI. New Inexpensive 3-D Printers Open Doors to Novel Experiential Learning Practices in Engineering Education. *In 2014 ASEE Annual Conference & Exposition*, 2014, pp. 24-932.
[6] Ford S, Minshall T. Invited review article: Where and how 3D printing is used in teaching and education. *Additive Manufacturing*, 2019, 25, 131-50.
[7] Loy J. eLearning and eMaking: 3D Printing Blurring the Digital and the Physical. *Education Sciences*, 2014;4(1):108-21.
[8] Kempton W, Killi S, Morrison A. Meeting learning challenges in Product Design education with and through Additive Manufacturing.
[9] Scalfani VF, Sahib J. A model for managing 3D printing services in academic libraries. *Issues in Science and Technology Librarianship*. 2013, 72(Spring), 1-3.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

THE ROLE OF EMOTIONAL VALUE AS A FACTOR IN SUSTAINABLE FASHION DESIGN EDUCATION

Wang MANQIAN[1] and Kim EUNYOUNG[2]
[1]Student of Japan Advanced Institute of Science and Technology / Lecturer of School of Fashion of Dalian Polytechnic University
[2]Professor of Japan Advanced Institute of Science and Technology

ABSTRACT
In recent years, sustainable fashion education has gained more and more attention in China. However, there lacks exploration from the aspect of consumer emotion. This study explores the relationship between the life cycle of young people's clothing and emotion through a curriculum experiment in northeast China. Through the wardrobe analysis and sorting experiment, students pick out the clothing item from their wardrobe which has been worn or kept for the longest time. It can be found that the clothing with the longest retention has special emotional significance to the user, especially the narrative emotion and attachment emotion have a strong correlation with the longer life cycle of the clothing. Besides, through bivariate correlation analysis, a significant correlation was found between product practicability and longevity.

Keywords: Sustainable fashion design education, emotional durability, sustainable design, life cycle

1 INTRODUCTION

Fashion is often regarded as the antithesis of sustainability; thus, it is essential for high schools to imbue future fashion professionals with the concept of sustainable fashion [1]. Currently, sustainable design education (SDE) is mainly based on the methods of energy-saving, recycling, and redesign. Little research has been conducted on the relationship between emotions and sustainable fashion education. According to the emotional design theory of Norman [2] and the sustainable fashion design research of Fletcher [3], emotions have a significant impact on the life cycle of a product. Artistic aesthetics may affect people's impressions and help enhance the emotional value of products. In a course for design thinking and methods for second-year fashion design majors, the researcher, as the lecturer, attempted to identify the role of emotion in sustainable fashion design.

The main research question (MRQ) is to associate how emotional factors affect the lifetime of young people's clothing. The sub-research question (SRQ) is to identify what emotional factors may help to prolong the lifecycle of fashion products. We bring these two questions into the course and conduct in-depth research through interaction with students so that students can discover the importance of emotion to sustainable fashion design from their own perspectives.

2 LITERATURE REVIEW

2.1 Sustainable design education in China

Higher education in China has gradually changed from elite to popular education, so it is necessary to cultivate the concepts of environmental ethics and sustainable development among students [4]. In terms of fashion design education, universities have introduced related courses on sustainable design. Xu has integrated the sustainable design method of "zero waste, upgrade and re-engineering, recycling and multiple wears" into her teaching for many years. Xu pointed out that the traditional fashion teaching mode, which is limited to artistic creation and practical technology cultivation, is not enough to promote the development of a sustainable industry, and interdisciplinary courses are needed to advance sustainable design education in the fashion industry [5]. The 5R principles of sustainable education proposed by Lv include Revalue, Reuse, Renew, Recycle, and Reduce [6]. Similarly, Xie emphasized the cross-learning characteristics of sustainable design courses and suggested cultivating students' integration ability to deal with comprehensive multidisciplinary problems [7].

Some design colleges and universities in China have established education courses or sustainable design majors [8]. According to Tao & Wang, sustainable fashion education in China consists of three aspects: enterprise cooperation, cooperation with the government or environmental agencies, and independent research courses [9]. By summarizing the sustainable courses of colleges and universities that offer fashion design courses in China, it can be seen that current sustainable fashion education is mainly carried out from the perspective of recycling and new materials (Figure 1), and there is little sustainable teaching method employed from the viewpoint of emotional needs. Consumer emotion directly affects the process of purchase, use, and abandonment as a whole (Figure 2). Introducing emotional needs into fashion design education is useful in cultivating students' comprehensive design ability and expanding sustainable design education. Thus, the study of sustainable design from the perspective of emotion has a strong research significance in fashion design education.

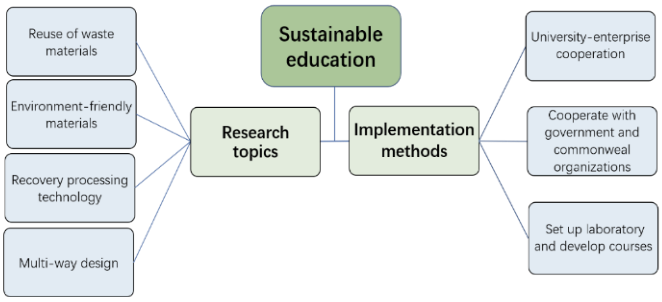


Figure 1. The sustainable education topics and methods in China

2.2 The emotional durability of fashion

Concerns about the product life cycle have been around [10]. “The sustainability crisis is a behavioural issue, and not one simply of technology, production, and volume” [11]. According to Chapman, it is possible to extend a product’s lifespan by relying on emotions, especially narrative emotions from the product itself [12]. Furthermore, emotions will directly affect people's participation in environmental protection [13]. Thus, the specific impact of personal emotions on the life cycle of fashion products needs to be analysed.

3 METHODS

3.1 Adjustment of the curriculum

The course which was named “design thinking and methods,” aimed to seek innovative thinking and design concepts and explore the expression of new design from multiple perspectives. The curriculum

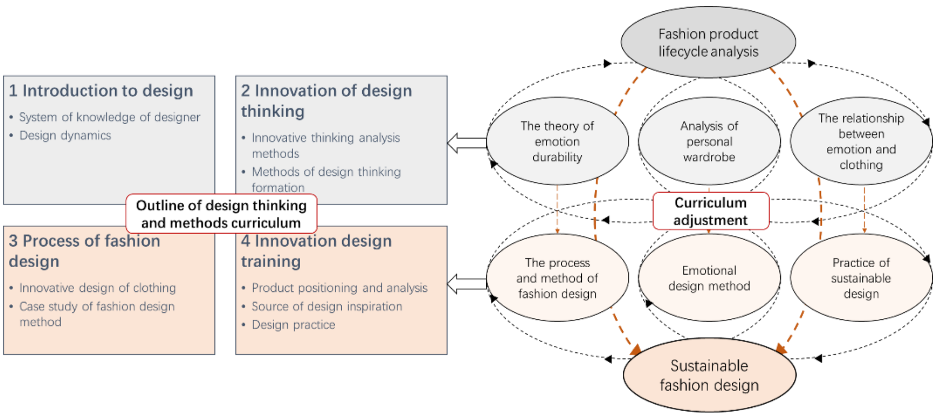


Figure 2. Schematic diagram of course adjustment

is a platform foundation course for sophomores. Before that, students mainly learned the curricula of the plane constitution, solid constitution, basic clothing craft, and other basic courses. Therefore, design thinking and methods are intermediate bridging courses from platform foundation courses to clothing design courses. The structure of the course is shown in Figure 2, it mainly includes four parts: the first two parts focus on letting students understand the design thinking method that designers need to master; The last two parts include the process of fashion design methods, as well as the innovation design training.
However, the concept and method of sustainable design are not introduced in the course. In the course of 2022, Norman's Emotional Design Theory [2] and the sustainable fashion design research of Fletcher [3] were integrated into the second part of the course. students stepped out of the traditional design method based on artistic modelling and material production and developed a more comprehensive understanding of the relationship between emotion and sustainable design. The second part of the course focuses on the relationship between the life cycle and emotion. Through the analysis of personal wardrobe to understand the influence of personal emotion on the lifecycle of clothing.

3.2 Survey of personal wardrobe analysis

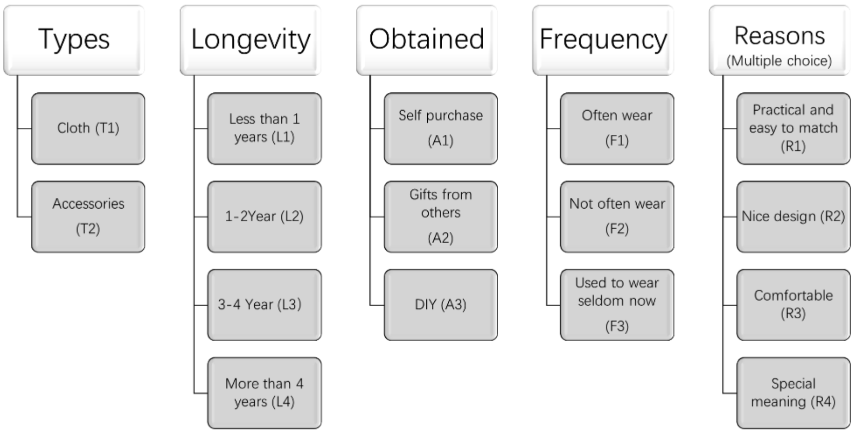


Figure 3. Content of personal wardrobe survey

This study adopts an intensive survey of the relationship between students' emotions and clothing life cycle. Each student is required to organize and analyse his/her wardrobe within one week. Figure 4 specifically shows the content of the wardrobe survey of students. Firstly, each student needs to organize his or her closet and find clothing or accessory (bag, shoes, etc.) which has been worn for the longest time. Then, questions need to be unanswered. 1) How the clothing and accessories were obtained? there are three alternatives to the question, self-purchase, given by others, and DIY (do it by myself). 2) How long have the clothes or accessories been worn? 3) Answer in depth the reasons for getting used to the item (Figure 3).
Through the survey of in-depth analysis of personal closets, students can learn more about their own closets. In addition, during the course, each student had 10 minutes to present the relationship been his/her personal information and the fashion items. By learning from each other, students learn about the relationship between young people's emotional needs for clothing and the life cycle of clothing.

4 RESULTS

4.1 Data analysis

A total of 48 students aged between 18 and 20 years participated in the survey for personal wardrobe analysis. Through sorting out the results of students' analysis, we made data statistics according to five items: Types, Longevity, Access ways, Frequency, and Reasons.
From Table 1, it can be seen that special meaning (R4) has the greatest impact on longevity by comparing the relationship between longevity and reasons. The Chi-square test was conducted, and the result shows that the p-value is .562633, which shows that there is no obvious connection between the life cycle and reasons. The practicability, comfort, and special meaning of clothing have a great influence on the life

cycle of clothing, which shows that the study of emotional design is as important as the aesthetic design and comfort of products.

Table 1. Data analysis of the relationship between longevity and reasons

Longevity	**R1**	**R2**	**R3**	**R4**
less than 1 year	2	1	1	1
1 – 2 years	8	3	5	7
3 - 4 years	10	10	8	10
more than 4 years	5	10	2	11
Sum	**25**	**24**	**16**	**28**

The chi-square statistic is 7.7196. The p-value is .562633. The result is not significant at $p < .05$.

Table 2 Result of bivariate correlation analysis

Correlations

		Longevity	Obtained	Frequency	Practical	Design	Comfort	Meaning
Longevity	Pearson Correlation	1	.141	.281	-.317*	.268	-.242	.130
	Sig. (2-tailed)		.337	.053	.028	.065	.098	.379
	N	48	48	48	48	48	48	48
Obtained	Pearson Correlation	.141	1	.216	-.310*	-.205	-.121	.439**
	Sig. (2-tailed)	.337		.140	.032	.163	.414	.002
	N	48	48	48	48	48	48	48
Frequency	Pearson Correlation	.281	.216	1	-.654**	.025	-.353*	.433**
	Sig. (2-tailed)	.053	.140		.000	.866	.014	.002
	N	48	48	48	48	48	48	48
Practical	Pearson Correlation	-.317*	-.310*	-.654**	1	-.209	.501**	-.521**
	Sig. (2-tailed)	.028	.032	.000		.155	.000	.000
	N	48	48	48	48	48	48	48
Design	Pearson Correlation	.268	-.205	.025	-.209	1	-.442**	.128
	Sig. (2-tailed)	.065	.163	.866	.155		.002	.387
	N	48	48	48	48	48	48	48
Comfort	Pearson Correlation	-.242	-.121	-.353*	.501**	-.442**	1	-.512**
	Sig. (2-tailed)	.098	.414	.014	.000	.002		.000
	N	48	48	48	48	48	48	48
Meaning	Pearson Correlation	.130	.439**	.433**	-.521**	.128	-.512**	1
	Sig. (2-tailed)	.379	.002	.002	.000	.387	.000	
	N	48	48	48	48	48	48	48

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation analysis was conducted on the longevity, obtained ways, frequency, and the four seasons in the survey, it was found that practicability and longevity were significantly correlated, the sig. is 0.028. Whether the product has special meaning to the user depends on how the product is acquired. Studies show that most of the clothes that students keep for a long time have special emotional significance. Besides, practicability also has a strong correlation with the frequency of product use.

4.2 Analysis of emotion toward longest-lives fashion products

According to Chapman's theory, the product's service life would be affected by six factors, including

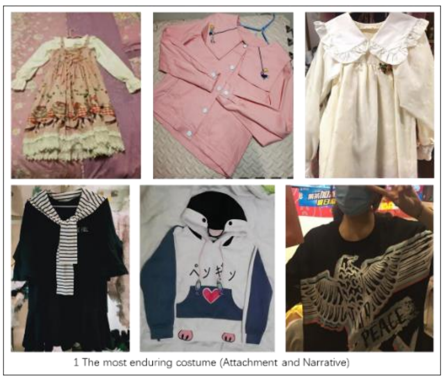


Figure 4. The samples with special meaning

Figure 5. The samples with classical style

Narrative, Detachment, Surface, Attachment, Consciousness, and Fiction. The top three factors were narrative (24 percent), surface (23 percent), and attachment (16 percent). According to students' emotional descriptions of their clothes, it can be found that the clothes with the longest life cycle can be divided into two types (Figure 4-6). 1）The cloth or accessory has special meaning to the student ； 2) The cloth or accessory is convenient and practical, and the classic style is easy to match.

The emotional factors carried by the clothing selected by students in this research can be classified into two categories: attachment and narrative. For example, the three clothes in the top row of Figure 4 are received as birthday gifts or commemorative gifts, which have special emotional significance for the student. The three clothes in the bottom row of Figure 4 are mostly related to attachment. According to the description of students, some of these clothes accompany them through the most difficult time of the college entrance examination, some of the clothes are considered to be lucky clothes.

The clothes in Figure 5 are not emotionally related to the students' description but are simply considered to be of good quality, simple and practical. The reason for the longevity of the accessories in Figure 6 has more to do with practicality. Especially for bag preferences, practicality is very important. This shows that young college students pay more attention to the function of accessories design.

5 CONCLUSION AND DISCUSSION

Through the experiment of personal wardrobe analysis, it is found that 1) Among the factors which clothing was retained for a long time, practicability, comfort, and special meaning of clothing have a great influence on the life cycle of clothing, which shows that emotion has an important impact on the sustainability of clothing; 2) Practicability and longevity were significantly correlated. Practicability has a strong correlation with the frequency of product use; 3) The analysis of the experimental results shows that clothing with a long-life cycle can be divided into two types: first, the clothing is retained with a specific emotional basis. Second, the classic style is easy to match. There are two main factors among the emotion towards the longest lifespan clothing: attachment and narrative. Through this course, students analyse the relationship between emotion and clothes' life cycle not only by individuals but by the whole class communicating. The students understand the importance of emotion in fashion design and lay a foundation for sustainable fashion design in the future. However, a limitation of this study is that the participants of the questionnaire survey were concentrated in one university, and a limited number of students participated in the experiment. In addition, the experiment required students to select only one garment or accessory for analysis, which resulted in insufficient samples. The researchers will absorb more samples for further analysis.

REFERENCES

[1] Murzyn-Kupisz M. and Hołuj D. Fashion design education and sustainability: Towards an equilibrium between craftsmanship and artistic and business skills? *Education Sciences*, 2021，11(9), 531.

[2] Norman D. A. *Emotional design: Why we love (or hate) everyday things. Basic Civitas Books*, 2004.

[3] Fletcher K. *Sustainable fashion and textiles: design journeys. Routledge*, 2013.

[4] Zhou H. M. The education of sustainable design based on the environmental ethics, *Design (China)*, 2020,33(11), 105-107.

[5] Xu H. Research on the application of low-carbon environmental protection concept in clothing design education, Journal of Hunan University of Science and Engineering, 2020, (5),3.112-114.

[6] Lv M.Y. Sustainable Design practice and Teaching in China, *Design Art Research*, 2015, 5（4，116-121.

[7] Xie F. Study on European sustainable design educational modes in Europe and their implications for China- Take the architectural design majors of Nottingham University and Hunan University for example, *University Education Science*, 2014, 54-58.

[8] Rong M. Q. Application and practice of sustainable design concept in environmental design specialty, *Anhui Architecture*, 2020 (10), 113-114.

[9] Tao H. and Wang Y. Y. Research on the problems and education strategy of fashion sustainable development in China, *Fashion Guide*, 2020, 9 (3).

[10] Cooper T. Durable consumption: reflections on product life cycles and the throwaway society[C]//*proc. of lifecycle approaches to sustainable consumption workshop*. 2002, 11-27.

[11] Chapman, J. *Emotionally durable design: objects, experiences and empathy, Routledge*, 2015.
[12] Kollmuss A. and Agyeman J. Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behaviour? *Environmental Education Research*, 2002.8(3), 239-260.

HOW TO ENABLE ENGINEERING STUDENTS TO APPLY SUSTAINABLE SOLUTIONS IN THE PRODUCT DEVELOPMENT PROCESS?

Sinah MALZ[1], Stefan ZORN[2], Olaf KESSLER[1] and Kilian GERICKE[2]
[1]Chair of Materials Science, University of Rostock, Germany
[2]Chair of Product Development, University of Rostock, Germany

ABSTRACT
Novice product designers are often insufficiently trained for sustainability-related challenges in engineering practice as sustainability or eco-design have not yet become standard topics in engineering curricula at German universities. The authors developed a course for engineering students to familiarise them with a sustainable way of thinking and train skills required to develop more sustainable solutions. This paper provides details on the concept's structure, content, and methods. The course is part of the Bachelor's and Master's programmes in Mechanical, Biomedical and Industrial Engineering. In order to understand the importance of the topic, students get an introduction to sustainability in general through diverse methodological approaches. Subsequently, they learn and apply relevant basic methods from the field of product development and material selection. Furthermore, special attention is paid to the synergy between university engineering education, science and industry through excursions and guest lectures. Evaluations assess students' learning outcomes, thus enabling the continuous adjustment of addressed content and applied methods.

Keywords: Engineering education, sustainable development, sustainability, materials science, materials selection, product design

1 INTRODUCTION
The world population is growing. By 2050, more than 9.7 billion people could live on this earth [1]. The global extraction of raw materials is steadily increasing and could reach over 100 billion tonnes per year by 2030 if the trend remains the same [2]. Due to the rapid pace of this resource consumption and the often missing recovery frameworks, there is a gradually increasing shortage of resources and a rapidly growing burden on global ecosystems [3].
Engineering designers play a key role in the necessary shift towards a circular economy, as technologies they develop actively use resources on a large scale and are a driving factor of social change [4]. This responsibility should be considered at the very beginning of the development of any product and process. However, prospective product designers are still insufficiently trained to consider their work's ethical and sustainable dimensions. Therefore, a comprehensive discussion of sustainability issues in product development is urgently needed for university engineering education, considering existing guidelines regarding the selection of materials and design [5, 6]. This paper presents a course at a German university intending to fill this gap.

2 COURSE CLASSIFICATION
As a response to the challenge of sustainability in engineering, there is a global shift towards student-centred learning in education for sustainable development (ESD). In global comparison Europe has the highest number of publications in this area. Particularly younger universities are demonstrating successful systemic approaches. Overall, however, the publications are still scarce, and one cannot yet speak of an implementation of ESD content in the engineering education on a large scale [7, 8].
In Germany one can find a few entire degree programmes on sustainability in the engineering sciences particularly at Universities of Applied Sciences [9]. However, corresponding approaches can also be found at a few universities, like the quite novel degree programmes "Sustainable Systems Engineering" at the University of Freiburg (since winter 2016/17) [10], "Sustainable Engineering of Products and

Processes" at the Technical University of Braunschweig [11] and "Sustainable Engineering" at the University of Hannover [12] (both since winter 2021/22). As stated in the German “National Action Plan on Education for Sustainable Development,” it is important to train "sustainability experts" in special degree programmes, as well as to integrate content on ESD into every degree programme via discipline specific and interdisciplinary courses [13]. In addition to the existing demand for corresponding competencies in engineering practice, the positive effects of interdisciplinary teaching on students and their later professional lives have already been shown [14].
The new course "Sustainable Material Selection and Product Development" presented here aims to promote relevant competencies of ESD in product design according to Bormann and de Haan [15] among engineering students through its innovative structure. It is offered at the Faculty of Mechanical Engineering and Marine Technology at the University of Rostock, Germany. The course is taught in equal parts and thus interdisciplinary by the Chairs of Product Development and the Chair of Materials Science, two disciplines that (should) go hand in hand for the design of sustainable products. It has been established and conducted for the first time during winter semester 2021/2022.

3 COURSE STRUCTURE

The number of students who can enrol in the course is limited to 24. Students from advanced Bachelor's and early Master's courses in Mechanical Engineering, Biomedical Engineering and Industrial Engineering can participate. Ideally this results in a very heterogeneous group with different professional perspectives, although we have not set a specific ratio of the number of students per degree programme. Learning and cooperating in heterogeneous groups can promote the development of design competencies (Gestaltungskompetenzen) according to Bormann and de Haan in the area of interdisciplinarity as well as social competencies [15], e.g., a multi-perspective approach, interdisciplinarity, cooperation and conflict of objectives. This distinguishes the course from standard engineering courses usually offered for a specific semester or a specific degree programme. Lectures, usually offered by one chair, run throughout the semester and tutorials facilitate the application of the lecture content through assignments. The acquired knowledge is then tested in a written or oral exam. In some courses, the students also complete laboratory work. This new course on the contrary offers a modified and varied approach to teaching. The unique elements are presented in Figure 1 and are described in more detail in the following subsections.

<table>
<tr><td colspan="6"></td><td colspan="2">week</td><td colspan="6"></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td colspan="2" rowspan="2">introduction to sustainability, semester project</td><td colspan="2">problem solving in design - theorie</td><td colspan="4">materials selection and material life cycle - theorie</td><td colspan="2">sustainable design guidelines - theorie</td><td rowspan="2">pre-paration of final presen-tations</td><td rowspan="2">ex-cursion, guest lecture</td><td rowspan="2">students presen-tations</td><td>final</td></tr>
<tr><td colspan="2">problem solving in design - workshops</td><td colspan="4">materials selection and material life cycle - tutorials with GRANTA EduPack</td><td colspan="2">sustainable design guidelines - workshops</td><td>closure and feedback</td></tr>
</table>

Figure 1. Timeline of the course "Sustainable Material Selection and Product Development", including seminars, lectures, tutorials, excursion, guest lecture and student contributions

3.1 Introduction

In the first two weeks, students will be introduced to sustainability in the form of a seminar. The students engage interactively with the concept and necessity of sustainability, the Sustainable Development Goals (SDGs), their role as engineers, and product design and materials engineering. An important meta-goal is the creation of a communicative and collaborative working atmosphere as a desirable prerequisite for the entire module. In addition, the semester project topics are determined during this time (see section 3.5).

3.2 Product development topics

Divided in two parts (weeks three and four, as well as nine and ten) topics of product development are devised in lectures and exercises. The first part examines the theory and practice of solution-finding methods and problem-solving processes, which should support defining the semester topic (see section 3.5). In the second part, the topics "Design for X" and guidelines for eco-design are discussed to summarise the materials selection topics (see section 3.3). This is applied by dismantling a washing machine and using eco-design guidelines to a coffee capsule.

3.3 Materials selection topics

In weeks five to eight the lecture deals with material selection topics. Starting with an introduction to systematic material selection, the students subsequently explore corresponding aspects in the following exercises with the GRANTA EduPack[1] software. Lectures on the material life cycle with a focus on the key materials steel and aluminium as well as polymer materials succeed the aforementioned topic. Online units created in a teaching and learning platform complement the lectures. In this way, students can activate their prior knowledge and develop new content before the lectures.

3.4 Excursion, guest lecture

During its first iteration, the course includes a guest lecture on Life Cycle Analysis and a virtual excursion in week twelve. The lecture is intended to give the students an overview of the topic while highlighting the complexity of this framework. The virtual excursion is organised at a large German car manufacturer which will demonstrate how sustainability issues are gaining practical importance in the industry.

3.5 Semester project

Instead of taking a written exam, students are asked to work on a self-selected topic that connects product design or materials selection and sustainability and is of particular interest to them. For this purpose, we included an event to identify subjects during the third week of the course. After presenting an example project, the students are asked to form teams of three to five and select a subject based on the SDGs. It must be relevant to engineering with reference to product development or materials science. Until the end of the semester they prepare this topic considering the following aspects:

- **Problem**: Motivation, relation to sustainability, relevance and consequences
- **Research**: Examples of current measures, initiatives, strategies to solve the problem and connection with product development/materials science
- **Own thoughts on solutions**: Classification regarding the SDGs and conflicting goals, presentation of a (self-developed) favoured solution (specific measure or specific product)

If required, students can get in touch with tutors. Otherwise, there is one fixed meeting in the middle and at the end of the semester (week eleven). The examination performance consists of a 30-minute presentation and a 15-minute discussion. This takes place in week 13. Relevant assessment criteria are personal skills (knowledge and own initiative), course of work (accuracy, systematics), documentation/result (content, structure, elaboration), and presentation style. The contribution of the whole project group is evaluated. Therefore, all group members receive the same grade. This design of the semester project, especially in connection with the SDGs, is intended to strengthen design competencies according to Bormann and de Haan from all three areas - subject and methodological competence, social competence and self-competence [15], cf. section 2.

3.6 Closure and feedback

In the last lecture in week 14, no additional content is developed, but a detailed review and feedback are conducted. This is done with the help of an online pinboard application and a subsequent group discussion. The students also complete an evaluation via a course management system (CMS, Stud. IP). This event aims to improve the course in the following semesters and adapt it to include ideas and incorporate suggested improvements by the students.

4 OBJECTIVES

Besides aiming for a good first run of the course, we focused on the three following objectives being evaluated via our observations and detailed student feedback (see section 5).

By examining the individual aspects, we want to determine whether students are becoming aware of sustainability in product design, how successfully interdisciplinary teaching and learning is implemented and how well students receive the interactive and hands-on contents, respectively. An evaluation of these questions is discussed in the next section.

[1] Leading educational software in materials selection being used by more than 1000 universities worldwide. With its help, connections between materials, processes and energy-relevant issues can be made comprehensible (https://www.ansys.com/products/materials/granta-edupack).

4.1 Awareness of sustainability in product design

Can the students be sensitised to the issue of sustainability regarding product design? How do they cope with the diverse range of topics? Do they express their thoughts? How is the overall engagement with sustainability evaluated?

4.2 Interdisciplinary teaching and learning

Is the cooperation between the chairs of product development and materials engineering fruitful and does the content really mesh well as planned? How do the students perceive interdisciplinarity in their ranks through the mixing of study sections and courses?

4.3 Interactive and hands-on contents

Since other courses often require less student engagement, are the practical components well received? Are they evaluated positively in retrospect? How are the contributions by guest lecturers and external companies received?

5 RESULTS

Most of the course took place in the form of face-to-face teaching. Only for the last four weeks of the course we switched to the online format due to the Corona pandemic. In the last lesson, we resumed the discussion on the progress of the SDGs, only then having a closer look on the consequences of the Corona pandemic. Due to the online format, the discussion required more time than expected, resulting in little time for detailed oral feedback afterwards.
However, ten out of 16 students took part in the evaluation via the CMS, which corresponds to a share of 62.5 %. Figure 2 shows the results of different aspects, which will be discussed in more detail below.

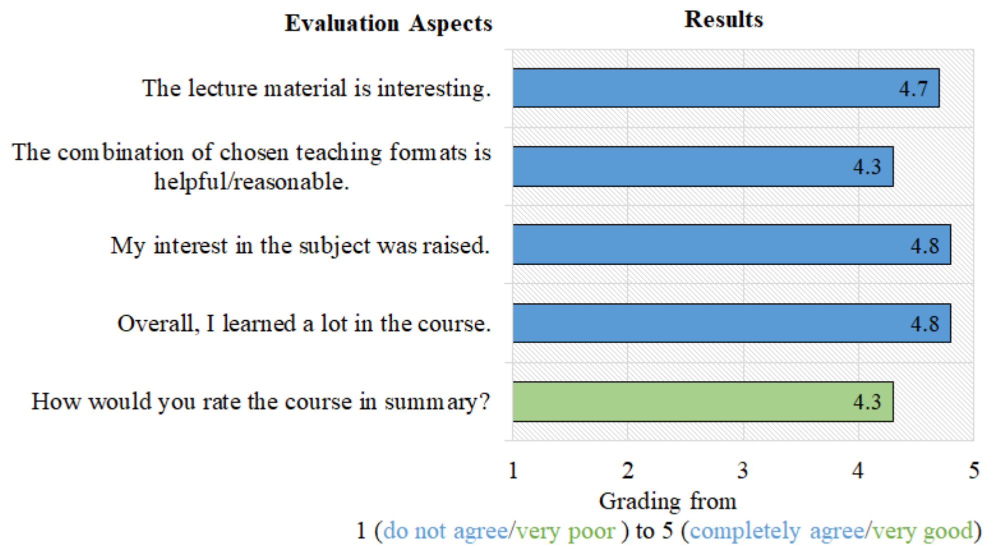


Figure 2. Evaluation aspects with results gathered via the CMS. The maximum score is 5.0

5.1 Awareness of sustainability in product design

From the authors' point of view, sensitising the students to issues of sustainability was successfully achieved, as the students repeatedly dealt with relevant content in each lecture. Throughout the course, they frequently asked in-depth questions, so that discussions could be encouraged. However, it was evident that the time available was often insufficient for a more in-depth study. In the semester projects, the students were also able to deal with content at the intersection between sustainability and engineering sciences with topics of their own choice. Out of the total number of 16 students, four groups were formed which chose the following topics for their projects:

- Sustainable materials for fused deposition modelling (FDM)
- Fibre-reinforced plastics
- Mass products in medicine
- The Great Pacific Garbage Patch

The link between sustainability, product development, and materials engineering remains vague when analysing the project titles. In the presentations, it was noticeable that despite the continuous exchange with tutors, the students found it challenging to narrow down their topics to such an extent that a more profound engagement would have been possible. Although the audience could gain further knowledge in the project presentations, the connection with materials technology or product development was not sufficiently addressed in some cases. The students' own ideas for solutions were also very brief or sometimes not mentioned at all. At the same time, the students' motivation for their topics became very apparent when establishing, i.e., creative approaches regarding the online instead of face to face presentations - caused by the Corona pandemic. For instance, one group used special presentation software, another had chosen the colours of the SDGs as virtual backgrounds. The four presentations were marked with grades A+ to A in the German system. Considering the direct feedback from the students, the form of examination was evaluated positively. The evaluation, indicated that the students' interest in the subject could be raised. Here, on a scale of 1 (do not agree) to 5 (completely agree) an average of 4.8 was awarded, which is an excellent result. The information content of the lecture material was rated on the same scale with a 4.7 (see Figure 2, respectively).

5.2 Interdisciplinary teaching and learning

All 24 offered places in the course were booked during the enrolment, and 17 students then actually took part in the first lectures, 16 of whom passed the exam at the end. Students from different degree programmes and levels took part, as Table 1 shows.

Table 1. Number of Students of different degree programmes and levels who took part in the course. 16 Students passed the oral exam

Degree Programme		Mechanical Engineering	Industrial Engineering	Biomedical Engineering
Number of Students	Bachelor	4	3	4
	Master	4	1	0

Thus, the heterogeneous composition of the overall group was successfully established, which promoted interdisciplinary learning. In addition, students from different degree programmes and levels came together in the small groups formed for the semester project, which made a level-based differentiated examination assessment dispensable. According to the authors, the topics from product development and materials selection complemented each other very well. Solely the order of lectures was not coherent: The lecture on design for X covered topics that had already been discussed in an exercise on GRANTA EduPack. In addition, the lecture on eco-design was not entirely coherent at the end, offering an overview of all topics. Conforming this only marginal inconsistency, in the CMS, students strongly agreed to the statement "Overall, I learned a lot in the event." which underlines the successful selection of course content. Despite this minor inconsistency, in the CMS the students agreed with the statement "Overall, I learned a lot in the course."(score of 4.8, see Figure 2), which underlines the successful selection of course content.

5.3 Interactive and hands-on contents

We could observe that the students appreciated the interactivity of the course and that their participation was above average compared to other courses held by the authors of this paper. Only during the guest lecture, the activity of the students in the subsequent discussions was not engaged. In contrast, the students' participation in the exercises was above average. Everyone got involved and developed good ideas. In the free-text feedback in the CMS and the online pinboard, the students rated the exercises with large practical parts positively. Figure 2 also shows the positive rating regarding the combination of chosen teaching formats (score of 4.3).

6 CONCLUSION AND OUTLOOK

In summary as you can see in Figure 2, the students evaluated the course with a 4.3 (scale from 1 (very poor) to 5 (very good)). The teachers and authors of this paper share this positive opinion. The students were sensitised to sustainability issues in product design, were very active as intended and appreciated the course's innovations - especially the high practical content. Therefore, this course efficiently supports prospective product designers to consider their work's ethical and sustainable dimensions. In the follow-up we want to further reduce the content to enable more space for discussions, hopefully resulting in a livelier discussion after the guest lectures. It would also be desirable to have a proper excursion in the follow-up if the pandemic situation allows it. Furthermore, we will state the guideline for the semester project much more precisely, facilitating and supporting a deeper engagement of the students with actual products in the context of sustainability. The topic of the semester project will be determined after the problem-solving event in order to give the students a better idea of their assignment and more time to narrow it down. We will bring forward the course on eco-design in order to use it as a starting point for introducing the following topics and the course on design for X will be used as a summary of preliminary course contents. The practical parts are to be further structured to enhance the resulting outcome in addition to a sole "fun factor." Finally, we aim for a more in-depth evaluation of the students' learning outcomes with regard to the three objectives (cf. section 4) and the design competencies for sustainable development.

REFERENCES

[1] United Nations, Department of Economic and Social Affairs, Population Division. Global Population Growth and Sustainable Development. *UN*, 2021.

[2] Giljum S., Lutz C. and Polzin C. Global implications of a European environmental tax reform. *petrE working paper*. SERI & GWS, Vienna & Osnabrück, 2010

[3] Masson-Delmotte V., Zhai P., Pörtner H.-O. et al. IPCC: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2018

[4] Mulder K. Engineering education in sustainable development: sustainability as a tool to open up the windows of engineering institutions. *Business Strategy and the Environment*, 2004, 13(4), pp.275-285

[5] Lacasa E., Santolaya J. L. and Biedermann A. Obtaining sustainable production from the product design analysis. *Journal of Cleaner Production*, 2016, 139, pp.706-716

[6] Hallstedt S. I. and Isaksson O. Material criticality assessment in early phases of sustainable product development. *Journal of Cleaner Production*, 2017, 161, pp.40-52

[7] Quelhas O. L. G., Lima G. B. A., Ludolf N. V.-E. et al. Engineering education and the development of competencies for sustainability. *International Journal of Sustainability in Higher Education*, 2019, 20(4), pp.614-629

[8] Hadgraft R. G. and Kolmos A. Emerging learning environments in engineering education. *Australasian Journal of Engineering Education*, 2020, 25(1), pp.3-16

[9] Stiftung zur Förderung der Hochschulrektorenkonferenz. Hochschulkompass. Available: *https://www.hochschulkompass.de/studium/studiengangsuche* [Accessed on 2022, 05 May], (2022) 05 May.

[10] Albert-Ludwigs-Universität Freiburg. Der Studiengang - Institut für Nachhaltige Technische Systeme - INATECH. Available: *https://www.inatech.uni-freiburg.de/de/studium/studieninteressierte* [Accessed on 2022, 03 May], (2022) 03 May.

[11] Braunschweig T. U. Sustainable Engineering of Products and Processes (Bachelor). Available: *https://www.tu-braunschweig.de/studienangebot/sustainable-engineering-of-products-and-processes-bachelor* [Accessed on 2022, 03 May], (2022) 03 May.

[12] Leibniz Universität Hannover. Sustainable Engineering - Leibniz Universität Hannover. Available: *https://www.uni-hannover.de/en/studium/studienangebot/info///sustainable-engineering* [Accessed on 2022, 03 May], (2022) 03 May.

[13] Nationaler Aktionsplan Bildung für nachhaltige Entwicklung. Nationale Plattform Bildung für nachhaltige Entwicklung (Hrsg.). Bundesministerium für Bildung und Forschung, 2017

[14] Biswas W. K. The importance of industrial ecology in engineering education for sustainable development. *International Journal of Sustainability in Higher Education*, 2012, 13(2), pp.119-132.

[15] Bormann I. and Haan G. de (Hrsg.). Kompetenzen der Bildung für nachhaltige Entwicklung. *Operationalisierung, Messung, Rahmenbedingungen, Befunde,* 2008 (VS Verlag für Sozialwissenschaften).

MAPPING DESIGN BRIEFS AND RESULTS OVER A DECADE OF UNIVERSITY-INDUSTRY STUDENT PROJECTS

Sara FIGUEIREDO, Vikki ERIKSSON, Tua BJÖRKLUND and Kalevi EKMAN
Aalto Design Factory, Aalto University School of Engineering, Finland

ABSTRACT
This research focuses on navigating the complexity of a modern approach to product development in the educational context, revolving around how to best equip future product developers. The PdP (Product development Project) course at Aalto University has been running for 25 years and is considered a success in what concerns Industry-Academia cooperation. Many changes have occurred in industry, education, and students' profiles during the last decade. Collaborative projects became substantially more complex and showed a significant degree of trans disciplinarity. This paper analyses the wide repository of data related to the PdP course to classify characteristics of industry project briefs and the nature of multidisciplinary knowledge used during their development. The findings suggest industrial partners favour providing design briefs with relatively high degrees of novelty and uncertainty in the course. It was also found that breakthrough types of projects have resulted in the most balanced disciplinary contributions to the project outcomes, whereas derivative projects have leaned on mechanical engineering. More conceptual research and development projects emphasize design and business, and platform projects have varied widely. The project typology and profiles can be of help to educators, students, and industry representatives alike in scoping and planning university-industry project-based courses.

Keywords: Product development, design education, university-industry liaison, live projects

1 INTRODUCTION
Product development and design represent vibrant fields contributing to business and societal goals alike, with significant technological and paradigm advancements in the last decades. From an educational perspective, this fast-paced evolution provides students with the opportunity to expand their field of expertise to create meaningful and cohesive product solutions. The use of university-industry collaborative projects as a pedagogic model is well established, and much has been written about the use of industrial briefs within design and engineering courses in higher education [1]. These collaborations reinforce experiential learning within educational programmes and boost industry value creation [2], [3], as they generate mutually beneficial knowledge and promote technology innovation exchange between parties. The format of these collaborations, or *live projects*, is often described as "out of the studio setting, repositioned in the 'real-world'" and existing "between the two tectonic plates of learning in academia and in practice" [4].

Research from several countries has explored the nature of collaboration and the cooperative principles that emerge between industry and university [5],[6],[1],[2]. Generally, these studies have listed benefits for students' learning experiences where they can test in practice methods and tools that they learn through studies and explore real industrial contexts [6]. Research also points to industry advantages, where university partnerships raise companies' profile upon an innovative approach, providing the opportunity to test ideas with no immediate commercial applicability and keep in touch with a set of fresh-thinking individuals who are relatively unaware of industry limitations [1]. However, such collaboration also has its own challenges, with university-industry student projects blurring the borders regarding rights, responsibility, economy, and information flow [5]. Indeed, there are multiple types of uncertainties and novelties at play within these projects. For example, in terms of the target of development, product development projects can be classified in terms of the degree of change in the product and the degree of process change [7].

With the contemporary world being marked by vague boundaries between artefacts, structures, systems, and processes [8], industry-provided challenges often require addressing an entire system and not just a single part or component. As such, the target scope of university-industry student projects can vary in width, clarity and uncertainty. Furthermore, addressing such complexity through highly integrated product development practices emphasises the need to transform design engineering education from disciplinary to transdisciplinary [9].

However, we know relatively little about how these changing degrees of complexity, novelty and uncertainty influence student experiences and learning outcomes. As extant studies suggest, students new to design might struggle initially to accommodate high levels of uncertainty inherent in most design and development projects [10]. Some types of projects might be more conducive for university-industry collaboration in project-based courses than others. The current study investigates the evolution of the type of industry-provided design briefs offered during the past decade and how these different project types interact with student output to provide a better understanding of how to foster collaborative projects that contribute value to the industry, students and academia alike.

2 METHODOLOGIES

2.1 The course context

This study examines changes in project brief typologies within the PdP course at Aalto University (www.pdp.fi), spanning 12 academic years. The course has been organised since 1997 and sparked the creation of a global network of Design Factory development platforms [11]. From 1997 to 2021, 2895 master's level students participated in this multidisciplinary course. From 2018 to 2020, 46% of students were from mechanical engineering, 22% from design, 10% from business and 7% from electrical engineering and information technology. Students form multidisciplinary teams with varying compositions and partner up with students from partner universities. Each student team works on a unique design brief with a specific industry partner which contributes a 10,000€ team budget to be used for product development and prototyping expenses by the team. The final project prototypes are presented during an open gala. Since 1997, the PdP course has collaborated with 135 companies that vary in size, annual revenue, and activity sector.

2.2 Data collection and analysis

To explore the types of projects suggested by the industry design briefs and how these connect to student output, the current study examined two archival data sets: (1) the 174 design briefs used in the course between 2009 to 2019; and (2) the 42 students project reports capturing the output of the course from three academic years during the studied period.

The course utilizes written design briefs, each representing an approximately 1-page long description of the project, distributed to the students at the very beginning of the course (and later expanded upon in meetings with the industry liaisons). These design brief documents were deductively classified into four degrees of novelty, building on the framework developed by Wheelwright and Clark [7] (Table 1). Figure 1 illustrates the different levels of methodological practices and degrees of novelty of the four types of projects. Each type of project was then mapped across different years of the course to examine whether the distribution of projects or degree of novelty had changed during the years by comparing descriptive statistics of the distribution.

After mapping the 174 design briefs, we then looked into the projects from three academic years in more detail: 2011-2012, 2015-2016 and 2020-2021, representing a total of 42 projects. We collected all of the student teams' final reports, which were submitted at the end of the course, and typically spanned 50-80 pages. Based on these reports, the content of the solution developed by the teams as well as the development process described within the reports were mapped into each five main disciplines in the course they represented: business, design, mechanical engineering, electrical engineering and information technology. Further, the degree of connection was assessed on a scale from 0 to 3, where 0 represented no connection and 3 a thorough connection in both solution content and reported process. Therefore, this analysis was divided into three levels where 1 represented minimal impact, 2 represented moderate impact, and 3 had a critical impact on the overall solution and product development process. These connections were then compared across the four design brief typologies as well as across the three years to examine which were salient and what were emphasised in different types of projects.

Table 1. Typology of Product Development Projects and PdP Requirements

Project Typology	Description based on Wheelwright and Clark [6]	PdP Team Requirement
Derivative projects:	Often range from cost-reduced versions of existing products and/or enhancements of current production process [7]. This typology can be divided into (1) Incremental Product Changes, (2) Incremental Process Changes, and (3) Incremental Product and Process Changes. In this typology of projects, a technical problem often exists.	Students should solve the problem by thinking about the product, process or both.
Platform Projects	Often entail more product and/or process changes than derivatives do, but they don't introduce untried new technologies. They typically deliver fundamental improvements on quality, performance and other range of dimensions over preceding generations [7]. Therefore, this category often includes product enhancement and technological integration. In other words, in this typology, a Product (1) or Technology (2) often exists.	Students should (1) solve the problem by improving the product for future needs or (2) by accommodating technology into a new product.
Breakthrough Projects:	Often, breakthrough projects establish core products and processes that differ fundamentally from previous generations by incorporating new technologies, materials, and manufacturing processes [7]. Due to the scope of this research, we expanded the extent of products from this typology to not only diverge from previous products but also create novel solutions so that this typology fits the PdP context. In other words, in this typology, a revolutionary Idea and concept often exist from Industry partners.	Students should find the technology required to implement the solution and go over the product development process.
Research and Development:	Often these are linked with the creation of the know-how and know-why of new technologies, materials and solutions that eventually translate into commercial development [7]. Therefore, the research scope tends to be wide and often unexplored. In other words, in this typology of projects, a general problem often exists.	Students should define the product and/or service that solves the problem and go over the product development process.

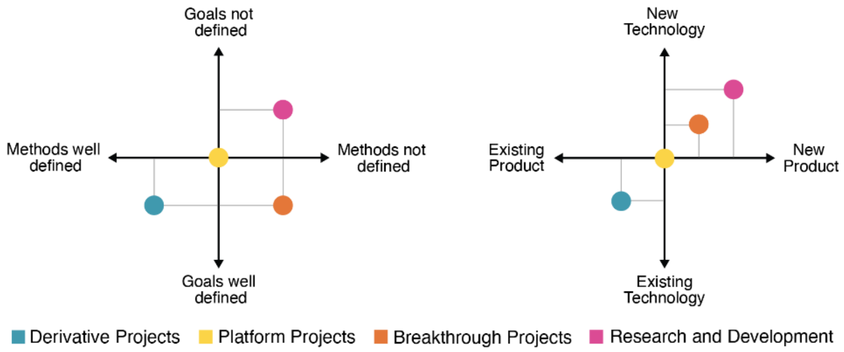


Figure 1. Project typologies – level of methodological practices and level of novelty

The emerging project typologies, across the 42 studies, each represent a unique disciplinary composition, based on the students within the team (Table 2). The multidisciplinary nature noted here is limited to the academic background of the participating students and does not take into account any knowledge or skills acquired outside of academia, which students may contribute.

Table 2. Disciplinary composition of project teams based on students' field of study

Type of Project Brief	Year																	
	2020-2021						2015-2016						2011-2012					
	Fields of Study (%)						Fields of Study (%)						Fields of Study (%)					
	BUS	IT	ELEC	ENG	DES	OT	BUS	IT	ELEC	ENG	DES	OT	BUS	IT	ELEC	ENG	DES	OT
Derivative	0	8	8	76	8	0	12,5	25	0	50	0	12,5	10	0	10	70	10	0
Platform	25	0	0	75	0	0	6	6	9	70	6	3	13	13	0	47	27	0
Breakthrough	9	12	9	49	21	0	7	18	4	56	15	0	7	4	12	54	10	12
R&D	17	0	17	49	17	0	13	15	11	42	15	4	10	17	5	40	23	5

DES Design **ENG** Mechanical Engineering **ELEC** Electrical Engineering **IT** Information Technology **BUS** Business **OT** Other

3 FINDINGS

3.1 The evolving typology of PdP product development projects

Examining the distribution of projects in different types (Figure 2), the analysis revealed the prominence of two industry project-brief typologies: Breakthrough (illustrated in orange) and Research and Development (presented in pink)[1]. These types both represented 35% each of all projects.

[1]During the process it was noted that 4% (n=7 industry briefs) could not be located (indicated in grey, in Figure 3).

However, examining change over time, a decrease in Research and Development Projects was noted from 2014 to 2021. Breakthrough Projects proved to be consistently prominent during the period observed. Similarly, Derivative Projects remained rare in the course throughout the study period (at an average of 6%). Platform Projects, in turn, fluctuated considerably, ranging from 0% (2010-11) to 50% (2019-20). Mapping how the industry project brief categories have shifted over time may allow the prediction of the project types that the students might encounter, and thus improve planning and course management. The mapping also showcases the nature of the collaboration between Industry and Academia, contributing to a better understanding of both industry's evolving and the requirements of project teams. Figure 3 illustrates the results of the analysis of three academic years in order to provide a longitudinal perspective through the lens of three sets of PdP project samples (total number of projects included n=42)[2]. These were a 2020 – 2021 sample (illustrated in the radial matrix as blue), a 2015-2016 sample (illustrated in orange) and a 2011-2012 sample (illustrated in pink). An average line was drawn representing the distribution of disciplines over the three sample sets analysed.

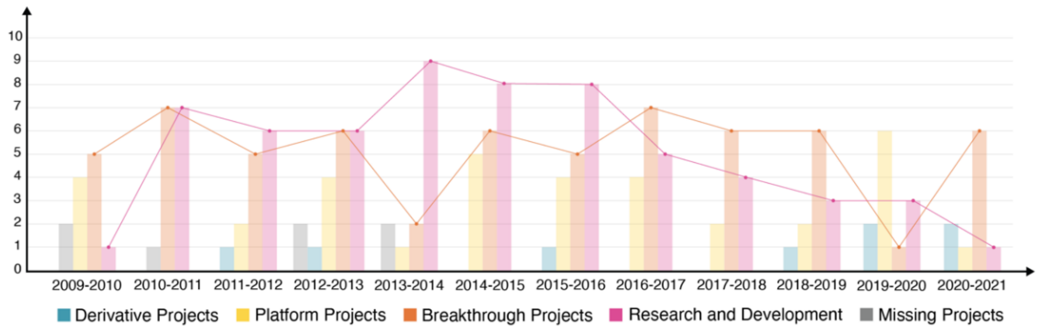


Figure 2. Distribution of project design briefs into the four types of projects between 2009 and 2021

Figure 3 stresses 3 prominent patterns: (1) Derivative Projects, described as technical product/process enhancement in the previous sections, often lean towards the right side of the pentagon. This highlights a critical impact on Engineering in this typology of project briefs and a growing trend in the electronics field. (2) Likewise, on Research and Development Projects, there is an apparent propensity on the left side of the pentagon where business and design are at the core of the accent. This reflects the unexplored nature of this typology. The students are required to conduct extensive research to understand the challenge and how to create a product service that answers the actual problem (3). Additionally, Breakthrough Projects have delineated a clear trend to become the 'perfect pentagon Transdisciplinary shape', which seems to cover all disciplines over the years on a consistent scale. Furthermore, both information technologies and electronics have become increasingly critical over the last decade. This analysis highlights the persistence of technological progress as a clear impact of project-based learning. Future product developers should be comfortable embracing interdisciplinarity and coping with the fast-paced integration of new technological innovations into their systemic product solutions.

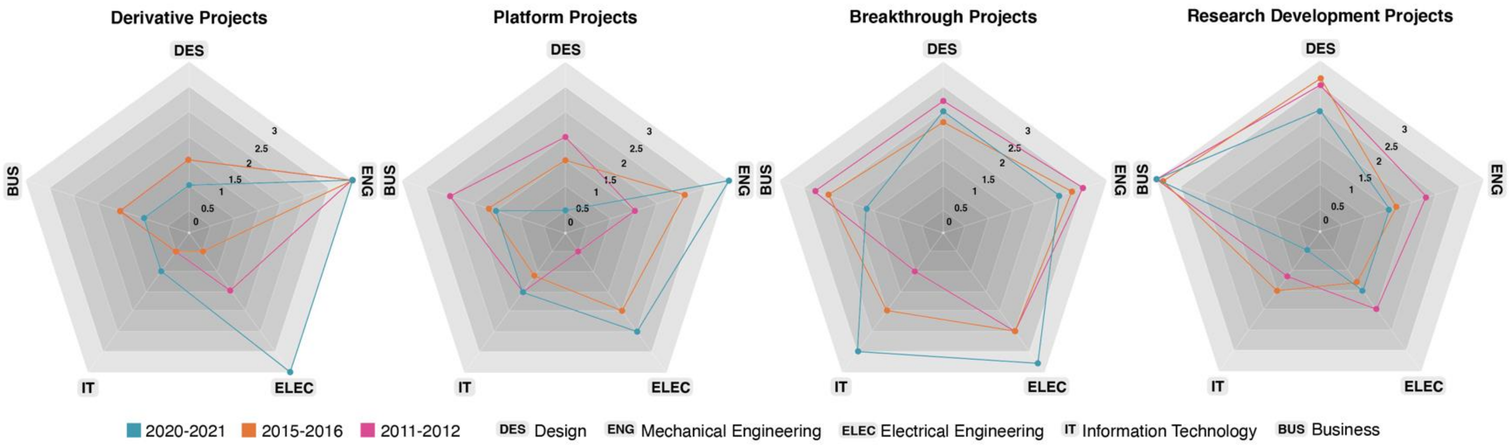


Figure 3. Radial discipline matrix based on project typologies over a decade of PdP

[2]Derivative projects (2020-2021; 2011-2012) and Research and Development Projects (2020 – 2021) constitute only one project each and thus represent a limited sample.

3.2 Derivative projects

Over the 3 sets of years analysed, Derivative projects constituted a limited sample, with 1 project in 2011-2012, 1 in 2015-2016 and 2 in 2020-2021. All of these 4 project outcomes leaned towards the right side of the radial pentagon, emphasising the rooted presence of mechanical engineering in this typology. Design, business and information technology have played consistently relatively minor roles, whereas electrical engineering has varied. For example, one of the projects focused on improving an existing pole fuse switch disconnector to make it more appealing, cost-effective, modular and competitive on the market. This was mainly an engineering project combining electrical engineering, mechanical engineering and design.

3.3 Platform projects

A total of 7 projects represented Platform projects in the 3 focal years - 2 in 2011-2012, 4 in 2015-2016 and 1 in 2020-2021. This type of project had less consistent disciplinary emphases over time, varying in all five dimensions across years and within the same years. The phenomena might be linked with the nature of the typology of projects, since those can vary from improving an existing product using a new technology to designing a non-existent product application based on an existing technology. This inconsistency in the disciplinary pattern is also noticed in the collection of projects in each year. One example was a project that combined air purifying and supply air technology and created a supply air diffuser that increases the quality of the indoor climate of schools and other premises with high demands on air quality. It combined chemical technology with electronics and mechanics after a business evaluation.

3.4 Breakthrough projects

A total of 16 projects represented Breakthrough projects in the three focal years - 5 in 2011-2012, 5 in 2015-2016 and 6 in 2020-2021. In these projects, a fairly systematic emphasis on Design and Mechanical Engineering could be seen, as well as a clear contribution of Business and Electrical Engineering. Furthermore, the role of Information Technology grew over time. One example of such a project was a system to improve health conditions of workers in construction sites which used prototypes of a particle, temperature and humidity sensor, called a “dust sensor”, connected to a web platform and an app to enable dashboarding and reporting in real-time. This project was supported by a large set of disciplines including engineering, electronics and information technologies encompassed by a strong design component, from device to service design.

3.5 R&D projects

A total of 15 projects represented Research and Development projects in the three focal years - 6 in 2011-2012, 8 in 2015-2016 and 1 in 2020-2021. Design and business were systematically prominent dimensions in these projects, whereas mechanical engineering played a smaller role than in the other three project types. Information technology and electronics also represented more moderate contributions than in Breakthrough projects. As expected, this project type is focused on new technologies. These could be broad, such as projects related to sanitation in Africa, or narrow like two projects in information technologies interconnection of home devices trackers for small appliances or a project focused on the automation of container displacement in harbours. Large organizations often proposed these projects and were clearly researching technologies not existent at their launching date.

4 DISCUSSIONS: IMPLICATIONS FOR COLLABORATION

Mapping the industry-provided project briefs used within the long-standing PdP course at Aalto University highlights the variety of projects tackled in industry-university collaborations and how those might impact interdisciplinarity. The findings reflect a noticeable shift in the typologies of students' project briefs during the period reviewed. Research and Development challenges have decreased in the last seven years, which has impacted the number of projects in which student teams both frame the problem space and conceptualise suitable solutions. The prevalence of Breakthrough projects, however, have remained consistent. In this project type, students actively engage in seeking appropriate technologies and in conceptualising a suitable product or service.

The depth of exploration required by Breakthrough projects allows student teams to engage in meaningful creative problem solving which leverages the transdisciplinary fields of knowledge represented in the teams. Indeed, the analysis shows that Breakthrough projects were the only type where all five disciplinary domains were systematically leveraged across projects. One possibility is that the high degree of novelty and uncertainty require a further degree of integration across disciplines, and the collaborative project style interaction can then support student learning and skills development [12], [13]. While additional research is needed on both the prevalence of different types of design briefs in other contexts as well as on the reasons for the observed distributions, the results highlight how different types of design briefs seem to either attract students of different profiles or facilitate their ability to utilise these disciplines to different degrees. Similarly, within the current study, electrical engineering and information technology represented a growing presence in the product development process of both Breakthrough Projects and projects overall. This suggests that a lack in these skills could place teams at a disadvantage. However, the degree to which this growing emphasis depends on the design briefs, their industry application areas and the changing student composition of the course requires further research.

5 CONCLUSIONS

The study suggests that capturing the varying degree of novelty and uncertainty within the initial design briefs, as well as the distinct disciplinary profiles of the project outcomes attached to each type of design brief, can reveal different types of patterns in project-based courses. While further research is required to examine whether other multidisciplinary product development courses have seen similar shifts in foci and how different disciplines contribute to different project types, this study provides a typology and starting point for educators to examine project-based course practices and a scaffold for discussing design briefs with industry liaisons and students.

REFERENCES

[1] Humphries-Smith T. et all. Industrial briefs for student projects - A company perspective. In the *13th International Conference on Engineering and Product Design Education*, EPDE’11, September 2011, pp. 23–28.

[2] Eriksen K. and Knudsen J. Collaboration between the design industry and design educations managed by a third party organization. In the *20th International Conference on Engineering and Product Design Education*, EPDE’18, September 2018, pp. 140-145.

[3] Castrén K., Celik S., Björklund T. and Nurmi N. (2020). Creating value in project-based multidisciplinary design courses. *American Society for Engineering Education*, ASEE 2020.

[4] Harriet H. and Lynnette W. (2014). *Architecture Live Projects: Pedagogy into Practice*. Taylor & Francis.

[5] Eriksen K., Schou F. K. and Jaeger T. A. Better collaborative projects with the industry. In the *12th International Conference on Engineering and Product Design Education*, EPDE’10, September 2010, pp. 466–471.

[6] Dyer B., Glasspool C. and Terry S. An educational and commercial product design symbiosis: A case study. In the *12th International Conference on Engineering and Product Design Education*, EPDE’10, September 2010, pp. 338–343. doi: 10.1016/j.procir.2018.

[7] Wheelwright S. C. and Clark K. B. Creating project plans to focus product development, *Harvard business review*, 1992, 70(2), pp. 70–82.

[8] Meyer M. W. and Norman D. Changing Design Education for the 21st Century, *She Ji*, 2020, 6(1), pp. 13–49. doi: 10.1016/j.sheji.2019.12.002.

[9] Butt M. et all. Transdisciplinary Engineering Design Education: Ontology for a Generic Product Design. In the *Proceedings of 28th CIRP Design Conference*, CIRP’18, May 2018, pp. 338-343.

[10] Tracey M. W. and Hutchinson A. (2016). Uncertainty, reflection, and designer identity development. *Design Studies*, 42, 86-109.

[11] Björklund T. A., Keipi T., Celik S. and Ekman K. (2019). Learning across silos: Design Factories as hubs for co-creation. *European Journal of Education*, 54(4), 552-565.

[12] Syahril S. et all. The Create Skills of Vocational Students to Design a Product: Comparison Project Based Learning Versus Cooperative Learning-Project Based Learning. In the *5th UOI International Conference of Technical and Vocational Education and Training*, ICTVET’18, September 2018, pp. 316–320. doi: 10.2991/ictvet-18.2019.72.

[13] Guo P. et all. A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, November 2019, 70(2), pp. 70–82. doi: 10.1016/j.ijer.2020.101586.

EXPLORE, RESPOND, ADAPT: THE ROLE OF RISK AND EXPERTISE IN HYBRID (SOFT/HARD) PRODUCT EDUCATION

Sue FAIRBURN and Stephanie E. PHILLIPS
Wilson School of Design, Kwantlen Polytechnic University, Canada

ABSTRACT

Design education is working in an expanding field of environmental contexts. The coming generations will witness changing climates that drive them toward migration to the poles and survivalism. As we explore and settle further from our familiar locales, how might we respond to risk before we adapt? Why are risk and expertise in extreme environments relevant to future design education?

In accessing extreme environments, humans require technical products and protective equipment (PPE) to survive and thrive. This paper shares experience from hybrid (soft and hard) product design education where extremes (environment and context) inform the curriculum. Projects are challenge-based and set in high-risk environments. Starting from the unfamiliar environmental contexts, students learn from experts who have mitigated risks and developed specialty knowledge-base and technical skills relevant to this expanded field. The year 3 curriculum model is collaborative, explorative and technically demanding with a 7-week project involving expertise in technology, the body and context/users. Iterative prototyping happens in on-site speciality labs with early and frequent testing. The student teams self-organize and project-manage their way to a full scale, functional prototype that is evaluated through design scenarios, expert feedback, field-based test protocols (on and off-site).

This paper reflects on project outcomes over 5 years. Informed by student and stakeholder feedback, it offers perspectives and recommendations on the necessity of an expanded 'environmental' field for this generation of risk-engaged designers. Future-proofing design education derives benefit from introducing the unfamiliar and unknowns so students can explore, respond, and adapt as designers.

Keywords: Protective equipment, extreme environments, human factors, technologies, industry partnerships, climate crisis

1 INTRODUCTION

Over the coming decades, design education will necessitate an awareness of an 'expanded field' of environmental contexts due in part to climate change and there is a growing human desire to democratise exploration and adventure tourism to all corners and surfaces of the planet [1]. These shifts require additional demands in the products that enable humans to explore, respond and adapt. The impact of climate change will be exposure to rapid weather systems, with more extremes (temperature, humidity, precipitation), and much of it involving coastal settings. Scientist/Author Jim Al-Khalili writes; *"Predictions about the way in which our lives will change thanks to advances in science and technology are spread across that wide expanse between the inevitable and the utterly foreseen*" [2] Climate Change Scientist Julia Slingo adds that the interaction of the systems on which we rely, both in everyday situations and in emergencies (e.g. telecommunications, transportation, etc.), are the basis for "*a new set of circumstances and pose new challenges about how secure we will be in the future"* and these aspects of the changing environmental context necessitate the need to *"go beyond plan and prepare to adapt - to climate-proof our lives"* [3]. Understanding the challenges requires us to access regions of the planet that test the limits of technology and the human body. While there are many places on the planet that are conducive to human life, there are many places where humans go that require them to prepare and adapt to extreme conditions. Our interest to date has been in polar regions, oceans, and mountains. In pursuit of these settings, we push the limits of the human body and protective equipment. In doing so, we encounter challenges that come with living in a range of non-ideal environments. It is these non-ideal, extraordinary, extreme environments that raise our interest and expand the learning of our students to work beyond what is known and ideal. We seek learning opportunities based in the survival measures offered by protective apparel/equipment/devices that human's pair with to explore extreme environments, or *survival through design*.

2 ENVIRONMENTAL CONTEXTS AS [DESIGN] EDUCATION PRACTICE

While the 'field' varies in location and context, the exploration of more extreme environments is growing in popularity and therein presents an opportunity to respond to user needs and meet the environmental demands. What is *every day* to some who regularly plan, prepare, and access environment-based recreation, may soon become extreme as conditions shift unexpectedly.

The peri-urban zone is a central part of the structure and functioning of urban systems, as it represents an important extension of major cities, accessed for resources, for recreation and leisure, and for infrastructure developments [4]. Regions offering mountain, forest and coastal features draw increasing numbers to the peri-urban environment, and the four-season access translates into incidents requiring Search and Rescue (SAR) interventions across numerous settings and weather conditions. Annual regional incident reports indicate a general increase in responses over the last 30 years (Figure 1b), more than population increases, supporting the trend towards a growing adventure tourism and the accompanying risks [5].

Figure 1a. Search and Rescue situation in alpine, winter conditions,

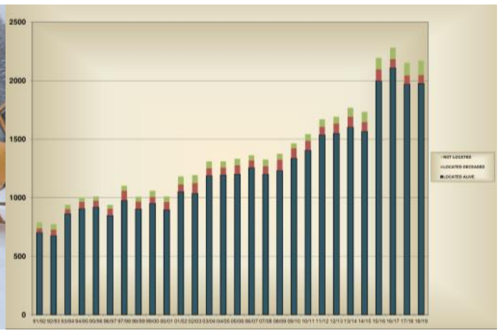


Figure 1b. Search and Rescue (SARS) Results 1991/92 to 2018/19 (B.C. SARS)

Adventure tourism and eco-education in polar climates is also increasing. Maher [6] attributes the increases to the unknown nature of arctic locales, the attention of the media to climate change, and to notable designations such as International Polar Year (IPY). He sums up the underlying reasons for the trend in the sobering statement that people want to "*see it before it's gone*". This desire to understand and connect with our planet and enjoy all that nature has to offer results in more people venturing into this cold and often harsh climate. Furthermore, new technologies in materials and equipment enable people to enjoy outdoor pursuits regardless of the weather in peri-urban areas, and to push the limits and explore the cold climates in more remote arctic settings in higher numbers, which in turn leads to greater risks. Institutional expertise, peri-urban and proximal-polar geographical setting, and industrial/academic partners are considered alongside the growing environmental need for students to respond to the challenges afforded by this approach to design education.

3 EXPANSIVE ENVIRONMENTAL [DESIGN] METHODOLOGY

In the field of design education, this meeting of object and opportunity is informing the curriculum in the design of technical apparel and equipment, but it offers potential across design. Meyer and Norman [7] note that "*skills for developing creative solutions to complex problems are increasingly essential.*" They group design challenges into performance, systemic, contextual and global and highlight the skills most relevant to each group before offering that *"designer's responsibilities are expanding beyond the technical to include the organizational and managerial."* Their position is to expand beyond a design school's emphasis on practice, and on the research university's emphasis on evidence, theory, and principles. What does it mean for a programme to offer both evidence-based design theory and principles alongside technical, practice-based education?

Designers are moving their attention from making-to-making sense of complex information to define the problem. Working with others, across disciplines, is inherent in these problems and this introduces multi-modal methodology. In the context of adventure tourism, these methodologies could include the knowledge of the limitations of the human body in various environments, technical tests for protective equipment, human and equipment-related demands for exposure, and competences to recover from unexpected incidents where human or equipment are insufficient for comfort or safety. In this case, curriculum draws on technical information from psychology, physiology, material science, geography, etc. and professionals in first response, health and safety, medicine, materials, and engineering, etc. The curriculum is collaborative, explorative and involves technically challenging prototyping to various degrees of fidelity. This 'expanded field' benefits from technologies and partnerships with emerging industries and the role of design is in understanding the layering and intersections of applied expertise that can be achieved with design methodologies that facilitate curriculum innovation.

4 THE ROLE OF THE [DESIGN] PROJECT

This paper exemplifies a project-based approach to accessing an expanded field of environmental contexts. Students confer with users to gather and analyse their needs, with the aim of innovatively and economically improving function, performance, and comfort, before considering manufacturing requirements in the development of solutions. At its core, the project involves experts as providers of knowledge, experience-based examples to contextualize that knowledge, and as mentors: **body expert, product expert,** and **user expert.** The project sits in term 6 (8 terms, 4 years) of an undergraduate design degree, when students are also undergoing industry experience practicums and considering careers choices. At the outset, the project serves as a 'testbed' as it requires them to identify their role, noting their strengths, skills, and area of specialization, in addition possible 'non-design' positions of leadership, project management, and team negotiation. Martela [8] identifies some of the essential benefits of teamwork in its' ability to focus on practical and emotional characteristics. The project and teams are given the space and the autonomy to self-organize and proceed with faculty guidance. In doing so, the intent is for them to achieve the characteristics of what Martela [8] describes as a '*well-functioning team'*, such as '*asking and giving advice, helping each other out, sharing the workload fairly, knowing each other's strengths and weaknesses, and trusting each other*.'

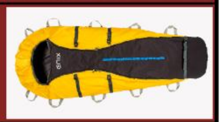
Project evaluation was informed by a survey distributed to all course alumni (2017-2021), who were reminded of the course contexts: dangerous and unpredictable. The questions informed insights into aspects of the course's learning objectives, content and activities in the areas of learning impact, risk, and expertise. Question formats included 5-point Likert scale, checklists and short answer.

5 A PROJECT OF ENVIRONMENTAL [DESIGN] CONTEXTS: A CASE STUDY

The project arose from discussions with industry: the timing reflects the industry standard for innovation projects (6-7 weeks) and the output reflects the manufacturing specialty of the region. The project runs in cycles, so yearly cohorts join a project 'in progress', which facilitates critical analysis of prior approaches but requires students to apply core principles to a new context; thus, integrating different experts, users, and criteria. The expansive and collaborative project space is presented across 5 iterations (2017-2021). The original project on which the course was based, was brought to the institution by a well-established industry partner in the protective apparel and equipment sector. Table 1 provides an overview of the projects to date, each for specific user and environmental context.

The project cycle is set up to ladder, with each set of 3 iterations building on aspects of the prior prototype. For example, year 1 thermal rewarming project was deployed and tested in field conditions using simulated protocols by students in the Design of Technical Apparel programme and professional SAR personnel. Year 2 thermal rewarming project underwent field-based testing aboard a vessel during a snorkel safari expedition where the prototype was deployed with a dry user and all features were demonstrated during simulated protocols. Year 3 thermal rewarming project iteration was deployed on a rescue vessel using a test protocol written for a coast guard team. The data from the testing was provided to the next group of students to build upon. The following figures show some of the key activities integrated into the project, defining the environmental context-specific functional hierarchy (Figure 2), design development (Figure 3), deployment examples (Figure 4).

Table 1. Products for extreme contexts soft & hard goods projects

Focus	Project	Context/ Environment	Experts	Methodologies	Concept Prototype	
Focus: Thermal Rewarming	**2017: PERI-URBAN BURRITO** TEAM SIZE: 5	Peri-urban (mountains, forested, snow, freshwater and coastal)	**USER:** Alpine Search Rescue Leader, Ski Patrol **BODY:** Thermal Physiologist **PRODUCT:** Engineer, Research and Development Manager	**SITE VISIT:** North Shore Rescue Community Base and Mustang Survival	Hooded hypothermia bag with three-way zipper for accessing points for vital areas and roll up and gusset for adjustability.	
	2018: POLAR BURRITO TEAM SIZE: 6 (1 International Exchange student)	Remote, Polar, water, shore, and ice pack	**USER:** Sedna Epic Expedition Leader, Polar Snorkeler **BODY:** Environmental Physiologist **PRODUCT:** Engineer, Research and Development Manager	**SITE VISIT:** Horseshoe Bay Marina / Sea Dragon Charters , and Mustang Survival FIELD TESTING: Snorkel Safari	Fur-hooded multi-layered extreme hypothermia bag with inflatable pillow, three-way zipper for accessing vital areas, and specialised locator toggle.	
	2019: MARINE BURRITO TEAM SIZE: 6 (2 international Exchange students)	Marine, commercial, recreational watercraft users.	**USER:** Dive Leader, Crew, Canadian Coast Guard **BODY:** Environmental physiologist **PRODUCT:** Engineer, Research and Development Manager	**SITE VISIT:** Coast Guard (Sea Island), Mustang Survival, Simon Fraser University Climate Laboratory for Exercise and Environmental Physiology (LEEP)	Hooded hypothermia bag with self-inflating pad, contour zipper for accessing vital areas	
Focus: Pneumatic building	**2020: HIGH ALTITUDE (HYPERBARIC)** TEAM SIZE: 10	High altitude, mountaineering, emergency descent.	**USER:** 2 Amateur Mountaineers (7 summit) **BODY:** Hyperbaric Physiologists, Wilderness and Expedition Medicine **PRODUCT:** Engineer, Research and Development Manager & Aerospace Design Engineer	**SITE VISIT:** Thin Red Line Aerospace, Richmond Dyke (rock formation).	Lightweight portable, roll-top hyperbaric chamber and pump system, with windows for communication /monitoring victims of high altitude illness	
	2021: ANALOG ASTRONAUT HABITAT (HYPERBARIC) TEAM SIZE: 10	Lava Tube, remote, temperate climate	**USER:** Anaglogous Astronauts **BODY:** **PRODUCT:** Engineer, Research and Development Manager	No site visits due to pandemic	Habitat for Analgous space mission in Iceland. Integrated simulated airlock, thermal floor and layered materials for thermoregulation	

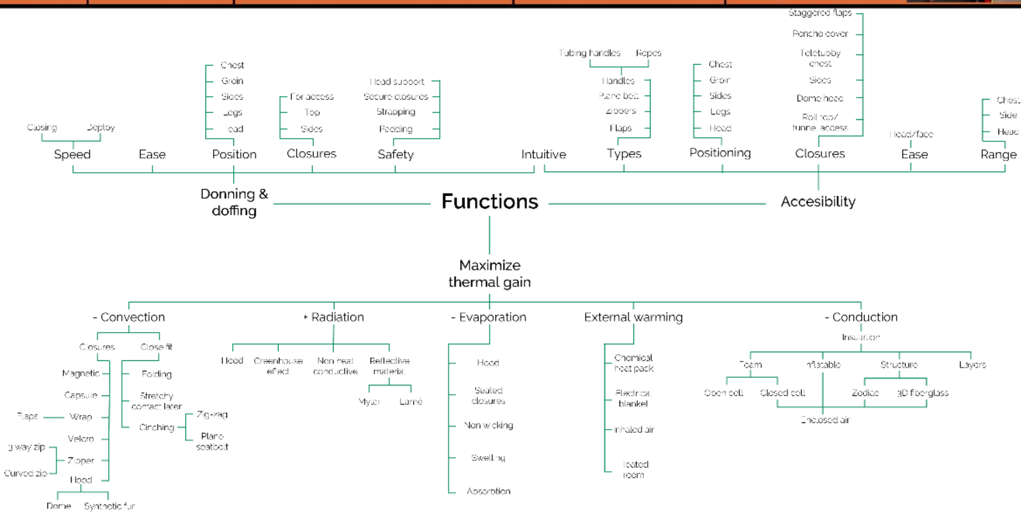


Figure 2. Functional planning and prototype assessment matrix (ENIX)

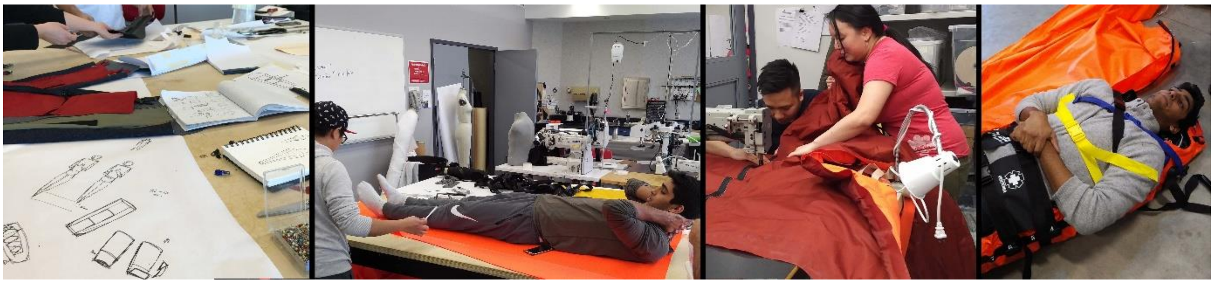


Figure 3. Iteration 1 - Small scale and full-scale prototyping of the Burrito: ideation development, anthropometrics, prototyping, and integration with medical equipment (image credits: Alisa Yao)

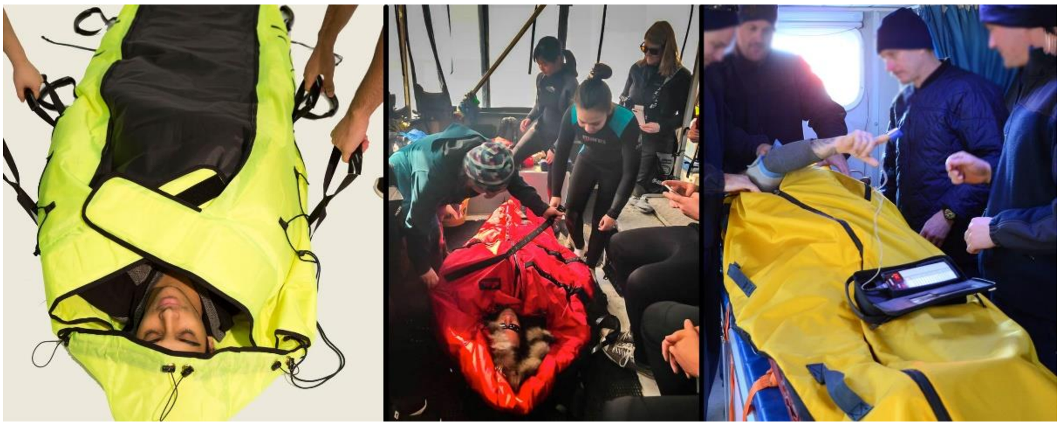


Figure 4. left: Thermal rewarming projects: left peri-urban SAR (2017) (credit: Alisa Yao), centre: Polar Burrito (2018) shown in field testing aboard a vessel during a snorkel safari (credit: Jeff Britnell), right ENIX (2019) for marine environments being field tested by the Coast Guard (credit: S. Phillips)

6 RESULTS, FINDINGS, AND INSIGHTS

Design education is a constantly changing field, with creativity a factor in pedagogy as well as practice. The specific project evaluation survey revealed insights on risk, laddering and expertise.

Risk: Thirteen responses were received for the project questionnaire (n=13 of 20, 65% response rate). All students responded that the project 'helped them grow as designers' with 77% of the students "strongly agreeing". Our enquiry into risk and expertise yielded interesting insights, in that 60% of students "agreed" with the statement that the project informed their willingness to take risks in their other design project, yet 23% were "neutral" and 15% "disagreed". In comparison, 93% of students "agreed" (of which 54% "strongly agreed") that the project informed their understanding of risk from the perspective of the users and the context (Figure 5).

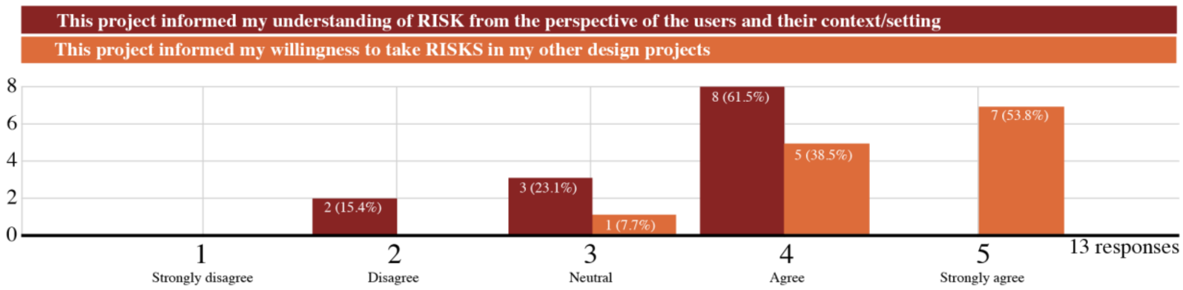


Figure 5. Student project questionnaire: Likert scale results on risk

Laddering: Another aspect of this project is the laddering cycle of 3 years. When asked how reviewing prior prototypes informed their design process, student responses focused on the value of reverse engineering and hands-on testing, both front-end analysis methods: "...*understanding why the previous year did what they did in terms of the last generation product was a great foundation to build upon. It evoked inspiration to push the previous boundaries and to find out what worked and what did not- to learn and improve on the next generation product."* Another student offered; *"By interacting with previous prototypes, we were able to discover problems (or great solutions) of that prototype's potential in that context...this allowed us to search for potential problems and test new ideas to resolve for our context."* Diving deeper into the project's approach, one student noted that they were able to integrate new knowledge "…*mostly by studying and testing the old product and comparing to the new prototypes to find out how to optimize usability, affordances and overall function*." The level of critical analysis was specific, with another student noting "…w*e could see the level of detail and overall scale we could expect and ... understand the product in a tangible way"* and another noted even more tangible elements of the design: "…*utilize similar closing techniques but iterate new solutions for a colder climate with increased variables that could limit the burritos success (cold, ice, wet etc.), this allowed us to build off previous prototypes closing system to understand what would be successful and not."*

Expertise: The programme focuses on critical thinking skills based on quantitative and qualitative research. Students review a range of secondary research sources (technical reports, scientific papers, patents, etc.) and learn skills to identify, access, communicate with and interview a range of experts.

The role of expertise is highlighted in this project due to the unknown context and the risk-level associated with the context. When asked of the importance of this aspect, 84.6% (11 of 13 students) strongly agreed it was important to their understanding. Students were also asked whether the project gave them skills or confidence in reaching out to experts with 23.1% strongly agreeing/46.2 % agreeing that they developed their skills through the project, while 38.5% strongly agreeing/46.2 %. This was echoed by one student's comment: "*Reaching out to experts and having interviews is really important to designers and for personal development. I feel I was already comfortable doing this but for those who may not have been, it would be an even more important experience to have."* The mediation of expertise is a central challenge for many designers and therefore one we explored and supported. When asked, 92% of the students (11 of 12) indicated that the project contributed to their ability to compare and evaluate information obtained from different sources.

7 DISCUSSION & CONCLUDING THOUGHTS

This paper offers recommendations and perspectives on the notion of an expanded field of context for a future generation of design practitioners. The roles of risk and expertise were explored in depth with the student cohorts for the past five years. The area of risk analysis is essential in complex environments where uncertainty is key and new research suggests that there are discrepancies between what users declare as risk behaviour and what they do [9]. The findings with regards to expertise reinforced the value in developing skills and confidence in reaching out and in comparing and evaluating information from different sources, as expected. However, researching the role of risk yielded interesting insights. While the faculty saw the students take notable risks in the project based on the 'big' nature of the deliverables, the demanding research element, and the multiple points of reference outside their knowledge base, the student survey results didn't support this observation. Instead, we saw that the project helped them to understand risk, but that understanding of risk was informed through the perspective of the user and context.

The curriculum model is a general foundation in design as well as specialization. Held in high regard are the niche manufacturing industries in the region (technical equipment, adventure apparel, material innovation, survival gear, and emergent technologies). The industry-based Programme Advisory Committee (PAC) guides the programme objectives and the specific skills needed by students/graduates, as they reflect on the changing labour market. The PAC has responsibility and opportunity. As evidenced by the project described in this paper, the faculty aims for a balance of theory and practice founded in direct industry experience and worthy problems. As the programme is growing quickly, and successive years see larger cohorts, this may introduce complexities to this project and team structure and roles, but it may also provide opportunity for further expanding the fields of context.

REFERENCES

[1] Buckley R. C. (2004b) Commercial adventure recreation in remote areas: the edge of tourism. In T.V. Singh (ed.) *New Horizons in Tourism* (pp. 37-48). Oxford: CAB International.

[2] Al-Khalili J. (2018) What the Future Looks Like, Ed by Jim Al-Khalili Pub the Experiment New York.

[3] Julia Slingo (2018) Chapter 3: Climate Change in What the Future Looks Like, Ed by Jim Al-Khalili Pub the Experiment New York.

[4] Bryant and Charvet, (2003) http://www.cjrs-rcsr.org/archives/26-2-3/1-Bryant.pdf

[5] Government of B.C. Report (2019) Emergency Management Operational Summary. *https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/embc/ecc-statistics/sar_results_fy_18_19.pdf* accessed 4 Mar 22.

[6] Maher P. T. (2017) Tourism Futures in the Arctic - Chapter 22 p 213-214 in K. Latola, H. Savela (eds.), *The Interconnected Arctic* — UArctic Congress 2016, Springer Polar Sciences, DOI 10.1007/978-3-319-57532-2_22

[7] Meyer M. W. and Norman D. (2020) Changing Design Education for the 21st Century, she ji, *The Journal of Design, Economics and Innovation,* Vol 6, No. Spring 2020.

[8] Martela F. (2014) *Sharing Well-being in a work community: exploring well-being generating relational systems.* Emotions and the Organizational Fabric. Research on Emotion in Organizations 10(79-110).

[9] Groves M. and P. J Varley (2020). Critical mountaineering decisions; technology, expertise and subjective risk in adventurous leisure, *Leisure Studies*, Vol.39, NO. 5, 706-720.

EXPLORING & DESIGNING IN THE CONTEXT OF SEARCH AND RESCUE

Susan CHRISTIANEN[1] and Sue FAIRBURN[2]
[1]Auðna | Technology Transfer Office, Iceland
[2]Wilson School of Design | Kwantlen Polytechnic University, Canada

ABSTRACT
In the face of extreme weather and terrain, Search and Rescue (SAR) volunteers face a growing challenge of rapid changes in environmental conditions. This demands that rescuers manage layered demands to prevent accidents and save lives. The volunteer-based work of ICE-SAR (Icelandic Association for Search and Rescue) is constantly balancing risks and rewards with each operation. With a community of 5000+ volunteers, their 'workforce' compares to the marine industry, energy sector and tourism companies in Iceland. With scale, they can be involved in research and development of technical personal protective equipment (PPE). Their circumstances are valued for beta-testing equipment in different rescue specialty group trainings, including mountain rescue, marine rescue and technical teams. In the SAR context design, engineering and technology transfer happen in real-time. Designing for complex systems calls for the right know-how and creativity, coupled with extensive knowledge, practice and field testing. Industry partners contribute further expertise, funding and equipment. This paper presents an innovative model for design and engineering education with lessons learned from an innovative Technology Transfer Design Sprint that took place simultaneously in-the-field, in studio and online. Bringing user-centred design to this context with "risk-familiar users" resulted in a vibrant opportunity for hybrid (soft/hard) design education. Introducing students to these users, who are trained to deal with unknowns and high-risk situations, can engage and prepare them to design inclusive, relevant and resilient solutions. Rapid and risk-receptive design processes are needed for adapting to the demand of SAR users, or better said: its "rescuesers".

Keywords: Extreme environments, technology transfer, technical apparel, personal protective equipment (PPE), search & rescue, design innovation, risk

1 INTRODUCTION
Living on a remote volcanic island brings challenges, such as possible rapid weather changes, extreme weather conditions, volcanic eruptions and other natural hazards. In order to respond to harsh conditions and emergencies in the best way possible, it´s important to design and develop reliable and optimised products, services and systems which can prevent accidents and save human lives and other valuables. Extreme conditions often present extreme product development challenges for the users, and for the designers. Search and Rescue (SAR) volunteers face rapid changes in environmental conditions and those working in Iceland face gale force winds, temperature shifts, lack of shelter and the island's natural hazards, among others. These conditions require rescuers to manage layered challenges to prevent accidents and save lives, while keeping themselves safe.
As Design Educators, our responsibility is to future-proof design education. Introducing students to the users, who are familiar and trained to deal with unknowns and high-risk situations, can engage and prepare them to design inclusive and relevant solutions. In order to connect the development of solutions for existing societal, environmental, economic, technological and (geo)political challenges to a larger context and goals, projects should be connected to a guiding framework, such as the UN Sustainable Development Goals and the objectives and policies of other governmental bodies such as the Arctic Council. Working in interdisciplinary teams on solving grand challenges increases the likelihood of developing appropriate solutions. Technology Transfer organisations can facilitate collaborative platforms where there is room for design and engineering students and other academia to engage with end-users, industry, governmental organisations, policy makers and other professionals with the aim to

develop inclusive, contextual and resilient solutions and applications to improve the everyday life of people and make a positive difference for the environment. During and after the process, Technology Transfer Offices (TTO) can also support academia with advice on Research and Development (R&D), innovation management, intellectual property protection, market analysis, and patent landscapes, with an objective of connecting inventions and innovative design and engineering projects with investors and the industry. The larger goal is to enable science & technology to have more impact on society, both nationally and internationally [1].

Contrary to popular belief, publishing your research will not guarantee that someone will notice your concept and develop it into a tangible product that will reach the end user. Technologies first need to be developed and that is achieved through collaborations with industrial partners [2] and Intellectual Property. This is one of the goals of the Technology Transfer Design Sprint. In a design sprint, facilitators aim to merge business strategy, behaviour science, innovation, and design thinking into one innovative process [3]. Knapp [3] describes the design sprint as a time-constrained, five-phase process that uses design thinking with the aim of reducing the risk when bringing a new product, service or a feature to the market. The process aims to help teams to clearly define goals, validating assumptions and deciding on a product roadmap before starting development. In fact, the method is ideal when seeking to gain insights on early concepts, to improve those concepts before building or launching a product [4]. It seeks to address strategic issues using interdisciplinary, rapid prototyping, and usability testing and guides you through the design process much faster and more directed. It combines both tangible output and progress as a team. It’s a learning-by-doing-process to experience a customer-centric and prototyping mindset [3]. The five phases include: (1) **Understand:** Discover the business opportunity, the audience, the competition, the value proposition, and define metrics of success, (2) **Diverge:** Explore, develop and iterate creative ways of solving the problem, regardless of feasibility, (3) **Converge:** Identify ideas that fit the next product cycle and explore them in further detail through storyboarding, (4) **Prototype:** Design and prepare prototype(s) that can be tested with people. (5) **Test:** Conduct 1:1 usability testing with the product's primary target audience.

In applying the design sprint model, this paper presents an innovative adaptation of the model, developed for design and engineering education via a hybrid model that took place simultaneously in-the-field, in the studio, and online, with a specific set of collaborators and a niche set of users.

2 THE CONTEXT OF SAR AND ‘RESCUESERS’

Introducing students to end-users who are trained to deal with unknowns and high-risk situations, can engage and prepare them to design inclusive, relevant and resilient solutions. Rapid and risk-receptive design processes are needed for adapting to the user demands and the environments in which they operate. ICE-SAR (Icelandic Association of Search and Rescue) has been active in Iceland for over 100 years. It is a non-profit, non-commercial, volunteer-based organization that specializes in SAR services on land and at sea around the coast of Iceland. The professionalism that characterizes the work of Icelandic rescue teams has brought worldwide attention. Specialist trainings undertaken by particular rescue groups has resulted in exceptional knowledge of the various conditions that are known to occur, both at sea and on land. Specialist training formats include seminars, courses, field exercises, first aid and wilderness first responder courses and exams. Both employees and volunteers travel to different parts of the country to acquire insights into the best ways to protect themselves and others from the dangers inherent in Icelandic environments. Their joint mission is to prevent accidents and save human lives and valuables. In order to fulfil that role, there are groups of volunteers always available, night and day, year round. Rescue teams are called out about 1800 times a year on average [5] to perform a variety of tasks in challenging situations**.**

Designing solutions for a niche user-group such as SAR teams requires involvement of its end-users who share their knowledge, experience and provide in-depth insights on the challenges they face. For example, the volcanic eruption of Geldingadalur in 2021 (Figure 1a) added extra challenges for Icelandic SAR teams; from searching for lost people, helping injured visitors and keeping everyone, including SAR volunteers, at a safe distance from lava and endangered grounds. The eruption was relatively close to the capital area, only approximately 50km away. SAR teams needed to be prepared and on duty 24/7. This scenario was unexpected when we started organising the design sprint in 2020, and it added an extra dimension and real-time element to the event. There were many red alerts for the area between March to September 2021, especially during the Auðna Technology Transfer design sprint, and still ICE-SAR members were dedicated to support the events and its participants with tours of their facilities, demonstrations of their gear, by speaking about the challenges and supporting participants. The situation in Geldingadalur made the mission of this design sprint extra urgent and real. The circumstances are valued for beta testing PPE in different rescue specialty group trainings for earthquakes as well as mountain rescue, marine rescue and technical teams.

3 ACCIDENT PREVENTION

Achieving goals under uncertain conditions and extreme environments demands skilful action and learned strategies in order to make good decisions and avoid harm. Concepts surrounding risk of loss or harm occurring have preoccupied humankind in many different forms and cultural representations throughout history, often linked to deep socio-cultural, technological and religious transformations over time [6]. Those concepts are of great value in design and engineering education and need to be taken in account in R&D processes while working with niche user groups such as SAR volunteers.

Figure 1a. Search and Rescue situation during the volcanic eruption in Geldingadalur, Iceland, 2021, 1b. Search and Rescue situation during the evacuation of victims, Iceland, 2021

4 ENVIRONMENTAL CONTEXTS OF SAR

Icelanders live with natural disasters of various kinds (Figure 1a, 1b). It is therefore important that in every area there is a group of volunteers who respond with knowledge and skills in an emergency. The nature of ‘search’ is that it is an emergency and every response involving a search must be immediate, therefore proximity is important. Around 100 rescue teams form a dense safety net throughout the country and their volunteers are ready to respond when shocks strike and accidents occur [5]. ICE-SAR volunteers are on standby 24/7 for emergencies. The rescue teams are specialized in search and rescue both on land and at sea. To be able to address the diverse tasks, the rescue teams are well educated in their fields and thoroughly trained. They strive to outfit their people to the highest standard, with both personal gear and specialist rescue equipment. In recent years, specialization within rescue teams has increased, making the work more purposeful: land and mountaineering groups, avalanche groups, marine rescue groups, diving groups, advanced groups, medical groups, technical teams, high-angle rescue groups, urban SAR, K-9 search dog groups and the International Urban Search and Rescue Unit (USAR) that is part of the International Search and Rescue Advisory Group (INSARAG) from the United Nations.

5 DESIGN BASED IMPLEMENTATION RESEARCH (DBIR) AND USER-CENTERED DESIGN

Design-Based Implementation Research, (DBIR) is an approach for working with multiple stakeholders such as researchers, designers, engineers, human factor experts, industry professionals, and governmental organisations. It aims to enable the collaborative identification of challenges, strategies, and design solutions while learning from the process to support innovations in new contexts [7]. There is a need for DBIR as a research approach that challenges educational researchers and practitioners to transcend traditional research barriers and facilitate the design of educational interventions that are effective, sustainable, and scalable. This approach was applied mainly during the development of the design sprint, specifically in the identification and integration of the contributors and their expertise. It is this latter aspect that warranted an integrated user-centred design approach.

User-centred design is based on 4 fundamental principles; (1) users are involved in the design process from the very beginning, (2) the importance of requirement clarification, (3) introduce a user feedback loop in the product development cycle, with the collection and analysis of feedback from users regularly to support more user-focused decisions, and (4) an iterative design process. While Principle (1) was applied extensively prior to the Design Sprint, Principle (3) was prioritized during the sprint. The following section outlines how the sprint was developed and delivered.

6 TECHNOLOGY TRANSFER DESIGN SPRINT FOR SEARCH AND RESCUE: A PIONEERING EDUCATIONAL MODEL.

Designing for complex systems calls for the right know-how and creativity, coupled with extensive knowledge, practice and field testing. Industry partners can contribute further expertise, funding and equipment. This paper describes an innovative model for design and engineering education that brings user-centred design to this context with "risk-familiar users". For the Auðna Technology Transfer Design Sprint the primary user group were the risk-familiar ICE-SAR members, and they were the main users represented. The secondary group was highly diverse since anyone can become a victim: including children, the elderly, tourists, outdoor enthusiasts and employees across industries on water or land. The preparations for the Design Sprint took 1.5 years from ideation to execution and included several high-level discussions between stakeholders that were facilitated by Auðna - TTO Iceland. The main goal of the collaboration was to develop resilient solutions for the challenging work of Search and Rescue teams. In support of user-centred design, a questionnaire was distributed to 5000+ ICE-SAR volunteers to aid in identifying the challenges they experience. The responses were analysed and grouped into **8 high-level main challenge-topics**.

1. **Clothing & Equipment**
2. **Hygiene**
3. **Environmental Monitoring**
4. **Communication**
5. **Nutrition**
6. **Augmented Reality / Virtual Reality (AR/VR) for remote healthcare and situational awareness**
7. **Remote Power**
8. **Advanced Materials**

The programme included lectures, exercises, mentorship, multi-disciplinary teamwork and more. Participants were from multiple disciplines, including scientists, designers, engineers, nutritionists, emergency medicine physicians, ICT-experts, human factor experts, chemists and more. While typically industry projects are 6-7 weeks, this 4-day Design Sprint provided participants with the opportunity to develop and test concepts in real-time with experts and end-users as part of the process. The criteria for the solutions were assessed by the ICE-SAR management, which should: (1) add value for the ICE-SAR organisation by increasing the safety of SAR workers and people in need, and by increasing the efficiency of ICE-SAR operations and (2) be realistic to execute, with a plan on how to bring it to the market within the next 5 years.

Figure 2a. Technology Transfer Design Sprint for Search and Rescue Poster 2021, 2b. Exercises and exploration of SAR challenges in the field during the Technology Transfer Design Sprint 2021. 2c. One of the solutions that teams came up with was a comprehensive real-time communication app.

The approach for Auðna Technology Transfer Design Sprint for ICE-SAR involved:

1. Identifying current challenges of SAR operations with ICE-SAR, suitable for design solutions (solutions were based on current challenges and the need to come up with implementable innovations).
2. Educating participants about Technology Transfer, SAR operations, and their operational environments.

3. Facilitating interdisciplinary teams to develop and design resilient solutions (products, systems, services) for the challenging operations of SAR teams.
4. Ensuring multi-disciplinary evaluation of proposals (SAR professionals, Arctic Council EPPR Working Group (Emergency Prevention, Preparedness and Response), ESA Space Solutions, ARCSAR (Arctic Security and Emergency Preparedness Network), industry professionals, explorers, design educators.
5. Bringing academia, industry and governmental organisations together to increase the chance for positive change and networking.

7 A HYBRID COLLABORATIVE PLATFORM

The design sprint model presented in this paper used a hybrid collaborative platform (Figure 3a, 3b) developed by the company East of Moon that had been applied to previous hackathons, across a range of fields. Of note, the platform was used as a key tool during the planning and development process and then was shared and provided as the key collaborative tool for all participants and contributors during the event. This real-time, on-line platform enabled a comprehensive and visual overview of all the topics, challenges and solutions for the workshop host, ICE-SAR and other partners, and it provided a way for the participants to share ideas, give comments and suggestions, get feedback from SAR mentors and other experts, and work in interdisciplinary teams despite different time zones.

Figure 3a. Collaborative mission development online hybrid platform, 3b. Direct feedback from on-site and remote SAR volunteers (image credit: Auðna Technology Transfer Office). 3c. Cross-disciplinary team-based working; remotely Canada/Iceland and on-site/in-person (image credit: S. Fairburn).

8 RESULTS, FINDINGS, AND INSIGHTS

Having SAR volunteers as primary users and advisers in the design process allowed students to work in collaboration with a unique skill set, knowledge base and culture. The Auðna Technology Transfer design sprint proved itself relevant for the field of SAR while simultaneously offering intense, immersive learning to diverse student groups working in multidisciplinary teams, both on-site and remote. During the design sprint there was a red alert situation with an ongoing volcanic eruption in Geldingadalur (Figure 1a). Despite this massive operation that took most of ICE-SAR attention during this period, ICE-SAR mentors were dedicated to contributing and supporting the design sprint activities between their shifts, further evidence of their commitment to the development of PPE suitable for their specific rescue contexts. This design sprint model accelerated the learning process of participants and enabled them to adopt a "field intense" attitude. There were 6 teams and each team generated 2-3 concepts. Team concepts included: smart solutions for better real-time communication systems, new solutions for nutrition, an improved a lightweight rescue stretcher among other solutions for hypothermia and hygiene in extreme conditions. Each team presented one concept to a high-level panel who gave valuable feedback. A month after the event, another feedback session was hosted with the ICE-SAR management, where participants presented further developed concepts and received additional feedback:

"The design sprint was a great learning experience. The online platform gave us the chance to work with people in different time zones on SAR challenges with direct feedback from SAR mentor and others. It allowed people with different backgrounds and expertise to collaborate, which is relevant for any product development process." – A. Grenier, Master student, Icelandic University of the Arts.

"It was such a unique experience for us here at KPU in Canada to be able to participate remotely..." – B. van Rikxoort, year 3 student, Wilson School of Design, KPU.

"It was more intense than was expected. We had to learn to split our workload, use skills faster, and we realised that you don't need to focus on details." – Gavin Grace, Wilson School of Design, KPU.
"It´s a fantastic initiative that we can co-create solutions for the challenges that our Search and Rescue operations face through the Auðna Technology Transfer Design Sprint. I look forward to continuing this collaboration and connecting this platform to the international biennial SAR conference (RESCUE)"– Guðbrandur Örn Arnarson, operations manager, ICE-SAR.
The participation of ICE-SAR members in the design process was a huge factor in the successful results of the teams. The ICE-SAR organisation attained ideas out of the Auðna Technology Transfer Design Sprint that can be implemented in their operations, with further opportunity to develop projects with the support of Auðna – Technology Transfer Iceland and other collaborators. The next steps are to continue and expand this platform and strengthen international cooperation on SAR and security operations further and bring to market a selection of relevant projects developed through the platform.

9 CONCLUDING THOUGHTS

The Technology Transfer design sprint proved itself relevant for the field of SAR while simultaneously offering intense, immersive learning to diverse student groups working in multidisciplinary teams, both on-site and remote. Bringing industry, professionals, governmental organisations, policy makers, researchers, designers, engineers and other creatives together, resulted in an opportunity for interdisciplinary collaboration and innovation, with the added support of the real-time collaborative platform. This hybrid: real-time/on-site/on-line model could be translated and expanded internationally and to other remote or extreme contexts. It created an immersive and relevant learning experience for all participants, especially with an ongoing volcanic eruption and proximal real-time emergency. Prioritizing user needs and contexts, and striving to create user-focused design, leads to products that better match user needs, especially when the lives of others depend on them.

REFERENCES

[1] Auðna – Technology Transfer Office Iceland (2018). Available: *https://www.ttoiceland.is* [Accessed on 28 January 2022].
[2] Lenagh A. (2012) UNeMed. Available: *https://www.unemed.com/blog/the-importance-of-technology-transfer* [Accessed on 28 January 2022].
[3] Knapp J. and Zeratsky J. (2016) The Design Sprint: How to Solve Big Problems and Test New Ideas in Five Days. Available: *https://www.thesprintbook.com/the-design-sprint* [Accessed on 28 January 2022].
[4] Thoring K., Klöckner H. and Mueller R. (2022), Designing the Future with the Delphi Sprint: Introducing a Novel Method for Design Science Research, Proceedings 55th International Conference on Systems Science, [Accessed 29 April 2022] Available: https://scholarspace.manoa.hawaii.edu/bitstream/10125/80046/1/0566.pdf
[5] Arnarson B. Ö. (2022), Icelandic Association for Search and Rescue. Available: *https://www.landsbjorg.is/icelandic-association-for-search-and-rescue* [Accessed on 8 February 2022].
[6] Lupton D. (2013) Risk, 2nd ed. New York: Routledge. Available: *https://www.academia.edu/2078301/Risk_2nd_edition_2013_London_Routledge* [Accessed on 6 March 2022].
[7] Ryoo J. (2015), Exploratorium, Design-Based Implementation Research. Available: *https://www.exploratorium.edu/sites/default/files/pdfs/brief_DBIR.pdf* [Accessed on 6 March 2022].

DIGITAL HEALTH INTERVENTIONS FOR PROMOTING SLEEP WELLBEING: A DESIGN APPROACH USING SELF-DETERMINATION THEORY

Bahar ŞENER[1], Sila UMULU[1] and Ayhan Ozan YILMAZ[2]
[1]Department of Industrial Design, Middle East Technical University, Turkey
[2]Biyomod Ltd, Turkey

ABSTRACT
The "Sleep-Well" project explored the problem and solution spaces relevant to design of sleep-wellbeing products, services and systems. It was set as an 8-week concept design project within the scope of a 15-week graduate course. In the first half the course, students were given formal input on design for health and wellbeing and in the second half of the course the project ran in collaboration with an industrial partner specialized in the healthcare domain. Students worked in pairs to generate final concept design proposals, ranging from innovative solutions to problems/opportunities that they identified; new approaches to existing products/systems; or unforeseen problems to solve. The 'Sleep-Well' project also had the pedagogical goals of successfully directing students: i) to learn how digital technologies can be best integrated to track and respond to people's health data and environmental conditions; and ii) to intrinsically motivate users by relating three principal factors from self-determination theory (i.e., autonomy, competence, relatedness) to their design proposals. Student learning was demonstrated through the diversity in outcomes and successful integration of the abovementioned goals, as well as formal student feedback received at the end of the course.

Keywords: Product design, design for health, sleep wellbeing, digital health

1 INTRODUCTION
At least one in three adults complain about their sleep: insufficient sleep quantity and poor sleep quality are common among adults. In industrialized countries, the average sleep duration among adults has decreased substantially during the past few decades, and complaints about poor sleep quality are frequent. Sleep clinics, which were a rarity, are now a feature of most major hospitals [1]. It may not be so easy to solve sleep problems caused by e.g., stress, medical conditions, or a baby screaming in the house, however we are likely to have more control on external factors, such as the environment in which we sleep, as it greatly affects the quantity and quality of our sleep.

The work presented in this paper was carried out as part of the authors' ongoing research looking into how people's health and wellbeing can be promoted through digital health interventions. The research aims to generate inspirational exemplars for further R&D in product design and innovation. In addition to generating exemplars for product design, the 'Sleep-Well' project had the pedagogical goals of successfully directing students: i) to learn how digital technologies can be best integrated to track and respond to people's health data and environmental conditions; ii) to consider engineering and healthcare domain constraints for utilizing most convenient technological methods, positioning relevant hardware components and adapting healthcare market structures and stakeholder requirements and iii) to intrinsically motivate users by relating three principal factors from self-determination theory (i.e., autonomy, competence, relatedness) to their design proposals.

2 SELF-DETERMINATION THEORY
Self-Determination Theory (SDT) is a broad theory of human personality and motivation, which was founded in the mid-1980s [2]. The theory concerns itself with human motivation, personality, and supporting our natural or intrinsic tendencies to behave in effective and healthy ways. Rather than just the amount of motivation, it focuses on different types of motivation. SDT states that three principal factors represent the innate psychological needs that drive human behaviour: Autonomy (a sense of

choice and endorsement in a task); Competence (the experience of mastery over a task or particular domain); Relatedness (feeling cared for and connected with others; sense of belonging) [3]. As mentioned by Peters [4], these factors have been validated across cultures and are measurable. Fulfilment of these needs is a predictor of positive domain-specific outcomes. As for designers, extrinsic motivation can be used to motivate users to do various things or behave in certain ways. Therefore, SDT can be useful within design processes because it tells designers how to provide the necessary factors that users look for in products/services. Yet, the SDT factors have only very recently got the attention of design researchers. This was a major motivation to include SDT in the concept design project reported in this paper.

3 SLEEP-WELL CONCEPT DESIGN PROJECT

The project reported in this paper, “Sleep-Well”, explored the problem and solution spaces relevant to the design of sleep-wellbeing products, services and systems. It was set as an 8-week concept design project at Middle East Technical University, Turkey within the scope of a 15-week graduate course ‘Design for Sports, Health and Wellbeing’ attended by 12 industrial design MSc and PhD students. Later in the semester, one student dropped the course because of an unforeseen circumstance caused by the COVID-19 pandemic, thus 11 students completed the course. The project was set in the second half of the course. In the first half, through lectures, invited seminars are workshop activities, the students were given formal input on design for health and wellbeing including the theoretical background (e.g., positive psychology, self-determination theory, types of motivation) and strategies to leverage people's motivation by integrating e.g., positive technologies and gamification strategies.

The project ran in collaboration with an industrial partner specializing in the healthcare domain. Throughout the project, a sleep medicine doctor was consulted for specialist knowledge on sleep disorders. The representative of the industrial partner was a health-tech entrepreneur, who had over 10 years of experience with R&D, product development, piloting, serial production and marketing phases of IoT and ICT solutions for certain sleep disorders. Having an industry partner is not an uncommon practice in design education [5], [6] within the scope of this project, the industrial partner attended the classes to offer input on technologies applicable for measuring, processing and tracking sleep related data, relevant constraints of technology selections on design considerations, as well as to offer critiques for students’ design development on potential impacts of design components based on end users’ pain points, healthcare domain structures and stakeholders’ expectations. Students generated their final concept design proposals ranging from innovative solutions to problems/opportunities that they identified; new approaches to existing products/systems; or unforeseen problems to solve.

3.1 Scope of the project

Students were expected to use the correct terminology from the literature covered in the first half of the course, to build a bridge between a constructed sleep persona and a final design proposal. The proposed solutions were required to be in line with positive design but also be functionality suited to the persona that students constructed. The students were organized to work in pairs (4 pairs and 1 triplet due to the departing student) to take a ‘design for wellbeing’ approach while responding to the common goal: “to design a physical product (and an accompanying app if relevant) that provides a solution for a specified sleep problem”. As the concept design project brief was set within a relatively short graduate-level course, the level of technical resolution expected for the project was modest. Students were not required to deal with manufacturing processes or product assembly. On the other hand, careful selection and integration of digital technologies was essential. It was argued that the most exhausted solutions on the market are in the form of a smartwatch and mobile app combination. This combination was relevant to the project, but equally, innovative solutions outside the combination were encouraged.

The following infrastructure components were pointed out to students as commonly used in health tracking, and that proposals based on such infrastructure were also welcomed: i) health IoT platform; and iii) a gateway (a wearable or stationary device with activity tracking capabilities, e.g., smartwatch, router, etc.).

Subsequently, the following evaluation criteria were defined for the project.

- identifying and detailing a ‘sleep targeted problem’ and a ‘sleep persona’ and situating the two in a consistent usage scenario; making a clear argument for how the final design proposal fits to an intended persona, identified sleep problem, and the scenario.
- a design solution for tracking and/or improving sleep quality.

- offering feasible technologies for tracking relevant sleep data.
- leveraging (perceived) three essential elements (i.e., autonomy, competence, and relatedness) of basic human needs through the final design proposal.

3.2 Stages of the project

A Miro-Board workspace was created for each pair to document their design process. The project was managed across the following stages.

3.2.1 Specialist input by the healthcare experts

To set the right scene and to provide foundations, the project commenced with two introductory lectures. The first lecture was given by a medical doctor, specializing in pulmonary diseases and sleep disorders, introducing basic sleep terminology such as sleep quality, optimum sleep, and sleep hygiene. It also covered topics including factors affecting sleep, whether these factors can be controlled, and how personal sleep tracking differs from a professional (clinic) sleep study. The second lecture provided a case study on sleep apnoea tracking, offered by the specialist from the collaborating firm. The study required domain knowledge from different fields, which was possible only through a multidisciplinary team consisting of professionals from healthcare, industrial design, user research and engineering. Although medical solutions were outside the scope of the Sleep-Well project, the case study usefully exemplified how sleep apnoea, as a serious health condition, and the medical device set-up to diagnose and track it, can be improved through a carefully planned user-centred R&D project. Students learned about the research and design activities that were necessary to carry out, and which design iterations and technical development stages were completed.

Later in the semester, the specialist from the firm offered a technical seminar on various kinds of sensors and sensing technologies that are relevant for tracking sleep data. The lecture covered topics including the types of sleep trackers available; what they track and how they track; and common sleep tracking features (e.g., time spent asleep, the quality of sleep, time spent in each stage of sleep, and sleep-related health metrics such as respiration, movement patterns, pulse oximetry, body temperature and electrophysiology data) and their correlation with environmental parameters (e.g., humidity, room temperature, particle concentration, ambient sounds and illumination), personal lifestyle (e.g., physical activities, stress and fatigue levels, daily habits, diet and exercise), health and living conditions (e.g., chronic disease, pregnancy, assisted or independent living). Two tracking technologies that were introduced to students in detail were Electrocardiography (ECG), which measures heart rate, and Electroencephalography (EEG), which monitors brain activity. As well as becoming knowledgeable about the provided facilities, possible limitations and resulting restrictions of regarding technologies, students were expected to evaluate which of the technologies might be most suited to their usage scenario. They were additionally advised to familiarize themselves with common wireless communication technologies (e.g., Bluetooth, Wi-Fi, GPRS etc.), their key specifications, and indoor/outdoor coverage relevant to product design.

3.2.2 Example solutions for tracking and improving sleep disorders

To build awareness of existing design solutions for sleep related problems, each student reviewed products (i.e., product, system, service that can be in the form of mobile apps, physical products, or some combination) targeted at tracking and/or improving sleep quantity and quality. These included non-medical, commercial or conceptual solutions identified mostly from Internet search or products that students own themselves. The students were then asked to choose two of these products and give a brief presentation covering the following information: What is the product? Who is it for? What problem does it aim to solve? How does it work? What technologies does it utilise? Where is it used? (indoor, outdoor, home, work, etc.) How is it used? etc.

The students were encouraged to include available media, such as photos and videos, to help explain the product; the system map (or a system schematic to explain the interaction/information flow between user-product-technology, etc.); and an overview of customer reviews (in the case of commercial products). If observable from the available information, the presentations also included a brief commentary on the following: Does the product employ a positive design approach? Does it incorporate aspects of 'motivation'? How would you develop the product to (better) motivate its users? They were asked to answer the questions by making direct references to the product's features, functions, interaction, etc.

3.2.3 Persona characteristics / identified problem / key design considerations
Students were asked to develop a 'sleep persona', including the main and secondary (if relevant) characters that they will design their product concepts and/or offer their solutions for. To guide the students, a work-template was provided, with sections including the characteristics of the persona; specific sleep related problem/situation that the persona is experiencing; key design goals; motivation strategy/wellbeing approach; technologies that may help to achieve the design goals (see Figure 1). Students were asked to work with their partners to discuss and elaborate on each of the sections by writing down and sketching out their notes.

3.2.4 Idea generation
Students' creative ideation commenced. They were required to sketch initial ideas for their 'Sleep-Well Products', attending to system, service (app), product, interaction and technology requirements. Ideation also included technical realization for the kinds of technologies that could help, as well as continual scenario iteration. Furthermore, students developed strategies for motivating users that would be relevant to their persona's needs and specific scenarios.

3.2.5 Interim project submission and student presentations
At this stage, each student pair was asked to present two design ideas, which could be two diverse concepts or a variation on a single concept, within relevant scenarios. Storytelling was requested to bring the scenarios to life, covering answers to questions posed at stage 3.2.3. The presentations were made using the presentation mode of the online collaboration software Miro.

3.2.6 Concept development
After presenting their ideas, students received feedback about strengths, weaknesses and aspects to improve for their concepts, then as a pair, they decided which concept to take forward for finalization. Throughout the concept development, instructors gave regular critiques to students. Experts also joined in some of the sessions for specialist input. Additionally, students were supported through mini-lectures followed by in-class activities (e.g., on motivation, gamification), as well as take-home exercises and directed readings.

3.2.7 Final submission and presentation
The final submission and presentation comprised multiple components: a Bēhance webpage (i.e., platform for showcasing and discovering creative work), 2-minute video presentation, and project report. The webpage presented the concept development stages in chronological order. The video included CAD renderings of the final design proposal with key aspects of the usage and interaction scenario, supported with high-quality renderings and animations supplemented with text labels/captions to identify parts, features, technologies used etc. and the context of use. Finally, the report included a detailed description of the project stages and the final design proposal; and reflections on how the three principal factors from self-determination theory were employed and the extent to which they were useful for driving their ideation.

4 DISCUSSIONS ON FINAL DESIGN PROPOSALS
The Sleep-Well project resulted in five diverse product proposals. The proposals varied based on the sleep-related problems that they tackled, as well as the personas and specific needs they responded to. All proposals took a product-service system approach, designed as a combination of multiple physical product components delivering complementary functionalities. Within the scope of smart connected products, information and communication technologies were implemented for tracking health and/or environmental conditions and giving relevant feedback to users. Although it was not a requirement, all student pairs decided to develop their final proposal with an accompanying mobile app. Summary information about the design proposal and aim, persona, product-service-system components, and digital technologies utilized in each project can be found in Figure 1.
One of the objectives in the course was to introduce students to the three essential elements of the basic human needs from the SDT during lectures, in-class discussions and activities. The outcome shows that students were able to successfully transfer the SDT elements of autonomy, competence and relatedness into their final design proposals (Figure 2). Indeed, the SDT elements were a driver for creative thinking and a motivating strategy for students to take a user-centred approach to their ideation. The nature of

this approach may inevitably lead students to consider aspects of autonomy, competence, and relatedness while generating their ideas. Introducing the topic in a more formal way helped students to make more direct connections to strengthen their final proposals. Student feedback gathered at the end of the course also supported this. For example, *"Since I have not worked on such a topic before, I think it has added a lot to me in terms of definitions and practices in different fields."*
At the end of the semester, various aspects of the course were evaluated by the students over a 5-point Likert scale survey. As a headline result, half of the students "strongly agreed" and the remaining half "agreed" that the SDT direction adopted for the project was useful. The survey showed SDT was useful for students as a way to increase empathy with their developed persona. As a new direction for most students, there were also comments about offering more concrete outlines to follow between SDT and quick in-class activities. This will be taken into account in subsequent delivery of the course and its projects.

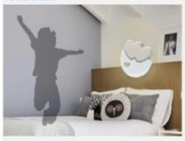
Design Proposal/Persona	Aim	Product/Service/System Components	Digital Technologies
Fall-E  Adults having difficulties in falling asleep due to anxiety	Supports users to create sleep and meditation routine by utilising guided EFT tapping technique	MAIN STATION: guides the meditation with ambient light and speakers SLEEP MASK: provides EFT tapping and collects data during sleep DATA TRACKER: detachable from the mask; portable to monitor daily stress level during the day APP: enables users to create a personalised routine	Sleeping mask and tracker: Photoplethysmography (PPG) sensor; Electroencephalography (EEG) sensor (to track sleep quality and collect data during daytime); Technology to enable EFT tapping By Açelya Küçükkurt, Yağmur M. Arık
Obversa  People with irregular sleep patterns	Helps users with irregular sleep cycles to have healthy sleep pattern by introducing an artificial circadian cycle	CEILING LIGHT: simulates natural flow of the day SHADE: a motorised device with wheels that automatically pulls curtains to block the natural light intake BAND: a wearable tracking device that collects vitals during daytime and asleep APP: enables users to create day-cycles and to review feedback about their sleep and wakeful wellbeing	ALL: Machine learning to create personalised sleep cycle; IoT (to provide proper sleep environment) BAND: Accelerometer; Heart rate sensor; Bioimpedance (to collect data during sleep and daytime) By Sarper Seydioğlu, Cem Özcan, Toprak İpek
Sleep Buddy  First-time parents wanting their babies to develop healthy sleep habits	Supports users to create sleep and meditation routine by utilising guided EFT tapping technique	MAIN BODY: an interactive device with a camera, LED lights and a speaker that creates personalised sleep environment for the baby and collects sleep-related data PARENT'S MODULE: detachable/portable part that remotely controls the main body, monitors the baby during sleep and displays baby's sleep-related data	MAIN BODY: Temperature and humidity sensor (via thermal camera); Motion sensor (to track movements during sleep); Sound processing (to gather sound data when baby asleep); Bluetooth By Öykü Elif Şare, Zeynep Özcan
Journey  Pregnant women experiencing sleep problems due to physiological discomfort or psychological state	Improves sleep quality of pregnant women by providing reassurance, comfort, and security	J-PILLOW: a personalised sleep pillow that ensures the best sleeping position for each trimester J-BUTTON: an interactive companion that provides psychological support and optimises environmental noise J-APP: displays sleep-related data, provides information regarding pregnancy and sleep	J-PILLOW: Pressure sensor (to track sleep quality); Bluetooth J-BUTTON: Touch control By Serhat Ünlü, Büşra Kabaoğlu
Cloudo  Children resisting to sleep at night or having sleep difficulties	Encourages children to go to bed on time provides them with comfortable, safe environment before/during sleep	PILLOW: a hug pillow provides vibration and light feedback, collects sleep-related data MAIN HUB: a hub attached to bed's headboard provides sound (music and stories) and light illusions APP (children): enables children to create bedtime stories, collect sleep points, grow avatars, and connect with friends APP (parent): displays children's sleep-related data and their progress overtime, enables parents to create bedtime routine for their children	ALL: IoT (to create a proper sleep environment); Bluetooth MAIN HUB: Motion sensor (to detect the child's position in bed); Heat and humidity sensor (to collect data and share it with the app); Voice control (voice recognition) (to interact with minimum distraction) PILLOW: Pressure sensor; Motion sensor (to track sleep movements) By Sümeyye Şimşekler, Eren Dönertaş

Figure 1. Key points of five Sleep-Well proposals

5 CONCLUSIONS

Sleep disorders are common and may adversely affect health and wellbeing. While some sleep disorders are quite challenging to treat, it is suggested that most can be easily managed with adequate interventions [5]. This paper demonstrated how digital interventions coupled with a design approach can lead to creative solutions. The Sleep-Well project was completed within a timeframe of eight weeks. The project requirements were found to be effective for graduate level design students, confirmed through formal

student feedback received at the end of the course, allowing them to demonstrate their advanced design skills as well as reporting their reflections on academic literature in a written format.
Students working on the Sleep-Well project were guided through a systematic approach, to provide them with specialist input on sleep, sleep problems, tracking and possible ways to alleviate sleep disorders, as well as relevant digital technologies. The expert lectures and the project development critiques given by the firm representative were invaluable in making sure that identification of the sleep disorders was realistic, and the solutions were technologically realizable. Final design proposals were evaluated by the course instructors, invited academic members, the firm representative and the medical doctor who gave a seminar at the start of the project. As envisaged, students created diverse solutions: some add-ons to familiar products to expand them with new features; some entirely new solutions; and some dealing with relatively less attended areas.

	AUTONOMY	COMPETENCE	RELATEDNESS
Fall-E	Allows users to create a personalised routine (App) Offers options for user preferences before/during meditation (All)	Provides daily feedback about the sleep quality and progress of the user (Tracker & App)	Offers personalised sleep and meditation programs according to the user personal data (Tracker & App)
Obversa	Allows users to take control over their sleep cycle and create artificial circadian cycle	Provides daily feedback about the users sleep and wakeful wellbeing	Provides user with an artificial environment which mimics the flow of the day, creates relatedness with the natural sleep-wake cycle
Sleep Buddy	Offers settings (e.g., song, ambient light, sleep duration etc.) to arrange before/during sleep (All) Enable parents to take control over their babys sleep routine	Provides simultaneous and daily feedback about babys sleep quality (Tracker & App) Enables parents to keep track of their babys sleep progress	Creates an environment promoting the sense of safety and comfort (as if they are companied by a family member) Enables connection between mother and the baby during sleep
Journey	Helps pregnant women to take control over their sleep routine (All) Increases empowerment by providing pregnancy-related information (J-App)	Provides information about stages of pregnancy and sleep during each stage (J-App) Presents sleep-related data (J-App)	Shares pregnancy experiences of other women (App) Provides psychological support by giving light feedbacks (J-Button) Offers personalisation and different usage options for each trimester (J-Pillow)
Cloudo	Enables children to create personalised stories and environment for themselves Enables parents to create personalised sleep routines for their children	Provides daily feedback about the sleep quality and progress of children (for parents) Enables children to keep track of their progress through the points	Provides children with a platform to communicate with their friends and exchange sleep-related experiences Introduces an avatar that grows as children gain points Promotes the sense of safety, comfort and attachment/companionship (J-Pillow)

Figure 2. Features supporting Autonomy, Competence and Relatedness in Sleep-Well proposals

ACKNOWLEDGMENTS

We would like to thank our student designers for their design contributions into the Sleep-Well project.

REFERENCES

[1] Leader D. *Why Can't We Sleep?* 2019, (Penguin Random House, UK).
[2] Ryan R. M. and Deci E. L. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist Journal*, 2000, (55), 68–78.
[3] Martela F., Ryan R. M. and Steger M. F. Meaningfulness as Satisfaction of Autonomy, Competence, Relatedness, and Beneficence, *J Happiness Stud*, 2018, (19), 1261–1282, (Springer Science+Business Media, Dordrecht).
[4] Peters D. Designing for basic psychological needs as a path to digital wellbeing. *CHI'19 Extended Abstracts*, May 4-9, 2019, Glasgow, Scotland, UK.
[5] Bohemia E. Working Knowledge: Industry-Based Projects in an Industrial Design / Engineering Program. *EPDE Conference: Changing Face of Design Education: 2nd Int. Engineering and Product Design Educational Conference*, September 2-3, 2004, Delft, the Netherlands.
[6] Hasdoğan G. and Şener B. "Motivations Behind Industrial Support to Education Projects: METU Industrial Design Department Graduation Projects, UTAK 2014: Design Research Conference: Education, Research, Profession and Social Responsibility, September 10-12, 2014, 219–234, Ankara, Turkey.
[7] Pavlova M. K. and Latreille V. Sleep Disorders, *The American Journal of Medicine*, 2019, 132(3), 292–299.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

THE SUSTAINABLE DEVELOPMENT GOALS APPLIED TO THE FUTURE OF DESIGN EDUCATION

Beatriz MARTINEZ-VILLAGRASA[1] **and José-Luis MENENDEZ-VARELA**[2]
[1]Universitat Pompeu Fabra (UPF), Spain
[2]Universitat de Barcelona (UB), Spain

ABSTRACT
The current social situation makes designers face increasingly complex challenges, closely linked to environmental and social issues. Design education has to respond to this, since design competencies are required to manage them.
In this context, the present research studies how designers face these challenges under a competency approach. This paper relates the designer's competencies to the 17 Sustainable Development Goals (SDGs) and the action guide proposed by the UUEE with the 2030 Agenda for Sustainable Development.
From this perspective, the competencies that designers acquire during their training must be aligned with the SDGs. However, recent research indicates that design students have competency gaps when working in social, environmental or sustainable design processes [1] [2].
In traditional education, core competencies for sustainability, such as Integrated Problem-solving, Strategic or Critical thinking, according to UNESCO 2019 Sustainable Key Competencies, are not considered particularly important. However, they are fundamental competencies defined in previous research on Design Creative Competencies. Moreover, authors point out that applying the competency approach to sustainability is relevant to solve real social challenges and opportunities [3]. That is why this article proposes a parallelism between designers' competencies, in other words, those they use when developing creative processes, and the SDGs.
It is also required to analyse the competencies that enable them to solve problems 'with respect to real-world sustainability problems, challenges, and opportunities' [4]. This context leads to innovative questions about design students' curricular profile in the 21st century.

Keywords: Creative competencies, design-education, education for sustainable development goals, design for social innovation, Agenda 2030

1 INTRODUCTION
Today's students are the designers who will have to respond to tomorrow's social issues, and they clearly aim at significant socio-environmental challenges.
This underlines the need for students to be trained considering real and future problems. In this sense, recent research shows that design students have a formative gap when carrying out projects that deal with socio-cultural issues [5], [6], [7].
This research suggest evidence of curricular gaps in the students' profiles. Particularly, in those processes directly related to circular economy or sustainable projects. This evidence shows that we are not training designers for the current challenges.
The major social problems worldwide are a reality. In response to them, Europe created the 2030 Agenda approved by the United Nations (UN). This 15-year plan aims to achieve a more inclusive and sustainable future. To this purpose, the 17 Sustainable Development Goals (SDGs) were formulated. These cover several related issues, such as the end of poverty, environmental protection, health, access to education and decent work.
The present paper proposes that the natural inclusion of the SDGs in higher education in design responds to the exposed problematic. This can be done through the acquisition of competencies that are directly related to the SDGs. The aim is to train professionals who have internalised these issues and design accordingly.

Furthermore, higher education is directly linked to the SDGs [8]. Particularly, SDG number 4 refers to Quality Higher Education and how it directly impacts the other SDGs. More specifically, the goal for target 4.7 Education for Sustainable Development and Global Citizenship: *ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development*.

In addition, as Kioupi and Voulvoulis point out, this objective is necessary to guarantee the other goals [9].

This paper proposes to relate the competencies of designers to the SDGs. It is assumed that the competency-based approach to higher education corresponds to the educational SDGs proposed by Europe. Since it focuses on the development of students' knowledge and skills throughout the learning process. Nevertheless, it is essential that all teaching and the competencies acquired by the student are permeated by the SDGs and the socio-environmental problems that they will face as professionals.

Studies such as that carried out by Romero et al. [10] analyse this issue from the field of engineering. This paper argues for the need to work on it also from the field of design and the arts. These fields are closely related to the means of production and the way in which we perceive and relate to the world in which we actually live.

This is a complex problem. This scenario raises questions about the competency profiles of design students in the 21st century and their correlation with the SDGs. In turn, it has to be addressed both by academia and by companies and institutions that consider current and future social, technological and environmental challenges.

A useful starting point is to consider which competencies students acquire in their higher education in design, and to correlate these with the SDGs. For effective and long-term learning, it is important to define the key competencies that will enable students to address complex social and sustainable challenges.

2 METHODOLOGIES

The aim of this article is to correlate the design competencies with the SDGs proposed by Europe. Since certain similarities that can facilitate the inclusion of the SDGs in higher design education are found. For this purpose, a relational analysis is performed. This establishes whether each competency is linked to one, none or several of the SDGs.

The list of 10 competencies is one of the results of a doctoral research on the competencies of designers [11].

The definition of these competences is obtained through a mixed methodology [12]. Fourteen design and engineering professionals and students are interviewed. It is then contrasted in a case study in a product design SME. Qualitative data is collected through non-participant observation of 105 students and young design professionals at three universities in Europe. And finally, at the same time, an online questionnaire is created to collect designers' self-perception of their competences on an international scale. A sample of 1025 responses is analysed. This methodology is used to collect data to define the competences, and their correlation with the SDGs is observed.

3 DESIGN CREATIVE COMPETENCIES AND THE SDGS

1. *Learning (Curiosity + Knowledge internalisation)* The capability of acquiring and applying new knowledge, abilities and attitudes efficiently through study or an experience that can arise before, during or after the design process. It has to do with the curiosity that feeds the exploration of new and diverse knowledge sources, as well as the capacity to internalise and practically apply what is learnt. **- SDG4 Quality Education.**
2. *Aesthetic sensitivity (Aesthetic appreciation + Aesthetic Criteria)* The capability to perceive, value and determine the basis for the formal aspects of a project. It refers to the interest in applying decisions related to aesthetics as a priority as well as the capability to support these decisions with arguments, so they are not arbitrary.
3. *Teamwork (Delegation + Tolerance)* The capability to cooperate when developing a project in which many people are involved. It refers to being able to delegate based on trust and the capacity to tolerate diverse criteria and other opinions. **SDG5 Gender Equality; SDG8 Decent Work and Economic Growth; SDG10 Reduced Inequality.**

4. *Critical thinking (Questioning + Improvement proposition)* The capability to inquire and find solutions to improve. It refers to the ability to question certain realities of a project in a constructive way; in other words, with an ability to identify and materialise possibilities for improvement and development. **SDG8 Decent Work and Economic Growth; SDG12 Responsible Consumption and Production.**
5. *Oral Communication (Planning + Charisma)* The capability to orally transmit a message in a clear and attractive way when presenting or pitching a project. This includes first preparing and structuring the information that needs to be transmitted and the ability to communicate it to generate a positive impact on the receivers.
6. *Social and ecological sensitivity (Awareness + Compromise)* The capability to reflect upon the social and ecological aftermath of a project. It refers to both the interest and respect for others and the capacity to act in consequence creating responsible and ethically sustainable projects. **SDG5 Gender Equality; SDG10 Reduced Inequality; SDG11 Sustainable Cities and Communities; SDG12 Responsible Consumption and Production.**
7. *Autonomy (Self-management + Initiative)* It refers to the individual capability to manage and organise work in an autonomous way as well as to personal initiative when modifying a project. **SDG5 Gender Equality; SDG8 Decent Work and Economic Growth; SDG10 Reduced Inequality; SDG11 Sustainable Cities and Communities.**
8. *Leadership (Strategic vision + Coaching)* The capability to detect opportunities and achieve goals through a strategic approach to projects. It refers to a designer's capacity to plan and direct work as well as the ability to motivate colleagues through empathy and enthusiasm. **SDG5 Gender Equality; SDG8 Decent Work and Economic Growth; SDG10 Reduced Inequality.**
9. *Research (Search for information + Experimentation)* The capability to enrich the design process with theoretical and practical research. It refers to the capacity of obtaining information on references and users as well as to the ability to experiment through different work tools and materials.
10. *Innovation (Originality + Realisation)* The capability to have original feasible ideas. It refers to the tendency of a designer to be creative and open-minded in his/her way of thinking as well as his/her ability to find a functional way to materialise ideas. **SDG11 Sustainable Cities and Communities; SDG12 Responsible Consumption and Production**.

4 ANALYSES

In reference to the 10 competencies defined, an analysis of how many times the SDGs appear linked to each one of them is carried out. From this count, it can be seen that SDG4 Quality Education is directly related to one competency; SDG5 Gender Equality relates to 4; SDG8 Decent Work and Economic Growth relates to 4; SDG10 Reduced Inequality relates to 4 competencies; SDG11 Sustainable Cities and Communities relates to 2; and SDG12 Responsible Consumption and Production relates to 3 competencies.

This means that these 10 competencies contribute to 6 of the 17 SDGs. It should be noted that they were not drafted with this aim, as they were defined before Europe drafted the 2030 Agenda. Therefore, they are closely related to the SDGs, despite not being an explicit aim in their formulation.

However, 11 SDGs are not directly related to them. These are: SDG1 No Poverty, SDG2 Zero Hunger, SDG3 Good Health and Well-being, SDG6 Clean Water and Sanitation, SDG7 Affordable and Clean Energy, SDG9 Industry, Innovation and Infrastructure, SDG13 Climate Action, SDG14 Life Below Water, SDG15 Life On Land, SDG16 Peace, Justice, and Strong Institutions, SDG17 Partnerships for the Goals.

Nevertheless, it is true that although not explicitly named, SDG4 on education is directly related to others, such as the cases of poverty SDG1, health and wellbeing SDG3, gender equality SDG5, decent work and economic growth SDG8, responsible consumption and production SDG12, climate change SDG13, and peace, justice, and strong institutions SDG16 as noted by Kioupi and Voulvoulis in their research [9].

The very definition of the 17 SDGs considers them to be interlinked. They depend on each other. We cannot achieve equality of opportunity if we do not allow more equal access to higher education, which guarantees the knowledge necessary to obtain a job with good conditions to enable us to escape poverty and have the resources to be responsible consumers. It is therefore essential to understand this

connection and to approach the SDGs as a set of interrelationships, rather than as elements isolated from each other.
A particular example is the relationship found in the study conducted by Fabregá et al. [13]. In that research, a positive relationship is statistically demonstrated between self-knowledge, innovation and environmental commitment to promote sustainable development. This study provides evidence of the correlation of some competencies that are present in the field of design, and how they enhance environmental commitment. In addition, it also relates it directly to SDG4, since these are competencies acquired in higher education. This makes education a crucial point for developing these competencies. Their paper also points out that sustainability implies using clean products, eco-efficiency, sustainable development technologies and eco-design, highlighting the crucial role of design in environmental awareness.
Furthermore, this comparative study reveals that there are competencies that can be considered transversal within the learning process, as they are necessary at several educational levels. One example is Autonomy and Critical Thinking. Both are considered necessary to be able to face the SDGs in the field of design.
Likewise, certain SDGs can be considered transversals throughout the training and subjects that compose the degree in design. This is why a competency-based approach to implementing the SDGs in higher education can bring significant benefits. It is assumed that students have to acquire the know-how related to the SDGs that they can apply in their academic and professional work.
The aim is that when doing professional work, the SDGs are a way of doing, not a goal to be achieved. Therefore, the student's competence profile will provide the necessary knowledge and skills to solve real social and environmental challenges [3].

5 CONCLUSIONS

As a conclusion, the list of creative competencies of designers is directly correlated with the SDGs. However, the approach to education and the connection of the competencies with the SDGs needs to be more evident in order to influence the students. The aim is to make it an active part of their processes, so that the SDGs become part of the designers' know-how.
Sustainability Education (SE) is one of the most relevant lines of research that aims to link higher education in design with the SDGs. According to this research, it is necessary to integrate the basic social, environmental and ecological vocabularies into design education [5], [6], [7]. In this way, it will become part of students' own language. These studies also indicate that the awareness of personal responsibility and behaviour, material science and the shaping of learning with standards in higher education should be enhanced. All of this with the aim of developing a holistic educational approach in accordance with behaviour and core competencies for sustainability.
All these characteristics can be achieved in higher education by working with real projects. Students' work needs to be related to the SDGs. To this purpose, one potential way is for design students' challenges to be directly related to real problems. Working on real challenges and applying all knowledge in response to current problems that require the SDGs to be carried out. In this way, they will work on projects related to the complex, uncertain, diverse, social and rapidly changing context of sustainability.
In this context, a study analyses a specific case in China [8], studying how some measures taken in education in relation to COVID-19 contribute to achieving the SDGs. Particularly, the SDGs 1, 3, 4, 5, 8 and 10 as a result of measures that include medical services, online education, logistical support and the promotion of graduate employment. According to this approach, and in relation to the discussion of this paper, several studies report that SDG 4 on education can be used as a link for the other SDGs' inclusion. This is the case of the study on energy sustainability in teaching and outreach initiatives [14]. Besides, regarding the 11 SDGs that are not related to the defined competencies, it is therefore worth considering whether education should address all 17 SDGs. Understanding that they are not closely related to education, some of them may be more of a target that concerns companies, such as SDG8 on Decent Work and Economic Growth. However, students should be aware of them. Some of the students will probably form a company in the future. Then, they will have a role directly related to SDG8. Therefore, it is understood that the 17 SDGs must be reflected in higher education, to a greater or lesser extent.
Understanding that the 17 SDGs are a whole and are closely interrelated, this must be applied in universities through the actions and policies of the institution itself. The SDGs should be part of the

university's policy, processes, activities and day-to-day life in a cross-cutting manner. They should not be introduced only in isolated subjects. In this way, they can become students' know-how from the very beginning of their education.

In social inclusion and environmental preservation, design is one of the most directly related disciplines. For example, when carrying out projects with a social impact, with the participation of specific stakeholders; or when choosing the materials to be used and the waste they generate during the useful life of the designed product.

Therefore, design is a great partner to be able to solve some issues related to the SDGs. However, for this to happen, it is necessary that students learn these values from their higher education, so that the SDGs permeate their future projects quite naturally.

FUNDING AND ACKNOWLEDGEMENTS

Funded by European Union-NextGenerationEU, Ministry of Universities and Recovery, Transformation and Resilience Plan, through a call from Pompeu Fabra University (Barcelona).

This work was supported by the Spanish State Research Agency [PID2020-112964RB-I00 / AEI / 10.13039/501100011033]; the Vice-rectorate for Teaching Policy and the Programme for Research, Innovation and Improvement of Teaching and Learning at the University of Barcelona [GINDOC-UB/103].

REFERENCES

[1] Biberhofer P., Lintner C., Bernhardt J. and Rieckmann M. Facilitating work performance of sustainability-driven entrepreneurs through higher education: The relevance of competencies, values, worldviews and opportunities. *The International Journal of Entrepreneurship and Innovation*, 2019, *20*(1), pp. 21-38.

[2] Østergaard T. The designer as agent of community. In *Proof of Concept: Service Design Conference*. Linköping University Electronic Press, Linköpings universitet, 2018 May, pp.76-91.

[3] Barth M., Godemann J., Rieckmann M. and Stoltenberg U. Developing key competencies for sustainable development in higher education. *International Journal of sustainability in higher education*, 2007, 8(4), pp.416-430.

[4] Wiek A., Withycombe L. and Redman C. L. Key competencies in sustainability: a reference framework for academic program development. *Sustainability science*, 2011 *6*(2), pp.203-218.

[5] Frisk E. and Larson K. Educating for sustainability: Competencies & practices for transformative action. *Journal of Sustainability Education*, 2011, *2*.

[6] Biberhofer P., Lintner C., Bernhardt J. and Rieckmann M. Facilitating work performance of sustainability-driven entrepreneurs through higher education: The relevance of competencies, values, worldviews and opportunities. *The International Journal of Entrepreneurship and Innovation*, 2019, *20*(1), pp.21-38.

[7] United Nations Educational, Scientific and Cultural Organization (UNESCO). *Education for Sustainable Development Goals: Learning Objectives, Cross-cutting key competencies for achieving all SDGs*, 2017, pp.10-55.

[8] Liu S. Higher education and Sustainable Development Goals during COVID-19: coping strategies of a university in Wuhan, China. *Journal of Public Health Research*, 2020, *9*(Suppl1).

[9] Kioupi V. and Voulvoulis N. Sustainable development goals (SDGs): Assessing the contribution of higher education programmes. *Sustainability*, 2020, *12*(17), pp.6701.

[10] Romero S., Aláez M., Amo D. and Fonseca D. Systematic review of how engineering schools around the world are deploying the 2030 agenda. *Sustainability*, 2020, *12*(12), pp.5035.

[11] Martinez-Villagrasa B. *Análisis y definición de las competencias creativas de los diseñadores. Creación de herramientas para el análisis de las competencias para su aplicación en el ámbito educativo y profesional del diseño* (Doctoral dissertation, Universitat Pompeu Fabra), 2020

[12] Martínez-Villagrasa B., Esparza D. and Cortiñas S. The creative competencies dictionary, between design practice and education in 21st century. In *Proceedings of International conference on engineering and product design education (E&PDE)*, vol. 20, London, 2018 September, pp.300-305

[13] Fabregá M. B., Masferrer N., Patau J. and Pérez A. P. M. Self-consciousness competence as driver of innovation and environmental commitment in higher education students. *International*

Journal of Sustainability in Higher Education, 2020, 20(7), pp.1507-1523
[14] Salvia A. L., Brandli L. L., Leal Filho W., Rebelatto B. G. and Reginatto G. Energy sustainability in teaching and outreach initiatives and the contribution to the 2030 Agenda. *International Journal of Sustainability in Higher Education*, *2020, 21(7),* pp.1607-1624.

INNOVATIVE BOARD GAME DESIGN IN AN ACADEMIC ENVIRONMENT DURING THE COVID-19 PANDEMIC

João MARTINS[1,2] and Luis MOTA[1,2]
[1]Instituto Politécnico de Viana do Castelo, Portugal
[2]CIAUD, Research Centre for Architecture, Urbanism and Design, Lisbon School of Architecture, Universidade de Lisboa, Portugal

ABSTRACT

Leisure or entertainment, like other everyday needs, are fundamental activities for human well-being. The creation of activities that lead to moments of satisfaction and relaxation are also a focus of attention and one of the areas of intervention where design can contribute solutions. This project challenged a group of students on a degree course in product design to develop modern, alternative board games, centred on users and on situations and environments of use, in order to exercise the practice of product design and seek to present innovative solutions. The challenge came through a local Cultural Association, with a tradition in promoting this type of game. The project followed a design project methodology that led students through a first phase of immersion in the theme, mechanics and strategies of games and their variety, going through the generation of ideas, models, evaluation tests, to the production of prototypes. The project was subject to the constraints of the Covid-19 pandemic, which forced students and teachers to work at home. To improve teaching and learning experiences, the project involved specialists and professionals who shared their knowledge and experience in developing this type of product. This gave rise to a great diversity of solutions, resulting from the use of an adequate methodology, making it possible to design new board games in which the mechanics, when articulated with a theme of interest to the target audience, can result in a proposal for an appealing and unique game.

Keywords: Board game, product design, design education, innovation, co-design

1 INTRODUCTION

Students and teachers in the 2nd year of the degree course in Product Design at the Escola Superior de Tecnología e Gestão of the Polytechnic Institute of Viana do Castelo, in the curricular unit of Project/Workshops II, were involved in an academic project to develop new board games. The theme arose through the Cultural and Artistic Association ArtMatriz de Viana do Castelo, which has a tradition in promoting this type of game and intends to disseminate the results of this partnership in various media and events, namely, in the 2022 event of Vianacon - Encontro de Jogos de Tabuleiro Modernos in Viana do Castelo, which it organizes together with the Municipality of Viana do Castelo. In the course of the project, several lectures were given by specialists in the area and entities in the field of board games. This project started in February 2021, during confinement, intending to promote the creativity associated with alternative and innovative modern board games. The students had several remote monitoring sessions by members and gamers, where they learned what currently exists in the landscape of modern board games and a little of the history of this activity. During the project's development, there were several practical presentations, highlighting the conversation with Game Designer Orlando Sá, who shared his creative process and working methods with the students. Methodologies for proximity to users (players / game creators), through ArtMatriz, its interlocutors and other expert guests, were defined through several work sessions, where it was possible to contextualize the constraints of the project's theme, identify and test guidelines, components and game mechanics, and get opinions on the intermediate results obtained. The cooperation and synergies developed between students and lecturers on the Product Design Course and the Cultural Association were crucial to obtain good results and culminated in the official partnership through the signing of a collaboration protocol. This article describes the activities carried out during the design process that included mixed teaching and learning strategies that challenged teachers and students to find answers to the questions and doubts that this type of teaching raises: will it be possible to develop a design project in pandemic with different partners intervening online and what impact does that have on the process?

1.1 Modern board games

Board games have been part of people’s lives over the generations and remind them of hours of fun with friends or family. In recent years the hobby has become increasingly serious with games that are more strategically and artistically elaborated. These are called modern board games. Mostly created and made in Europe, they demand more from their players, making the activity a true passion. The universe of board games is huge and fascinating and in times of confinement due to the COVID-19 pandemic, modern board games were excellent, solitary or collective, activities. In the more elaborate board games, there are differences mainly in the gameplay. The main feature of modern board games is that players are not eliminated from the game, but are able to participate until the end, and all have a chance of winning. In addition to improved rules and features, modern board games also stand out for their whimsical look and attention to detail. Whether with illustrations made by award-winning professionals or carefully crafted pieces, the items in each game make the activity even more pleasurable, in addition to becoming true collectors' items. Nuno Sentieiro and Paulo Soledade, from What's Your Game, regarding the Nippon game, state that “Developing a game like this, of strategy, oriented to more experienced players, requires many hours of work”, in this case two years, because the duo already had experience. “We have to read, study and also have a drink at the classics, to do something new and interesting” [1].

2 SOLVING THE PROBLEM THROUGH DESIGN

The problem posed to students and teachers was ambitious from the outset, as the intention was to encourage participants to develop innovative modern board games. This problem, within a higher design course, required adopting design methods that could support and improve the development process from the correct understanding of the problem, raise subjective and objective requirements and define guidelines for the product, going through several stages until the elaboration of the game prototype. The design process benefited from knowledge about design methods from different authors [2], [3], [4], [5]. In preparing the project, a product design process was validated, given that, according to the same authors, the application of a design methodology is not dependent on the areas or type of product, but on its ability to adapt to the requirements of the project in terms of objectives, available time, teams and expected results. Therefore, the project was divided into five well-defined stages: problem analysis, development (idea generation), specification, execution (prototyping) and presentation (communication). At all stages, discussion and reflection were constant and, at various times, participants were subject to assessment and intervention by experts in the field, online such as Ricardo Ferreira in a presentation of games from his private collection and Game Designer Orlando Sá from his home in Holland where he works who talked about his design process. (Figure 1).

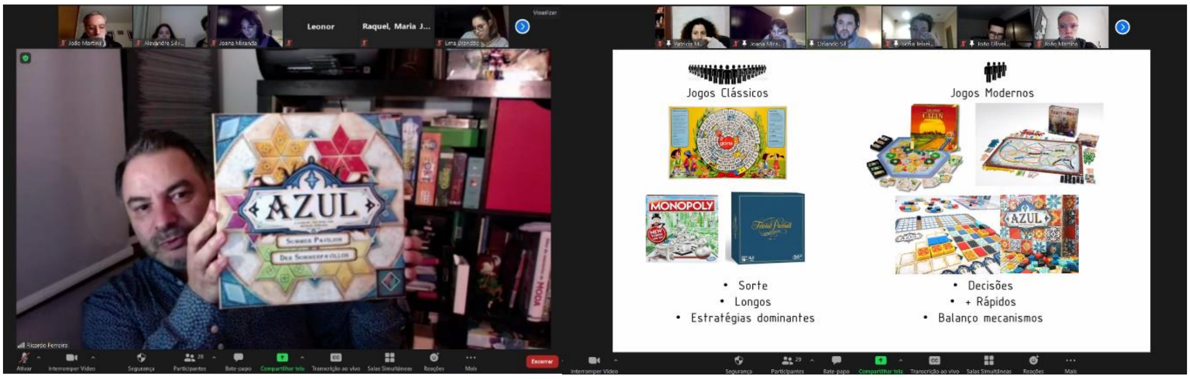


Figure 1. Lecture given via Zoom by the specialist in modern board games Ricardo Ferreira (left) and lecture with Designer Orlando Sá (Right)

2.1 Problem analysis

The project was developed in teams of two and three students who, at this stage, carried out research presented in the form of a mind map to better understand and manage the amount of information needed

(Figure 2). The construction of this diagram started from a centre with the title "Board Games" and led to themes revolving around this main idea: type of game, mechanics, players, publishers, authors, variety of shapes and dimensions, blogs, articles, story, objectives, game contexts, components, rules, motivations, etc. In this way, the students were able to represent, in detail, the conceptual relationship between dispersed information. Paths, words and illustrations sought to give an overview of the field where the project was developed and on which actions and strategies could be planned to achieve the objective of thorough understanding of the world of modern board games.

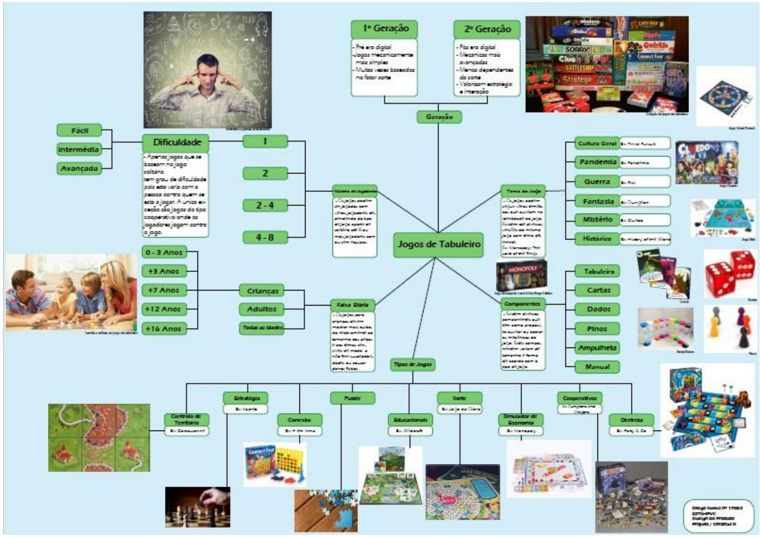


Figure 2. Student Diogo Neves Mind map

2.2 Development

Once the problem was defined, the next step was to generate ideas to solve it. At this stage, it was suggested that within a given time, each team should develop at least two ideas/concepts, supported by two concept panels with keywords, general and particular drawings, operational diagrams and other elements illustrating each of the idealized solutions (Figure 3).

Figure 3. Concept panel of the proposal entitled “B Design” by students Diogo Lopes, Maria João Dias and Raquel Ribeiro

The two possible solutions were accompanied by two full-scale study models where it was possible to demonstrate the concept and exemplify the functionality. On the defined date, one of the two possible ideas was chosen after evaluating both the appropriateness to the problem and the added value of each one. The validity of the ideas depended on meeting the following criteria:

- Concept (innovation).
- Gameplay (game operability)
- Game theme (suitable interest)
- Feasibility (production)

The criteria were verified by testing the game models, that is, by simulating several moments of the game which, in an intermediate phase of the project, served to choose the best game concept out of two possible ones (Figure 4).

Figure 4. Test of the game model entitled "Portus Cale" by students Beatriz Cruz, Ema Brandão and Leonor Oliveira

2.3 Specifications

This phase aimed to specify the proposals chosen in the previous phase. Here, students had to elaborate a set of elements with the technical detail of the selected idea. This phase led to achieving the accurate full-scale design of the board and game components, the full-scale model as faithful as possible to the game design, faithful reproduction of the remaining game components on the same scale and the selection of materials and manufacturing processes (Figure 5).

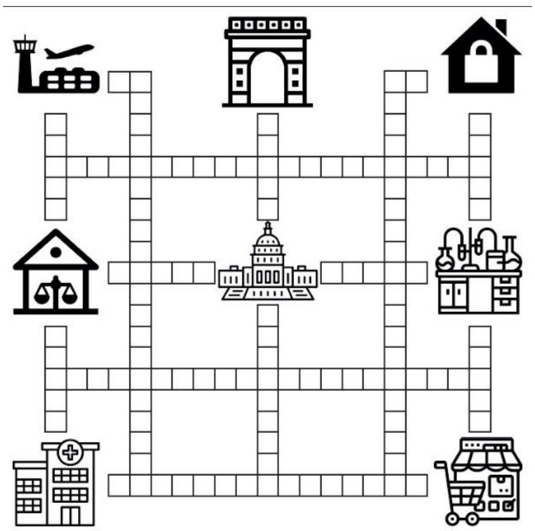


Figure 5. Board game entitled "Agents" by students Alexandre Silva, Diana Sousa and Paulo Dias

2.4 Execution

This phase dealt exclusively with construction of the prototype. This phase corresponded to achieving the solution, the last phase in conceiving a new product, and it was at this stage that the project began to materialize with a first prototype of the proposed solution, accompanied by a document containing all its technical specifications (Figure 6).

Figure 6 . Prototype of the "Multiple Nationalities" game by students Ana Canossa and Joana Santos

2.5 Presentation

At this stage, each group should make a photographic record of their board game, presenting images of the game, with all its components, its gameplay, with enough images to understand how the game operates, and the diagram of operation. In addition, each group created a digital PowerPoint file presenting the following product, concept and reference elements; game theme; the gaming board and other components; playability and operability; and an explanatory and demonstrative video of the proposal's gameplay lasting a maximum of 3 minutes. The presentation was made in person and was attended by a group of experts and players from the project's partner association (Figure 7).

Figure 7. Students present board game proposals to a group of experts through the prototypes built in the execution phase

3 RESULTS

The final results showed a great diversity of solutions, as a result of using an appropriate methodology, making it possible to design new board games in which the mechanics, when articulated with a theme of interest to the target audience, resulted in an exciting and unique game proposal. The main results were released at a national Modern Board Games Meeting, in 2021, which took place in the city, organized by the local Cultural Association and the City Council. At this meeting, the quality of the games was evaluated and discussed and the proposal of one group of students attracted the interest of a games publisher who invited them to improve the proposal in some less developed aspects, and to present it again to the same publisher who will evaluate its market introduction. Of thirty-four prototype ideas submitted to the competition, seventeen were finalized. The winners were "Hang" by students Francisco Araújo, Patrícia Moreira and Sofia Teixeira; 2nd Place: "Year 3000 Return to Home" by students André Antunes, António Ribeiro and Marco António; and 3rd place for "Agents" by Alexandre Silva, Diana Sousa and Paulo Dias. With the success of this project, it was possible to test the validity of the initially planned product design process, which was based on mixed teaching and learning strategies with face-to-face and online components.

4 CONCLUSIONS

The use of collaborative design processes and methodologies facilitated the creative process, allowing the project to evolve and contributing to improving the solution to the problem of creating modern and innovative board games. The pandemic caused by Covid-19 required sudden changes in the teaching and learning process, leading to a reconfiguration of educational practices that implied the development of skills in online teaching and learning by teachers and students. Having been well planned, the methods became everyday procedures that flowed unconsciously, becoming part of the project. The use of technology and collaborative software, such as Miro and Sketch drive, constitutes a set of interactive tools that made it possible to easily share, visualize and discuss online visual work during lockdown. In game projects where the theme, concept, mechanics and rules are part of the same product, we can see how important teamwork is, with the participation of specialists, which is characteristic of multidisciplinary design projects. The creators (students) were aware of the need to follow each phase of the project and the specific objectives within each one that must be achieved in order to produce better and faster, with a greater certainty of success.

REFERENCES

[1] Faustino S. and Oliveira S. Vai uma partida? 10 jogos de tabuleiro portugueses para toda a família. Available: *https://visao.sapo.pt/visaose7e/comprar/2020-12-12-vai-uma-partida-10-jogos-de-tabuleiro-portugueses-para-toda-a-familia* [Accessed on 2021, 10 July], (2020).

[2] Baxter M. Projeto de produto: guia prático para o desenvolvimento de novos produtos. 2ª ed, 3ª reimp. *São Paulo: Edgard Blücher*, 2005.

[3] Cross N. *Designerly ways of knowing*. Basel: Birkhäuser, cop. 2007.

[4] Jones J. C. *Design methods*. 2nd ed. New York : McGraw-Hill, cop. 1991.

[5] Löbach B. Design industrial: bases para a configuração dos produtos industriais. *São Paulo: Edgard Blucher*, 2001.

IDENTIFYING ISSUES IN TEACHING THE PROBLEM-FINDING STAGE FACED BY INSTRUCTORS - A CASE STUDY ON SDGs CHALLENGE PROJECT IN HIGH SCHOOL

Yanfang ZHANG[1], Leon LOH[1], Noriko TAKANO[1], Moe SHIMOMURA[1] and Christian CRUZ[2]
[1]Kyushu University, Faculty of Design, Japan
[2]Yamaguchi University, Faculty of Global and Science Studies, Japan

ABSTRACT
The purpose of this study is to clarify the difficulties instructors from different subject disciplines faced during the problem-finding stage, especially during the 'Period for Inquiry-Based Cross-Disciplinary Study' ("spirit of inquiry" as verbatim meaning), when conducting the SDGs Challenge Project, a pilot programme using design thinking methods with Fukusho High School. Pre- and post-questionnaire surveys were conducted to clarify the challenges faced by instructors in identifying social issues and the issues related to support. Before the programme started, the instructors had major issues with the understanding of the SDGs, design thinking, and the overall progress. Once the project got started, it was realized that the presence of even more specific issues such as student communication, use of digital tools, and use of design thinking strategies such as the KJ method. The challenges in implementing the programme can be categorized into (1) understanding the educational process of using design thinking, (2) facilitating group work, (3) using educational tools, and (4) others. Issues (1) and (2) were particularly prevalent.

Keywords: SDGs, design process, design thinking, problem-finding

1 INTRODUCTION
We are commencing the 21st century and the world is already facing several challenges of social nature, for example racial discrimination, income inequality, forced migration, among many; others such as major environmental catastrophes originated in the (human influenced) instability of the climatic systems; or digital (deliberate) man-made risks such as information warfare in the form of information manipulation and disinformation, such as the so-called "fake news" or "alternative facts". These have generated massive social and economic changes, and in order to deal with them, it is necessary to develop a new breed of human resources who have the competence to understand and currently manage the only solution at hand, the Sustainable Development Goals (SGDs) [1] by proactively proposing solutions complementing the existing base of skills derived from conventional knowledge-oriented education.
According to the Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) revised courses of study for high school in 2018, the new "Period for Inquiry-Based Cross-Disciplinary Study" will be implemented in high schools in 2022 to foster the "zest for life" required by society [2]. Hence, students need to develop the qualities and abilities to better identify and solve problems while considering their own way of being and living through independent, interactive and deep learning.
According to the "Survey on High School Education Reform 2021" report conducted by Recruit College Preparatory Research Institute, 93% Fukusho High schools in Japan have introduced the "Period for Inquiry-Based Cross-Disciplinary Study" [3]. The main areas of focus for implementing the new curriculum guidelines are to enhance classes from the perspective of improving students' abilities to be independent and interactive deep learners and to think, judge, and express themselves, in addition to improve the instructors' ability to develop teaching materials and design lessons. While each school has

begun to work toward such quality learning, there are several studies [4] on teachers' concerns and lack of teaching methods.
The implementation of this "spirit of inquiry", which fosters students to become active learners, is difficult to achieve only by improving educational methods in a localized manner and based on individual initiatives, on the contrary, it needs larger systemic changes related to the organizational theory of what kind of school should be built [5]. In order to implement inquiry-based learning compatible with the principles of Sustainable Development Goals (SDGs), it was suggested the need of an environment with appropriate evaluation methods, effective teacher assignments, and sufficient time for activities, as well as to provide information on how to promote inquiry activities [6].
As seen in the Governmental White Paper on Science and Technology (2013 edition) [7] and various government policies on science and technology innovation, the characteristics of design as a discipline that provides effective and efficient systematic tools and methods for generating innovation is gathering a lot attention at the moment of considering the candidates for developing new mechanisms of education. Design thinking is a way of thinking (processes systematization) that uses design concepts and methods to find solutions to arising problems and issues [8]. The main methodological structure is comprised of three steps: problem-finding, ideation, and realization. It has been adopted by Japanese companies since the early 2010s, following the trend from Europe and the United States. Currently, it is widely used in new market development, customer creation, and service and product development [9]. There is research done on the subject of using design to teach students about solving social problems [10] and incorporating design programmes into Japanese high school education to enhance awareness of SDGs, develop 21st century competencies (21CC), and social-emotional learning (SEL) [11]. However, there is still no research relevant to the difficulties faced by instructors in using design thinking methods for the new "Period for Inquiry-Based Cross-Disciplinary Study" that is to be implemented in 2022.
The Faculty of Design of Kyushu University established the SDGs Design Unit in April 2019. As members of the Design Unit, the authors of this academic document began an SDGs Challenge Project with Fukusho High School in 2019. The SDGs Challenge Project aims to nurture students' ability (develop design thinking) to identify and solve problems, work independently, think, judge, and express themselves while producing proposals with a strong and broad orientation toward society and its most pressing issues. The programme started with a small group of 17 students in 2019, following 50 students in 2020. In 2021, for the first time, the SDGs Challenge Project was adopted into the "Period for Inquiry-Based Cross-Disciplinary Study" for 314 third grade students with 27 teachers of various ages, for Japanese Language, Social Studies, and Art among the eight subjects included.

2 PURPOSE

Using Fukusho High School as a case study, this paper aims to clearly identify the difficulties teachers from different subject disciplines faced during the problem-finding stage when conducting the SDGs Challenge Project during the "Period for Inquiry-Based Cross-Disciplinary Study".

3 RESEARCH METHODOLOGY

3.1 Programme overview

The people involved in this programme were as follows:
Fukusho High School: 1 teacher-in-charge and 2 committee members. 27 teachers teaching the programme (5 Japanese Language, 2 Mathematics, 4 English Language, 5 Social Studies, 4 Science, 4 Health and Physical Education, 1 Art, 2 Home Economics)
Kyushu University, Faculty of Design: 4 members.
The programme was conducted from mid-April to mid-October 2021, with a total of 17 lessons. All lessons were conducted in a workshop format of 50 minutes, not including the introduction and presentation. There were 314 students involved, who were divided into 61 groups. Each teacher supported (as facilitators) 3 or 4 groups. In addition to the above mentioned three (macro) steps of Design Thinking, 'Problem-finding', 'Ideation' and 'Realization'; 'Sharing the problem findings and 'Divergence and Convergence of Ideas' were added between 'Problem-finding' and 'Ideation', and 'Ideation' and 'Realization', respectively.

3.2 Methodology

The research methodology used were pre-and post-questionnaire surveys with the instructors teaching the subjects.

There were two pre-questionnaire surveys conducted among the 27 instructors. The purpose of the first survey was to discover the instructors' level of understanding of the SDGs and Design Thinking concepts. Instructors were asked to rate their own level of understanding of SDGs and Design Thinking considering 5 levels, with level 1 as don't understand at all (not understanding SDGs' definition and concepts) and 5 as understanding very well (understanding SDGs' definition and concepts).

The purpose of the second survey was to determine the level of anxiety, concerns, and support needed to implement the subject. There were two questions asked. The first question was, - 'How anxious are you about teaching the General Inquiry?'-. Instructors were able to rate their anxiety level, with level 1 as not anxious, level 2 as a little anxious and level 3 as very anxious. The second question was, - 'What are your concerns in conducting the general inquiry lesson?'-. They were given 5 (multiple selection) options, "I did not understand the process of the project", "I did not know how to facilitate the discussion", "I am not confident in using Information and Communication Technology (ICT)", "I did not understand the SDGs", and "I did not know how to implement the lessons".

The pre-questionnaire surveys allowed the team to develop interventions to help the instructors. After each lesson, post-questionnaire surveys were conducted to find out the specific issues instructors faced in conducting each lesson. For this study, investigating the difficulties teachers met in the problem-finding stage, post-questionnaire surveys of 4 lessons related to problem-finding were used for analysis. The survey had open-ended questions for instructors to list the challenges they faced or state any comments or questions they had besides the ones provided by the question themselves.

4 RESEARCH FINDINGS

4.1 Results of pre-questionnaire surveys

The first pre-survey was conducted among 27 instructors, with 24 surveys completed. Instructors who rated themselves with level 1 and 2 are considered as having a low level of understanding. Teachers who rated themselves as level 4 and 5 are considered as having a high level of understanding. Of the 24 teachers who completed the survey, 16.7% had a high level of understanding of the SDGs, and 33.3% had a low level of understanding. Regarding design thinking, 8.3% of the instructors had a high level of understanding, and 83.3% had a low level of understanding.

The second pre-survey was given to 27 instructors, with 17 surveys completed. For the question -'How anxious are you about teaching the General Inquiry?'- Of the 17 instructors who completed the survey, 0% were not anxious, 65% indicated having a high level of anxiety, and 35% as having a little anxiety. For the question on -'What are your concerns in conducting the general inquiry lesson?'-. Of the 17 instructors who completed the survey, 29% did not understand the process of the project, 14% did not know how to facilitate discussions, 24% were not confident in using ICT, 12% did not understand SDGs, and 21% did not know how to implement the lessons.

4.2 Support system

Based on the results of the pre-questionnaire surveys, the Kyushu University Faculty of Design members and Fukusho High School committee members devised the following support system to address the instructors' concerns before implementing the programme. (Figure 1).

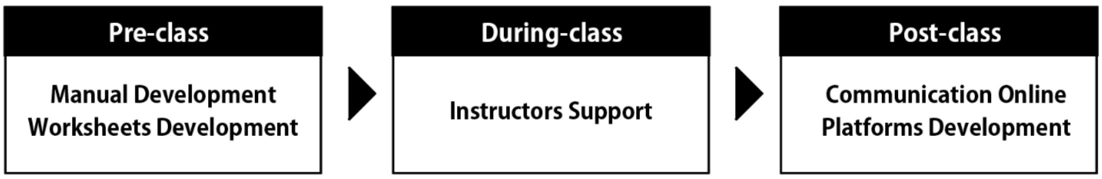


Figure 1. Support system

1. Developed an instructor's manual with relevant information such as the purpose of the SDGs Challenge Project, the design process, etc.
2. Designed worksheets for instructors' use in the lessons.

3. Fukusho High School committee members circulated around the classrooms providing assistance to the instructors during lessons.
4. Developed communication digital tools using online platforms such as Google Forms for instructors to share the issues faced, comments or questions after the lessons (post-questionnaire surveys), Google Jam board to share ideas between instructors and students, and Google Classrooms to communicate between instructors and students.

4.3 Post-questionnaire surveys analysis

There were a total of 35 issues, comments, or questions that surfaced after the 4 lessons related to problem-finding. These were sorted and compiled as shown in Table 1.

Table 1. Post-questionnaire surveys results

	Issues Faced	Issues count
1	Facilitation for problem-finding	8
	• Problem discovery (5)	
	• Problem definition (3)	
2	Facilitation for groups that progress at different speed	6
3	Motivating students	5
4	Promoting communication within the group	4
5	Using the KJ method	2
6	Explaining the lesson process to the class	2
7	Using digital tools	2
8	Using the worksheets	2
9	Understanding the content of the manual	1
10	Answering questions from students	1
11	When to give the homework assignments	1
12	Means to collect information	1

Table 1 shows that the highest response was the issue of facilitation for problem-finding. The instructors who responded to this issue explained that they faced challenges in facilitating problem discovery where students needed to expand on the theme to identify more problems. The students did not have enough experience or knowledge themselves, consequently, they could not empathize or discover other people's problems, e.g., the elderly, troubled family composition (divorced families), etc. In addition, some faced difficulties in facilitating the problem definition where students had to decide on a problem to attack based on its seriousness, that is to say, the hierarchy of the problem prioritization. The next high response issues, were the ones in which the instructors were not sure how to do facilitation among groups with different speeds, keep students motivated, and encouraging group discussions. The challenges in supporting teamwork are due to the differences in the students' understanding of the SDG education programme based on their personalities and communication skills.

5 DISCUSSIONS

For this programme, the curriculum is organized along the lines of the design thinking process, starting with ‘Problem Finding’, arguably the most fundamental stage and proportionally the most challenging one, it immediately set the tone of difficulty for the instructors. The analysis of the surveys shows that the major hurdles are as follows:

Prior to the programme start, the instructors had “strategic” (macro level) hurdles; major issues with the understanding of the SDGs, design thinking, and overall progress. As they proceeded, the realization of more “tactical” (micro level) issues set in, e.g., student communication, use of digital tools, and use of design thinking strategies such as the KJ method [12]. The challenges in implementing the programme can be categorized into (1) understanding the educational process of using design thinking, (2) facilitating group work, (3) using educational tools, and (4) others, as shown in Table 2. Issues (1) and (2) were particularly prevalent.

Table 2. Classification of the issue of facilitation for problem-finding

Issued faced	Classification of Issues
Facilitation for problem-finding	Understanding the educational process of using design thinking
Using the KJ method	
Explaining the lesson process to the class	
Answering questions from students	
Facilitation for groups that progress at	Facilitating group work
Motivating students	
Promoting communication within the group	
Using digital tools	Using educational tools
Using the worksheets	
Understanding the content of the manual	
When to give the homework assignments	Others
Means to collect information	

Most of the instructors reflected with respect to (the difficulty of) understanding the educational process and the incorporation of design thinking, particularly the problem-finding stage. From the findings, it is very clear the difficulties rely not only on the problem definition alone, but rather on the procedural aspects of the facilitation process itself. The cause of the difficulty might depend on the lack of understanding of the purpose of design thinking, thus leaving them (instructors) in the difficult position of not being able to explain the lesson process to the class nor competently using strategies such as the KJ method. Though an instructors' manual was developed in discussions with the Fukusho High School committee after the pre-questionnaire surveys (83.3% has a low understanding of Design Thinking), the lack of understanding of the manual's contents and guidance on how to put the manual into practice rendered this initiative mostly useless. The lack of a support system is considered the root cause of the problem.

The second type of challenge that many instructors responded to, is the facilitation of the group work. As a consequence, groups working at different speeds, lack of motivation, and poor communication between students in the group was evident. In high school education, most lessons are instructor centred. Communication is usually unidirectional. In this workshop-style class where student initiative is important, communication in both ways is fundamental, not many instructors are capable of handling this condition and find it difficult to overcome or at least catch up with years of “traditional” teaching.

The third type of issue that instructors face is using educational tools. The instructors’ manual and worksheets were designed and prepared by the members of Kyushu University and the Fukusho High School instructor-in-charge and committee members. The 27 instructors who carried out the lesson were not involved in creating these materials. As such, they may not understand very well the materials provided. The other issue could be that the content in the manual may not be sufficient for the lesson to be efficiently and effectively carried out. Key points, examples, among others, could be added to make it more comprehensive. In addition, after distributing the instructors’ manual, there is no opportunity to communicate (and gather relevant information) with the instructors to discover and shed light on their concerns and (or) questions.

6 CONCLUSIONS

The purpose of this study is to identify the difficulties instructors from different subject disciplines faced during the problem-finding stage when conducting the SDGs Challenge Project, a pilot programme using design thinking with Fukusho High School, during the "Period for Inquiry-Based Cross-Disciplinary Study".

There are issues that need to be addressed by the committee's instructors in charge, including (1) understanding the educational process of using design thinking, (2) facilitating group work, (3) using educational tools, and (4) others. In particular, issues (1) and (2) are shown more frequently. It was also found that instructors with a low understanding of the SDGs had more issues than those with high levels of understanding.

Based on the results of this study, more diverse support is needed in the future during discussions with Fukusho High school committee's instructors-in-charge and members. The following are some suggestions.

- Provide hands-on workshops for instructors to understand design thinking.
- Provide a variety of support tools other than manuals, such as instructional videos.
- Facilitate communication among instructors.
- Fukusho High School to nurture mentors within the high school.

In future research initiatives, in order to expand the gamut of possible solutions to other stages beyond the problem-finding one, it will be necessary to identify issues in the ‘ideation’ and ‘realization’ stages. In addition, it may also be necessary to pinpoint the characteristics of the instructors in relation to the issues faced. For example, will the length of teaching experiences or the different subject backgrounds of the instructors affect the kind of problems faced?

For this programme to be successful, it is also necessary to understand the effect of external factors such as the Japanese educational system in its entirety, and the level of digital literacy of the instructors, this last one a point of great relevance since the outbreak of the COVID-19 pandemic and the adoption of digital tools beyond common messaging system and information boards by schools in general. This sudden massive embrace caused major struggles in a generation of instructors who are for the most part (44% of the surveyed instructors) in their 50s or older and whose digital competence is not up to the current digital trends, especially those related to massive multi-communication live platforms such as Zoom, WEBEX, MIRO, among others. In addition, the mentoring necessary to level this digital illiteracy is not up to the demands of the current situation and the instructors are left to rely on each-other’s basic, segmented, and limited comprehension.

REFERENCES

[1] United Nations, *the 17 goals*. Available: https://sdgs.un.org/goals [Accessed on 2022, 10 March], (2022) 17 February.

[2] Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT). *Period for Inquiry-Based Cross-Disciplinary Study*. Available: https [Accessed on 2021, 10 June], (2018) July.

[3] Recruit College Preparatory Research Institute. *High School Education Reform 2021 report*. Available:http://souken.shingakunet.com/research/kaikaku2021_houkoku.pdf [Accessed on 2022, 14 March], (2021) June.

[4] Masao M. Trends in deep learning in “Period for Inquiry-Based Cross-Disciplinary Study”. *Tokai Gakuen University Education and Research* Vol. 5, 2019, pp.86-95.

[5] Nakahara J. High School for Raising Active Learners: Actual Conditions of Active Learning and Latest Practical Examples. *Japan Education and Research Innovation Centre academic publication.* 2016.

[6] Sugio K. and Miyaguni Y. An Analysis of Perceptions of the SDGs for Project-Based Learning: A Case Study on a High School. *Graduate School of Education, University of the Ryukyus Bulletin of Advanced Teaching Profession Practice (Graduate School for Teacher Education)* Vol.4 2020, pp.85-95.

[7] Ministry of Education, Culture, Sports, Science and Technology. Science and Technology White Paper (2013 Edition), *Matsueda Printing*. 2013.

[8] Peter G R. Design Thinking. *MIT Press Reprint.* 1991.

[9] Konno N. Design thinking for business. *Toyo Keizai.* 2010.

[10] Kashiwagi H. Textbook for design. *Kodansha Reprint. 2011.*

[11] Loh W. L., Shimomura M. and Zhang Y. F. Unlocking Creative Minds to Engage SDGs Through Design Education in Japanese High School. *Proceedings of the 22nd International conference on engineering and product design education(E&PDE).* 2020.

[12] ResearchGate, *the KJ Method: A Technique for Analysing Data Derived from Japanese Ethnology*. Available: https://www.researchgate.net/publication/243785588_The_KJ_Method_A_Technique_for_Analyzing_Data_Derived_from_Japanese_Ethnology [Accessed on 2022, 11 March], (1997) June.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

IMPROVING THE EDUCATION EXPERIENCE IN A DESIGN HISTORY COURSE USING CANVA, INSTAGRAM AND LINKEDIN

Bryan F HOWELL, Addie Payne MORGAN and Asa River JACKSON
Brigham Young University

ABSTRACT
The History of Product Design course at Brigham Young University has successfully implemented Instagram into its curriculum over previous years, and these efforts have been studied, documented, and published at past E&PDE conferences. This study aims to re-evaluate this course's presentation tools, improve the current use of social media, and enhance the overall learning experience. First, we assessed the value of using Instagram as an educational tool. Second, we evaluated the differences between Adobe InDesign and Canva as a presentation tool. Canva's advantages over Adobe Suite products include a shorter learning curve, spell-checking, video integration and built-in compatibility with social media products. Third, we assessed the impact of incorporating LinkedIn in our posts to extend the reach of student presentations. The results indicate that Canva decreases presentation building time, focuses student content decisions and increases visual quality. We also demonstrate that using Instagram and LinkedIn as education tools somewhat increases interaction with the larger design community and student attention to content quality.

Keywords: Design education, classroom social media, Adobe InDesign, design student presentations, design dissemination

1 INTRODUCTION
With the prominence and breadth of social media, exploring how these tools are used in the classroom and their impact on student learning warrants exploration. Student familiarity with social media applications like Instagram, LinkedIn and TikTok enable young designers to share ideas, questions, and concepts with like-minded people outside the classroom, school and country. As social media gains popularity in educational settings, it is important to investigate the methods and technologies that effectively support meaningful learning experiences in design education [1]. Specifically, the practices for implementing social media sharing should be assessed beyond the current research [2].
Adobe suite products are prevalent in design education settings and reflect contemporary industry standards. Unfortunately, these tools are challenging to learn. New online software tools like Canva have emerged in response to these pains. Canva is a growing online application bridging the gap between creative presentation creation and a thoughtful interface, thus impacting how students formulate and disseminate class assignments [3]. Canva's advantages over Adobe Suite products include a shorter learning curve, spell-checking, video integration and built-in compatibility with social media products.
Instagram provides a comfortable avenue for expressing and connecting with design information for students who grew up with social media. Students commonly engage with Instagram and TikTok for contemporary cultural information and often follow established designers' accounts to gather design insights. LinkedIn is the social media standard for industry professionals; however, students have typically not embraced it as a career-building tool. Introducing LinkedIn to students in a course structure can expand their learning opportunities and increase their network as they establish their careers in design.
This paper represents the latest learnings incorporating social media tools in a classroom and extends the learning found in this same course researched, published, and presented at previous E&PDE conferences in 2018 [4] and 2019 [5].

2 METHOD

2.1 Participants

Nineteen students, eight females and eleven males participated in the study. Seventeen students were industrial designers, and two (one female and one male) were graphic designers. Participants were informed that the tools they used to create, present, and disseminate their work would be switched for their final class presentation, and their experience with the new tools would be evaluated. All participants were undergraduate students at Brigham Young University (BYU). Participants received no extra credit or compensation and were free to withdraw from the study at any time.

2.2 Stimuli Study One - Adobe and Instagram

Students were assigned to conduct research on assigned historical or contemporary designers and create a 10–15-minute class presentation that included facts about the designer's life and training, images of their work, an explanation of their design philosophy, a video link if available and examples of how the designer influenced contemporary design, as applicable.

Students were provided with a 10-page Adobe InDesign template, as seen in Fig. 1, formatted for use on Instagram. Since January 2018, students have posted their presentations on the course Instagram account @byudesignhistory. The template, presentation content, and posting details are explained in Howell et al., 2019 [5].

Figure 1. Previous InDesign Instagram template

For the study, the course Instagram account was converted from a general account to a corporate account between study one and study two. This change allowed researchers and students to use Instagram's analytics tools which show total accounts reached, engagement, top cities and countries, quantified post engagement and the audience's age and gender.

2.3 Stimuli Study Two - Canva and LinkedIn

The content expectations for study two were identical to those in study one. Most design students are immersed in Adobe's ecosystem and are unaware of Canva as a simple-to-use presentation tool. Canva's interface is optimised for presentation and social media use, helping students easily organise and disseminate their information. To introduce Canva to the class, instructors demonstrated two of its key benefits: 1- Canva includes video and GIF capabilities that are not available in InDesign, and 2- Canva is significantly easier to load and manipulate photos and type. Utilising Canva to create student presentations should save time and aid in audience engagement and learning. As in the previous study, all students received a 10-page Canva template optimised for Instagram use, as seen in Fig. 2. The Canva template instructions, including video tutorials, were embedded within the template.

Figure 2. Canva Instagram template

LinkedIn is a design industry standard for seasoned professionals. It is a living résumé, with employers frequently studying candidates before scheduling an interview or hiring. Students were expected to have a personal LinkedIn account; they were asked to create one if they did not. Instructors gave demonstrations and directions on posting students' presentations directly to LinkedIn and linking their Instagram presentation post to LinkedIn. Additionally, students received instructions on accessing LinkedIn analytics tools that display profile views, post views, and search appearances.

2.4 Procedure
Students were required to research, build, and present five different presentations roughly two weeks apart over the semester. The first four presentations were created in InDesign and posted on Instagram (Study 1). For the fifth presentation, students learned Canva and either linked to or posted their presentation on their LinkedIn account (Study 2). Researchers administered a digital survey via Google forms for the first and second studies. The first survey occurred during the fourth set of presentations and covered InDesign and Instagram. The survey took 15 minutes to complete. The second survey was administered on the last day of class and took about 15 minutes to complete; and covered Canva and LinkedIn. All participants had used Canva for their final presentation, and most had shared their presentation on LinkedIn.

2.4.1 Study 1 - InDesign and Instagram as Education Tools
Survey one was divided into three sections: Instagram use, InDesign as a presentation tool, and social media content dissemination. Students were asked about their experience using Instagram, how likely they were to reference the class's information, and if they view Instagram as a learning and education tool. Regarding InDesign, students were asked to evaluate the current templates, rank their presentation creation and assembly priorities, and express any changes they would like to make to the existing template. Respecting content dissemination, students were asked how they felt about engagement on the account, how familiar they are with social media management tools and how they felt about analytics for our account.

2.4.2 Study 2 - Canva and LinkedIn as Education Tools
We modified two components of the class organisation after considering the findings from Study 1. For the second study, Canva replaced InDesign, and LinkedIn was used along with Instagram to disseminate content. The Instagram analytics tools were used to evaluate what made previous posts effective, and the 10-page InDesign template was modified and replaced with a Canva template. Students were provided with the new Canva templates and instructed to download Grammarly, a free grammar check program, to help avoid spelling errors in their presentations. Students were asked to post or link their presentations to their LinkedIn accounts, enabling a second method of content dissemination with an alternative audience and format. Students were taught about hashtags, tagging and post analytics in both Instagram and LinkedIn, and they were encouraged to respond to and comment on their peers' posts.
Survey two also contained three sections: LinkedIn use, Canva as a presentation tool, and LinkedIn as a dissemination tool. Students were asked about their experience with LinkedIn, how often they interacted with it, and which tool Instagram, or LinkedIn, they considered more valuable to their future career. Regarding Canva, students were asked about their experience with the tool, the comparison of Canva to InDesign and which program they would recommend for future classes. Respecting content dissemination, students were asked; what value they place on knowing how to disseminate their work, how utilising social media strategies has changed their view of sharing content, and how the quality of their presentations changed after discovering they had a worldwide audience.

2.5 Data Analysis
The results of these two surveys were assessed to understand the impact of the changes made and the overall influence of the course and its structure on the student learning experience.

3 RESULTS
The sections below will discuss the quantifiable data and shared comments on social media use, class presentation tools, and material dissemination from the two surveys. Numeric responses are given based on a 5-point scale.

3.1 Study 1
When asked about the experience of Instagram as a course tool, students responded positively with an average of 3.76 and recorded referring to the Instagram page more than five times during the semester. Students responded with an identical 3.76 when asked how likely they were to reference the Instagram material in the coming two semesters. Lastly, students replied with an average of 3.06 when asked about the likelihood of referencing the material in the next five years. When asked about Instagram as an education tool, most students agreed that it was undoubtedly a resource for learning, inspiration, and

exposure. Some qualified that by saying it was not always reliable, nor could it be easily referenced. A few students even said that they actively try to avoid using social media to inform themselves. However, this contrasted with the majority.

When asked about the most important elements of presentation creation, the majority said researched content was a priority and that classroom discussion questions were last on the list. When asked about Adobe InDesign as a presentation tool, students replied with an average of 3.41 and 3.59 regarding the experience with templates. It is worth noting that only three scores of 5 were submitted between these two questions, implying a less than optimal experience. Over one-third of students also recorded spending under 50% of their time researching, with the rest spent using InDesign to assemble the presentation. Lastly, when asked about the most and least important purposes of a template, most students suggested that fewer decisions were a priority and that unity with the other presentations mattered the least.

One question asked for suggestions for a future template or problems with the current template. A prominent request was for the template to include an easy way to embed and display different media (e.g., audio, GIF, video, etc.). Other minor suggestions addressed the aesthetic direction or branding and a wider variety of layout options. One individual stated that the template was "fine". Comments about issues within Adobe InDesign were similar to the previous question but with additional qualms surrounding editability, exporting files, scaling text and inserting motion media.

Regarding engagement with their posts, students scored just below indifferent at 2.81. In contrast, students recorded an average of 4.06 when asked to state their familiarity with personal social media usage. The last question for this section regarded student familiarity with social media analytic tools, which received an average response of 2.88.

One question informed the students how international the scope of our Instagram account was, of which they had previously been unaware. They were informed that 77% of viewers were from outside the BYU community. The average number of account impressions per month was 4,000 (roughly 40,000 total for the previous 12 months). When asked what this meant to students, the majority suggested they would strive to make better presentations, and many had a more positive attitude towards this method of sharing. It should be noted that a few students did not alter their opinion after seeing this information.

3.2 Study 2

In contrast to Survey 1, when asked about the implementation of LinkedIn as a course tool, the average response was 4.1 (vs 3.76 for Instagram only). One question also inquired which of the two, Instagram or LinkedIn, students plan on investing more time in as they enter their careers. The heavy majority favoured LinkedIn. When asked to comment on LinkedIn as an education tool, around a third said it was helpful in learning, but the majority assigned the program as a tool for networking, connecting, and meeting individuals outside of their current sphere. Students said they were insecure when posting on LinkedIn essentially because it connected more directly to their emerging professional identities. Most respondents said they would use hashtags and review analytics in the future. As some final questions, students responded with an average of 4.19 when asked about their insecurity when posting for the class on Instagram, and a 3.25 with respect to LinkedIn (5 was most secure).

The overall response to using Canva as a presentation tool was 4.81 on average, with a 4.75 when asked about the template (compared to the 3.41 and 3.59 regarding InDesign). The new template did not alter opinions regarding the priority of researched content in the presentation, but it did increase and unify the average time students spent researching versus assembling. Most students spent 60%-80% researching and the rest assembling. When asked overall, which program, InDesign or Canva, was easier to learn, every student responded with Canva, and many admitted they wished they had used it for their portfolios.

Regarding Canva, most of the suggestions for template changes were minor (e.g., colour, alignment, text). Additionally, learning Canva through videos and instructions within the template improved the tool learning experience. All students suggested using Canva for future classes due to its flexibility, simplicity, and interface.

3.2.1 Material Dissemination

When asked about content dissemination for the second time, the average response was 4.5 regarding the value of sharing work through social media (compared to 2.81 for Instagram). Students also shared that the content displayed in class enhanced class conversation but did not necessarily increase their discussions outside of their current design community.

Upon analysing the social media analytics, we discovered our shared Instagram account had 14,478 impressions during study two, representing a 66% increase compared to the previous month of the semester and Study 1 (4,760 impressions). In terms of engagements, the account received 869 engagements, representing a 65.5% increase over the previous month (263 engagements). Most of our impressions (77%) came from outside of BYU. The United States, Malaysia, Germany, and Italy are the leading countries for impressions. Several factors contribute to these significant improvements, including the use of hashtags and in-post tagging by students and the additional visual interest offered by the Canva templates.

A few students shared the analytic results of their posts with the class. One student used hashtags and tagging on Instagram and linked to LinkedIn, and her post garnered 1,182 impressions and 321 impressions on Instagram. A second student used the identical social media methods as the previous student mentioned and obtained only 83 Instagram impressions yet gained 2,144 impressions on LinkedIn. These results demonstrate that students can effectively disseminate information on both Instagram and LinkedIn, and individual posts can perform differently on each platform. For successful dissemination and increased social media reach, students should practice communicating their information succinctly.

Lastly, when asked to comment on this class's effect on personal design philosophy, all students agreed that it helped them explore and place their design work in the broader design ecosystem. Students also expressed increased empathy, understanding and knowledge from course participation.

4 DISCUSSIONS

4.1 Adobe InDesign and Canva

The overall attitude and experience of presentation creation and dissemination improved after the transition from InDesign to Canva (Study 2). Design students were familiar with Illustrator and Photoshop before this class, but not with InDesign. InDesign is a standard for the design industry but proved to be a steep learning curve for the course. Students prioritised research in preparing their presentations, and the percentage of time spent researching rather than building the presentation increased between Survey 1 and Survey 2. The implications of these results encourage the use of simpler, newer presentation tools to help students enhance their learning experiences.

4.2 Instagram and LinkedIn

Instagram and LinkedIn occupy different realms of content dissemination. Based on the responses, students feel more comfortable sharing content through Instagram because it is less tied to their professional identities, but also say that they plan to rely more on LinkedIn in the future for that same reason. To encourage the dissemination of knowledge through social media, it seems that Instagram provided a safe and encouraging place to practice, particularly once instructed on social media strategies and outcomes. For both Instagram and LinkedIn, those who engaged in sharing contributed to an impressive number of interactions from across the world, expanding their network within design. It is also worth acknowledging that many said they would take more pride in their work if they planned to share it on Instagram and LinkedIn.

Interestingly, students replied to the survey by saying that LinkedIn was a resource for connecting and networking, but not for learning, while Instagram was the opposite. In looking to the future, making a better connection between content dissemination and personal identity might encourage more students to share their work more often.

4.3 Impact of Dissemination

A better connection between content dissemination and personal identity might encourage more students to share their work through social media. The purpose of introducing Instagram and LinkedIn into the course was to expose students to the different resources for sharing their knowledge and work while also encouraging connections with others interested in design. In consequence of the account being linked to the school and class, students made it less a part of their identity but maintained its viability and enjoyed discussions with various individuals across the world, particularly after hashtags and tagging were reinforced. Similarly, the minority of students that posted effectively on LinkedIn enjoyed a significant increase in connections and interactions regarding their work and ideas. The largest problem revealed from the survey was the perceived difference between education and business contexts. Students were willing to accept Instagram as a place to openly share their work, while LinkedIn maintained a feeling of business, deterring students from openly sharing. Moving forward, we will include more class discussions about the impact social media can have on their professional growth.

4.4 Dynamic Class Content

One criticism that follows the format of this course is that because most instruction and content is taught by students, with the instructor guiding the discussion, content is inconsistent, and some key points might be missed. Some students perform much better than others in researching and presenting their findings. However, students in their responses from Survey 2 indicated an unanimously positive experience with the class, with personal philosophies expanded and greater knowledge of how the history of design impacts them here and now. We believe it is beneficial for students to explore and discuss what they are curious about. If significant ideas or projects are left out of a presentation, the instructor makes additions or corrections.

5 CONCLUSIONS

Overall, the outcome of the course can be expressed through two student course ratings:

> *"This class also helped me to see the power of sharing my knowledge on social media and how much social media can be a tool for gathering information and data."*
>
> *"The class was organised well and provided plenty of opportunities to evaluate one's personal perspective and philosophy. The emphasis on posting presentations online to gain exposure and possibly international recognition was interesting. Using LinkedIn is a better platform for professional exposure, but I would only post presentations associated with my account about designers I agree with."*

Disrupting the current standards for design presentation tools, like Adobe or PowerPoint type products, with tools like Canva and encouraging broader dissemination of content by using Instagram and LinkedIn expands any design course's implications and enhances student learning experiences. As content dissemination continues to evolve within the world of design, eventually, the culture and process of the classroom will commonly reflect those changes.

REFERENCES

[1] Carpenter J. P., Morrison S. A, Craft M. and Lee M. How and why are educators using Instagram? *Teaching and Teacher Education*, Vol. 96, 2020.

[2] Arceneaux P. C. and Dinu L. F. The social mediated age of information: Twitter and Instagram as tools for information dissemination in higher education. *New Media & Society*, Vol. 20, Issue 11. November 2018, pp. 4155-4176.

[3] Maolida E. H. and Salsabila V. A. Canva and Screencast-O-Matic Workshop for Classroom Purpose: A Community Service for Madrasah Ibtidaiyah Teachers. *Jurnal Pengabdian Kepada Masyarakat,* Vol. 1, No. 2, October 2021, pp. 54–60.

[4] Cardall H. Q. and Howell B. F. Using Instagram to Increase Student Engagement with Design History. In *International Conference on Engineering and Product Design Education, E&PDE'20*, London, September 2018, pp.726-731.

[5] Howell B. F., Siebert J. and Hill M. New Uses of Instagram in Design History Education. In *International Conference on Engineering and Product Design Education, E&PDE'19*, Glasgow, September 2019.

PROJECT BASED LEARNING IN THE CONTEXT OF CUTTING-EDGE ROBOTICS COMPETITION

Suk Wai Winnie LEUNG and Zexiang LI
Division of Integrative Systems and Design, Hong Kong University of Science and Technology

ABSTRACT
RoboMaster is an annual robotics competition pitting student's cutting edge robot designs in a Multiplayer Online Battle Arena (MOBA) gamified shoot-out battle. The highly technical-advanced competition rules are designed to encourage innovation in robotics automation and intelligent systems while placing robot battles at centre-stage. It manages to display the beauty of engineering technology and popularize robotics to the wider audience by balancing technical challenge and entertainment value. Hong Kong University of Science and Technology (HKUST) sees RoboMaster as a unique platform for promoting STEM to the wider university student body. Through 4 years of team development and student participations, we have homegrown a group of outstanding scientific and technological engineers who have excelled in both academic research and entrepreneurial ventures. In this paper we review the development, growth and success of the 4 years of the HKUST RoboMaster ENTERPRIZE team and evaluate assessable learning outcomes of the competition as a project course. The degree of engineering design complexity and resulting the comprehensive learning outcomes, inspired the launch of a new bachelor programme in which many foundation engineering courses are replaced by year-long cornerstone project courses mirroring the RoboMaster project course. The outcome is a more individualized high-impact programme allowing students to build their engineering studies around technologies of our time.

Keywords: Project-based learning, multidisciplinary robotics competition, team-based design

1 INTRODUCTION
Project-based learning (PBL) has been proven effective in many contexts [2] and encouraging student teams to join competitions are also common in higher education [4]. In recent years, these two activities have combined in pedagogical innovation to provide even more well-rounded and comprehensive learning opportunities for students in engineering design.

Launched by DJI a few years ago, RoboMaster is one of the largest and most popular robotics competitions in the world. In the past game year, RoboMaster attracted around 7,000 students from 173 university teams around the globe to participate, while millions of live and online audiences watched and cheered on. It attracts millions of students and technology hobbyists by its overwhelming competition theme, exciting visual impact and intense competition. DJI hosts the competition in hope for creating a positive landscape for robotics industries drawing attention through its intense battles, strict scientific standards, and innovative event schedules. There is also a genuine desire to promote and co-develop project-based learning components to universities in the region.

Project-based learning has shown real success within the HKUST campus in uncovering students' makers potential and extending their learning beyond the traditional classroom. Survey of global emerging trends in education innovation strongly indicates the move towards multidisciplinary, student driven and highly individualized programme design [1]. HKUST RoboMaster team also helps drives on-campus advanced prototyping facilities and an open technology laboratory. Through experiments and tests in robotics competitions, scientific theory and practice are more closely integrated.

In this paper we review the development, growth and success of the 4 years of the HKUST RoboMaster ENTERPRIZE team and evaluate assessable learning outcomes of the competition as a project course. We believe that this model could be a suitable blue-print for the engineering design education community in creating more formal scaffolded education programme towards student competitions and providing students with recognition and assessable learning outcomes that can help in their academic and career development.

2 THE COMPETITION

The match itself is arguably the most advanced and complex robotic competition for undergraduate students in the world. Each team is to engineer 6 type of robots and each type of robot has different roles and functions within the whole game. Taking RoboMaster 2017 as an example, there are two kinds of shooting pellets: 17mm small plastic pellet and 42mm golf balls that would result in different scoring against opposite team. Base robot is a fully autonomous robot with self-defence mechanism using computer vision to identify incoming attackers. Infantry robots that can load and fire 17mm pellets are remote-controlled robots with maximum agility and manoeuvrability. Hero robot is a remote-controlled robot that can load and shoot 42mm golf balls for offenses or disablement of enemy base. Engineer is a remote-controlled robot providing supporting function such as transporting energy-depleted robot to re-charging station and refilling ammunition for the Hero robot. The Supply Depot automatically loads 17mm pellets to Infantry. Finally, the team must programme a remote-controlled drone to unlock game's power play.
The game is an 8 vs 8 strategic robot combat game. Each game has two teams (Red Team and Blue Team) fighting against each other through shooting pellets to deplete opposing team's overall energy. The game field of 18m x 10m takes centre stage at the Shenzhen Bay Sports Centre every year. The 2017 game field shown below hints at the strategies involved in playing the game.

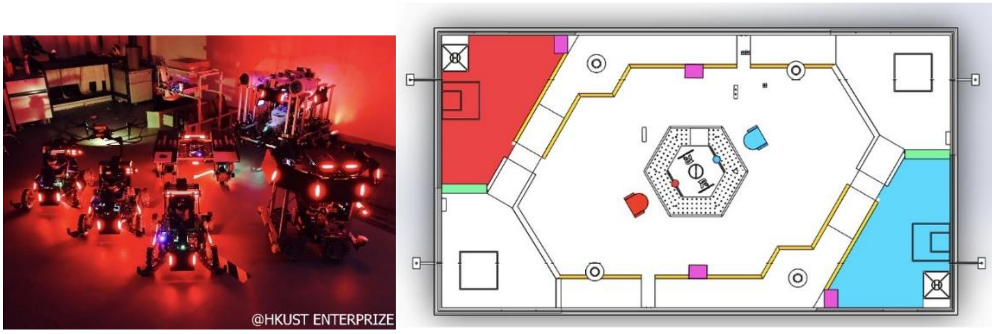


Figure 1. HKUST Enterprise 2017 Fleet and Game field

First gamer's viewpoint for the 6 remote-controlled robot makes the game exciting to watch and to participate in. Certain systems that need to be implemented by students in all robots from all teams include Ultra-wideband (UWB) used to accurately locate the robots, rectangular pressure-sensing plates measuring pellet hits and working as part of the game judging system, and live video streaming stacks to provide robot's view to the control station and audience viewing.
New elements are introduced in the game each year either as an additional robot requirement or in the game rules. In 2017, there was a focus on robot automation and image processing. Infantry was to be equipped with computer vision to identify and shoot at target symbol randomly appearing in a 3x3 matrix to unlock a period of power play. Drone was introduced as a required robot in 2018 which focuses on stable take-off and landing. The drone was further required to drop golf balls at enemy's base accurately in 2019. An autonomous base defending robot, Sentry, that is mounted and slides on a rail was also introduced in 2019.
While new elements are introduced, the base chassis and platform are common to many of these robots, therefore teams with prior years' experience and development have the advantage of building upon mechatronics design and codes to tackle the new games' challenges. Documentation and knowledge transfer therefore becomes an important part of each university team. Since 2016, HKUST ENTERPRIZE team has established on GitHub detailed version control codes, hardware and mechanical designs, and accumulated training materials, manufacturing and supply chain records to be shared with succeeding teams.

2.1 Engineering Complexity

The competition prides itself with the demanding engineering requirements in order to satisfy basic system tests to enter the competition. Each robot, stand-alone, is a fully functional product that would challenge even trained engineers. A sample short list of basic skills and knowledge necessary to build any of the robots include:

- Mechanical locomotive and suspension design
- Pneumatic or electrical actuation and control
- Kinematic analysis for Mecanum wheeled vehicle
- PID controller
- Circuit board design and prototyping
- MCU programming: drivers, communication protocols stack, etc.
- Power storage and distribution

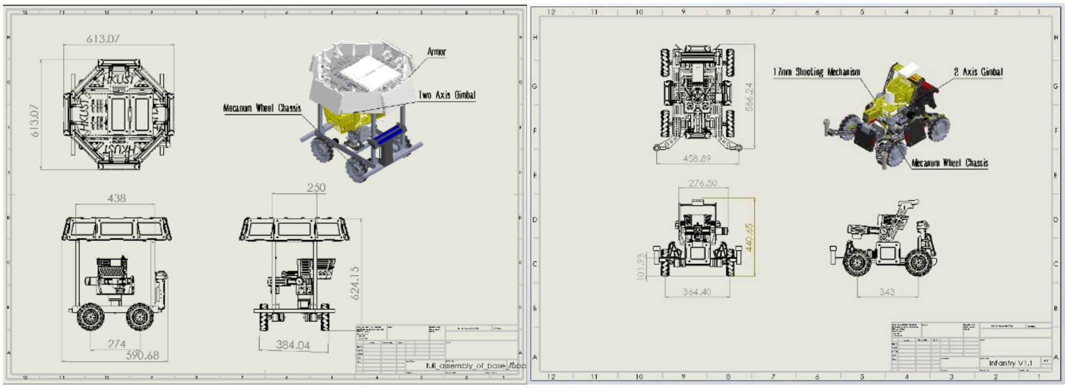


Figure 2. Engineering Drawing of Base and Infantry of HKUST Enterprise 2017 Fleet

2.2 Advanced Project Management Training

For the HKUST ENTERPRIZE team, all level of students is welcome and in the team formation process, commitment and learning ability are given more weights than prior experience. However, there is only about 9 months for the teaming, R&D and build of the set of 8 robots yearly. A highly intensive training and development timeline is therefore needed.

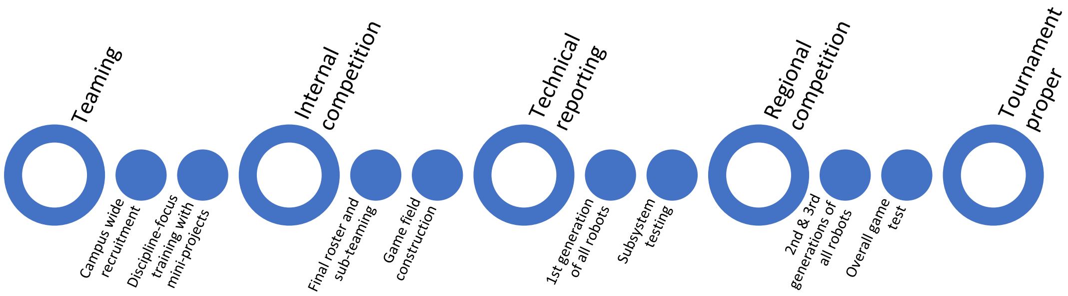


Figure 3. Project timeline from recruitment to tournament (Oct to Jul each academic year)

3 ROBOMASTER AS A PROJECT COURSE

The project is framed as a 4-credit course at HKUST, and it spans over the spring and summer semesters. Students who are officially selected into the team after the internal competition can enrol in the course. In this section, we will describe characteristics of the project course.

3.1 Training by Disciplines and Mini-Projects

At the beginning of the academic year, right after recruitment is completed, a 5-day intensive tutorial followed by 5 weeks of mini-projects and homework help students to learn the basics. The training is mainly divided to two technical streams with the following training covered.

Mechanical Team

1. Basic skills and competence in SOLIDWORKS 3D CAD design
2. Basic knowledge and usage on non-powered mechanical tools and parts
3. Basic skills and competence in manual handwork
4. Basic knowledge and usage on 3D printing
5. Basic understanding of mechanical design and manufacture process and thinking

6. Basic knowledge and usage on pneumatics

Hardware and Embedded System Team
1. C program basic and RTOS Introduction
2. Basic electronics: basic PCB, wiring, connector soldering
3. Basic STM32 Programming: GPIO programming, config GPIO to control peripherals
4. CAN communication
5. Basic PID controller motor tuning
6. Mecanum wheel kinematics

3.2 Internal Competition

A unique feature of the ENTERPRIZE team is the use of an early internal competition for delivering learning components, teaming and screening (in order of importance) at the end of 2-month training. Just as the RoboMaster match itself, the internal competition game rules change every year. In the mock-up competition, teams of 5 are to develop from the chassis of Infantry a remote-control robot tackling mini-challenges that echo certain requirements from the real competition. The idea is to practise agile product development within 2-3 short weeks to 1) identify students who are versatile in the process and 2) test solutions to bite-sized engineering problems from the main competition. E.g., in 2018, hardware students were asked to develop new board to include P/S distribution, XT-30/ XT-60/ GH 1.25mm compatibility, DBUS invert, 24V to 5V regulator, within 2 weeks. As for the internal competition of that year, teams were to build an ‘Engineer’ robot to pick up and load ammunition into an autonomous ‘Turret’ robot that shoots at a display when certain number appears.

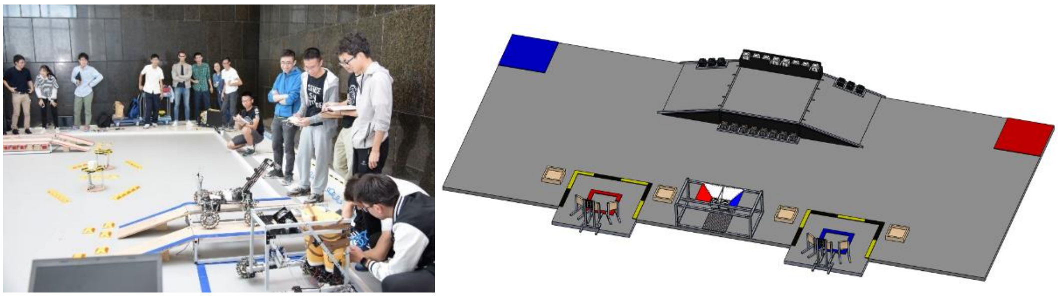


Figure 4. Internal competition in 2017 (left) and Internal game field of 2018 (right)

3.3 Team Organisation Structure

ENTERPRIZE team when founded in 2016 was only run by 8 HKUST robotics fanatics representing HKUST at the RoboMaster competition. The team has grown in the past 4 years to 40 people strong in 2019; which is still considered undermanned compared to top winning teams of 50+. Its performance has also risen through the ranks; established as champions in the international qualifier for 4 years in a row and reached top 12 out of 173 teams in 2019. Literature has shown how a large team size manifests as a technical project management challenge to the students and faculty alike [3]. The team organization is mostly student-driven with guidance from supervising faculty. Operating like a real-world engineering team, each student reports to his/her technical manager for platform design, and ‘robot’ product manager for functional feature design and implementation.
The competition is highly costly with the multiple generation of iterative prototyping needed to bring the robots to game-ready. Each year, 2-3 students also focus on promotion and fundraising, and they have been successful in obtaining sponsorship from ADI, Infineon and Kerry Logistics in the past.

4 LEARNING OUTCOMES AND IMPACT

At the end of the 2019 season, a survey was conducted with past members to assess the impact the project course has made. So far, 50 students responded with 10 studying in graduate schools, 5 working in technology companies and 35 are still undergraduate students.

4.1 Technical Competencies Development

Within the multidisciplinary project course of heavy technical focus, many students have expressed that they learned more effectively and developed deeper understanding of some concepts that are normally taught in class. To obtain quantitative assessment of the phenomenon, students were asked to estimate proportion of courses that could be covered by learning components achieved in the project course.

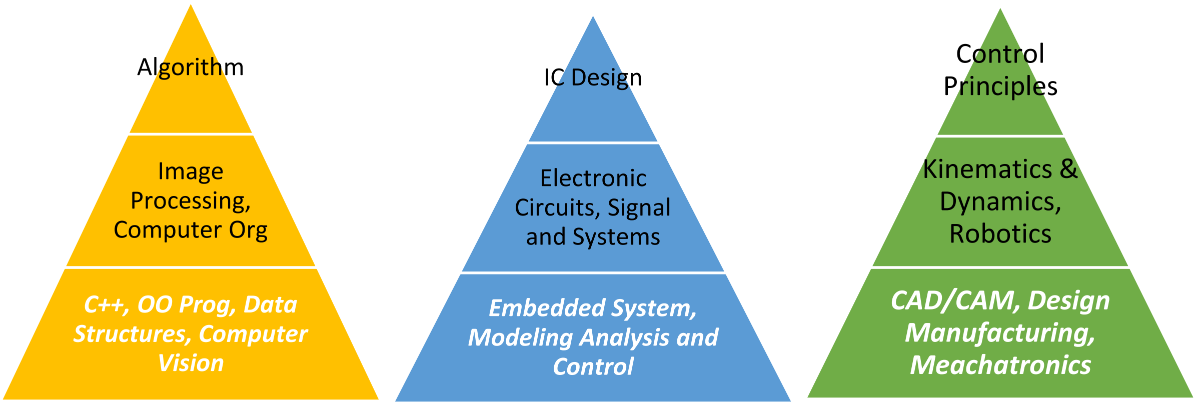


Figure 5. Foundations in Computer Science/ Computer Engineering CS (yellow), Electrical and Electronic Engineering EE (blue) and Mechanical Engineering ME (green) formed by students within their learning experience in RoboMaster

4.5% of all response entries even went as far to claim that 100% of certain course is covered in their ENTERPRIZE project experience. The data summarized above are useful when consideration is made to turn courses into PBL mode and/ or the possibility of offering course credit equivalence if specific project components are fulfilled and demonstrated in ENTERPRIZE.

Equipped with this feedback from the multidisciplinary group and recognizing the needs for new model for engineering education, a new degree programme of Integrative Systems and Design (ISD) [5] was founded in 2017 with special year-long cornerstone projects mimicking the structure of the RoboMaster project course. These projects provide a platform for ISD students with different disciplinary strengths to develop their design and engineering competencies through student-driven project-based learning. These new courses took lessons from the RoboMaster project course in advancing students' knowledge, competencies and abilities in systems design and/ or disciplinary technical focus (CS/ EE/ ME).

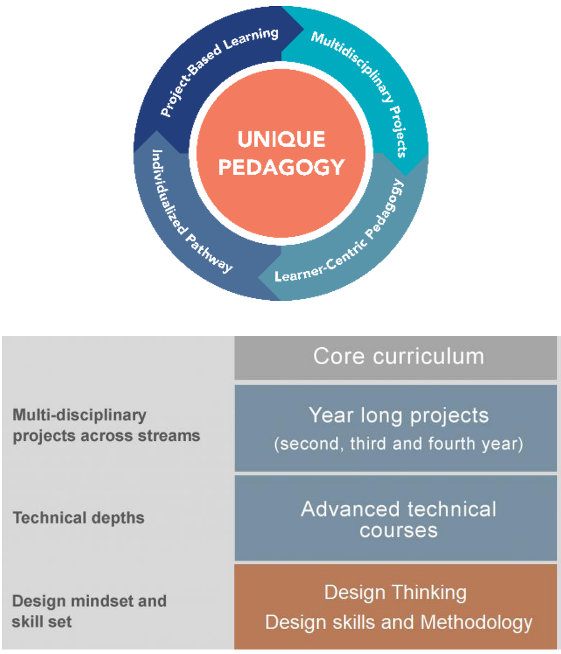


Figure 6. ISD Degree Programme Characteristics

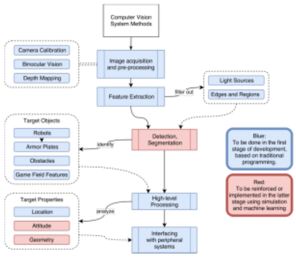
4.2 Research Competencies Development

Aside from hands-on robotics skills, the additional challenges put in the game each year also encourages some students to go through more rigorous academic research process and develop theoretical understanding in order to create competitive solutions. Three examples from investigative studies to white papers are listed below.

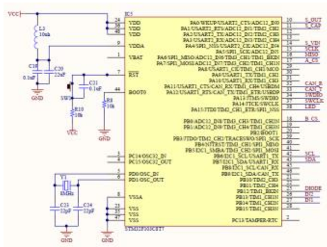
Table 1. Research publications from ENTERPRIZE and illustrative photos/diagrams

2016 When the pellet shooting mechanism was in its infancy stage, a Year 4 mechanical student Jack Zheng designed, performed and documented sets of experiments to select the right type of high-speed silicon parallel rotating wheels and the 'pellet' barrel to optimize the 'shooting mechanism in a 10-page report. Testing was done with various motor speed (20-30m/s), frequency of shot made (5-10/sec) and clearance for pellet passing (57-60mm) evaluated against shooting accuracy, precision and abrasion to the barrel.

2017 As the computer vision requirement increased to support autonomous tracking and aiming of enemies' pressure plates for higher precision shots, the PG teaching assistant Beck Pang presented his work at ICRA (International Conference on Robotics and Automation) that year using computer vision and machine learning to simulate and experiment the control algorithm to position of the Infantry robot and its gimbal for best aiming.



2018 Year 2 student Alex Wong designed a super-capacitor module through inventive power switching between when the chassis is operating vs. when it is at rest. The design contributes to higher instantaneous acceleration for the Infantry robot. His work was submitted as a white paper to the competition organizer's call for innovation entries and won an additional paper award.



5 CONCLUSIONS

For four years, under the theme and motivation of competing in advanced robotics event, RoboMaster, HKUST has developed a multidisciplinary credit-bearing project course and about 100 students have participated and contributed to the growth of the student-driven endeavour. Beyond being a typical extra-curricular activity, the course has shown potential in supporting students' technical advancement and developing students' research capability. The lessons learned in design education pedagogical approach has inspired the creation of a new degree programme focusing on using similar project courses as cornerstones to integrate disciplinary technical learning, an alternative to the traditional model.

REFERENCES

[1] Melchior A., Cohen F., Cutter T., Leavitt T. and Manchester N. More than robots: An evaluation of the first robotics competition participant and institutional impacts, *Heller School for Social Policy and Management*, Brandeis University, 2005.

[2] Kocharoen P. (2012). The Robot Competition: Project-Based Learning in Undergraduate Microcontroller Courses.

[3] Verner I. M., Waks S. and Kolberg E. Educational Robotics: An Insight into Systems Engineering, *European Journal of Engineering Education*, 24:2, 201-212, DOI: 10.1080/03043799908923555, 1999

[4] Krithivasan S., Shandilya S., Lala K. and Arya K. Massive Project Based Learning through a Competition: Impact of and Insights from the e-Yantra Robotics Competition (eYRC -- 2013), 2014 *IEEE Sixth International Conference on Technology for Education*, Clappana, 2014, pp. 156-163.

[5] Division of Integrative Systems and Design, HKUST. Available: *https://isd.hkust.edu.hk/* [Access on 2022, 2 May], 2022.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

AI IN THE DESIGN PROCESS: TRAINING THE HUMAN-AI COLLABORATION

Fabio Antonio FIGOLI, Francesca MATTIOLI and Lucia RAMPINO
Politecnico di Milano, Italy

ABSTRACT
Artificial intelligence (AI) systems are attracting more and more attention as possible tools to enhance creativity in the design process. However, alongside potentialities, introducing non-human agents in a design team can bring specific criticalities, which need a high level of awareness on the part of designers to be tackled. An exploratory study on the perception of design students regarding the inclusion of AI tools in the early stages of the design process was conducted. The results are discussed in the paper, with a specific focus on the possible role of training in supporting the development of critical awareness regarding the challenges posed by human-AI collaborations.

Keywords: Artificial intelligence, human-AI collaboration, human-AI criticalities, human-AI perception, human-AI training

1 INTRODUCTION
With society increasingly becoming more and more complex, new challenges arise in the design discipline. Nowadays, designers must address ever-changing wicked problems in their design process [1], taking into consideration the technical, the human, the digital, and the social perspectives [2]. Due to the wide range of specific knowledge designers need to keep up with today's dynamic society and rapid technological advancement, design tools and competencies run the risk of being inadequate to design products that are well aligned with the user's needs [3].
Artificial Intelligence (AI) appears an intriguing solution to address this challenge, able to provide many potentialities during the design process, particularly in the early stages. Indeed, AI's impact on the process outputs exponentially increases if applied in the early phases, considering that the most polarizing design decisions are made here [4]. However, some criticalities regarding human-AI collaboration might emerge when introducing non-human agents in the design process and design teams.
Regarding human-AI collaboration, many studies have already highlighted "technical" and "sensitive" criticalities. *Technical criticalities* are related to AI and humans' practical competencies and management [5], [6]. Instead, *sensitive criticalities* are related to the team members, with their own experiences, sensibilities, and inclinations. Being more nuanced, we can identify three kinds of sensitive criticalities: predisposition [7], perception [6], and communication [8] criticalities.
Essential knowledge regarding the impact of AI systems in the design processes is still missing [9]; hence designers approaching these technologies need to develop a high level of critical awareness to use them efficiently and safely. In this regard, since designers can learn and improve their ability to collaborate with AI agents over time [10], proper training on the implementation and usage of AI systems would expand their knowledge and encourage them to optimize the use of these technologies, bringing competitive advantages on team effectiveness [11].
On the contrary, if educational programmes poorly acknowledge the importance of disruptive technologies such as AI, they will form uncertain professionals [12] unable to comprehend the current socio-technical paradigm fully. Therefore, higher education should prepare students by equipping them with the right tools and competencies to approach these new technologies properly with a proactive and welcoming attitude [13] while being aware of the associated limits and risks.
Based on this state-of-the-art, an explorative study was undertaken to understand design students' perceptions regarding the inclusion of AI tools in the early stages of the design process. Also, the study aimed at understanding the possible role of training in supporting the development of awareness regarding the criticalities of human-AI collaborations. The present paper discusses a specific part of a

more extensive research activity, which is described in: (*Artificial intelligence in the design process: The Impact on Creativity and Team Collaboration* [14].

2 METHOD

A qualitative study has been conducted in the Design & Engineering Master's at Politecnico di Milano by designing and delivering a workshop that involved 16 students as participants [14]. The workshop aimed to create the condition for students to engage with a short hands-on design experience cooperating with specific AI tools. It formed the opportunity for the researchers to collect data about students' perception of AI tools before and after the design activity.

In a simplified manner, the workshop simulated a design process up to the definition of one or more concepts through three phases: the research, the sketching, and the colour selection phase.

The participants were divided into eight groups composed of two students. During each distinct phase, the team members collaborated with different non-human agents (i.e., Google search for the research phase, sketch-run for the sketching phase, and Coolors for the colour selection phase). The eight groups were split into two types, simultaneous and delayed. Simultaneous groups worked throughout the whole duration of the workshop alongside the AI systems. Instead, per each phase, delayed groups had an initial period without the help of the AI system, followed by a subsequent period with it.

All students were asked to answer three questions with a rating scale of 1 to 10 by filling out a survey at the beginning of the workshop to observe pre-existing perceptions towards the human-AI design collaborations.

After the activity, throughout a final survey, the same three questions were posed to students to observe possible changes in their vision. In the third question, participants had to state their position (i.e., in favour or against) the inclusion of AI tools in the early design process; the question was followed by an open question to explain the reasons concerning the workshop experience. The dataset was qualitatively analysed to make students' perceptions emerge.

3 RESULTS

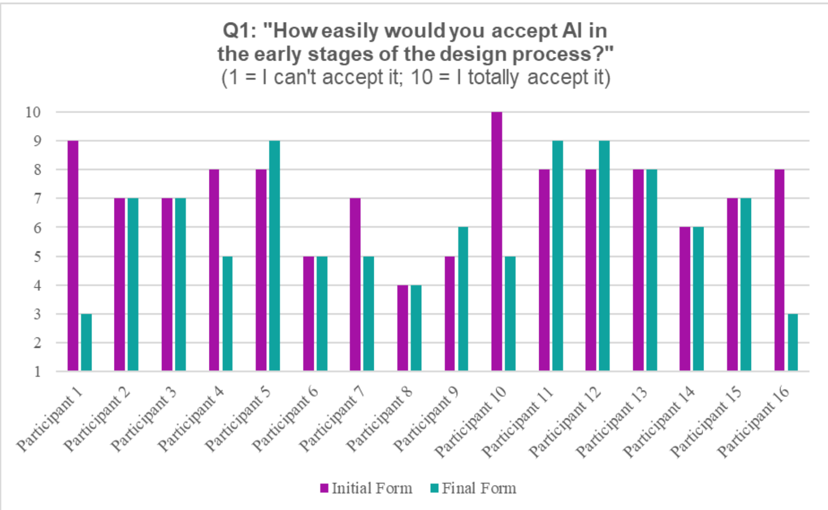


Figure 1. Participants' answers to the first question

The first question was intended to understand the students' level of acceptance towards the use of AI systems in the early stages of the design process (Figure 1). The answers to the initial survey highlighted an overall welcoming attitude, with most of the participants positioning themself on the higher half of the scale. This result is consistent with the answers to the students' final survey at the end of the design activity. However, a correlation between the direction of the changes and their intensity emerges from comparing initial and final answers. Indeed, considering only the participants who changed their position before and after the workshop, we can identify the ones who took a more favourable position (participants 5, 9, 11, 12) and those who took a less favourable position (participants 1, 4, 7, 10, 16). Positive shifts are moderated, while unfavourable changes are far more substantial, with the extreme cases of participants 1, 10, and 16 showing an initial perception of openness towards AI, which became negative after the workshop. Therefore, using AI tools within the workshop experience caused these participants' sudden and intensive re-evaluations, which can become a challenge in human-AI relationships.

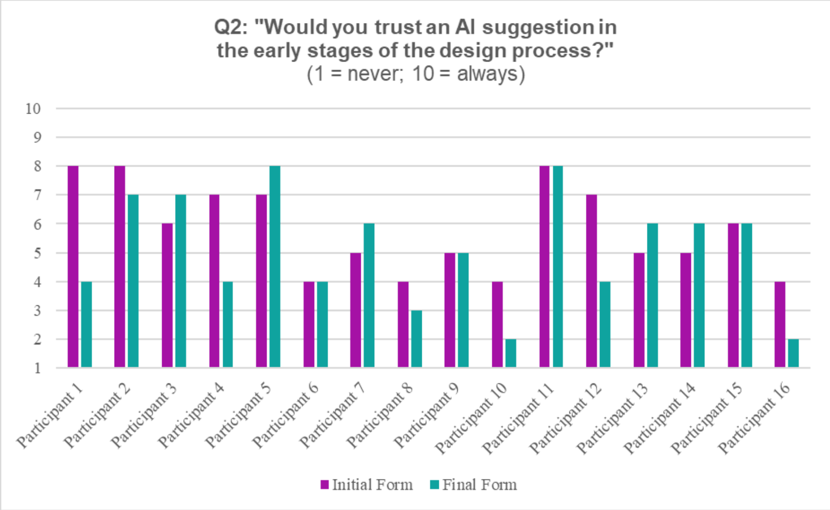


Figure 2. Participants' answers to the second question

The second question focused on the level of trust participants would grant to AI systems. Compared to Figure 1, the answers in Figure 2 lay lower on the scale, showing that participants struggle to trust AI suggestions in the early stages of the design process. In this case, almost all participants have shifted from their initial perception, demonstrating how trust can easily change in a human-AI relationship. The intensity of such changes is less marked and more varied than in the previous case. However, 6 participants' shifts were directed toward a less favourable position, highlighting that students were more susceptible to experiences that worsen their perception than those that improve it. Participants 1, 4, 12 can be seen as extreme cases.

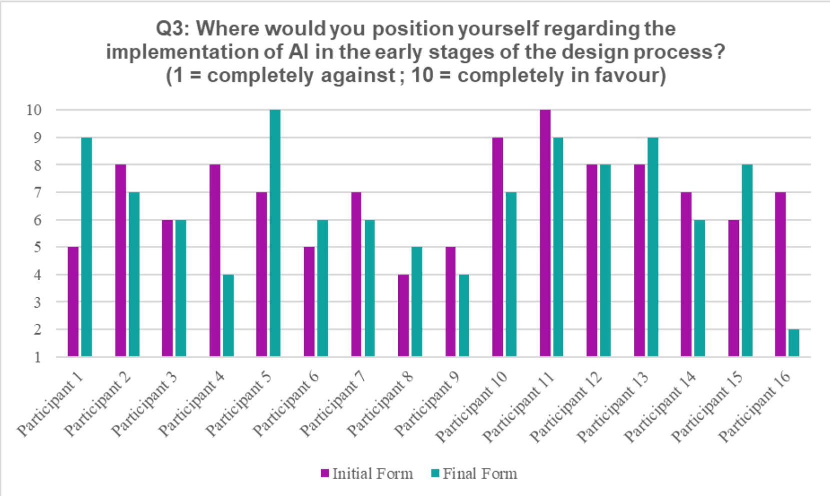


Figure 3. Participants' answers to the third question

The third question was meant to make the participants' position towards AI emerge. The answers are more varied than the first and second questions (see Figure 3), not showing any average or tendency. Even if all students experienced the same design activities during the workshop, we could observe that, between the initial and the final survey, there are both shifts from an unfavourable position towards a more favourable one (participants 1, 5, 6, 8, 13, 15) and shifts in the opposite direction (2, 4, 7, 9, 10, 11, 14,16). Moreover, some of these changes are substantial (participants 1, 4, 5, 16), while others are only minor. Even if students received the same inputs, they reacted personally, leading to distinct opinions and perceptions regarding using AI tools in the early stages of the design process. Moreover, participants' answers to this question provides evidence to assume that the workshop influenced the students' perception and sensitivity toward the issue. This means that working with AI systems even for a short duration impacted participants' perception and awareness. The open answers where participants motivated the evaluation to the third question provide insights on this phenomenon. Some participants highlighted the role of the designer in a relationship with AI systems (Table 1), others targeted possible improvements aimed at optimizing the human-AI collaboration (Table 2), and others made a position statement (Table 3).

Table 1. Open answers with a focus on the designer role within the human-AI relationship

	Regarding the third question, in a short sentence, can you tell me why?
Participant 1	I think that having a couple of eyes more (even if not human ones) is always a good idea, and a can be very helpful. even because at the end you are the one who is having the final word on the choices.
Participant 2	I am still interested in being inspired by the AI's results, but in the end, I recognise that I need to make the judgment myself and understand if an AI-generated idea is good or not.
Participant 10	AI Tools can't replace a proper concept-driven design process - but I think it can really enrich it. If the designer knows how and when to use it, it can show us possibilities that we have not thought of before. But we should treat the results carefully and use them more as an inspiration.

Table 2. Open answers with a focus on human-AI relationship improvements

Participant 7	In general, AI is pretty useful. but it has to know your design process. For instance, if you are in a divergent phase of reasoning, it should provide "out-of-the-box" suggestions. Meanwhile, if you are in a convergent moment, it should help narrow down your choices.
Participant 13	Because the design is a creative process, and the AI should be used more as a tool that helps the designer to understand what he struggles to find and express rather than the main part of the creative process.

Table 3. Open answers related to the third question with a position statement

Participant 4	It is useful, but I like to start from scratch and not let my imagination and creativity be affected by any hint that AI can give.
Participant 6	AI can be really helpful in finding new random and complex shapes but is really hard to use when you have a clear idea about what you want.
Participant 11	While some AI can be helpful in the process, it really comes down to the quality of the tool, and the extension of its use. If we try to make a design following the directions of AI tools, the possibilities of innovating are short.

4 DISCUSSION

From these results, some considerations can be made. In the answers to the first question, participants displayed an overall welcoming attitude towards introducing AI systems into the early stages of the design process. However, this positive curiosity was also tempered by uncertainty, especially from the second question answers, where students expressed their doubts regarding AI trustability. Moreover, most participants changed their views after completing the workshop, highlighting a high level of influenceability. The direction of such judgmental shifts was varied, with participants adopting a more favourable stance and participants adopting a less favourable one. Even if the same design experience was proposed to all the students, they perceived it personally, leading to different conclusions. That being said, a correlation exists between the direction and the intensity of the shifts. Indeed, participants who changed their view towards a more favourable one displayed moderated shifts. In contrast, participants who changed their opinion towards a less favourable one expressed intensive shifts with higher frequency. This shows that participants were cautious about adopting a more accepting and open perception towards AI while being more susceptible if they adopted a sceptical view.

The unpredictability of shifts in students' perception and the tendency to be susceptible to worsened experiences can become critical in training designers to use AI. The lack of deep-rooted and aware opinions about the issue put the participants in a delicate phase of evolving thinking and experimentation, far from holding a clear argument and, thus, extremely malleable. Therefore, the first collaboration experiences with AI systems are vital in defining students' views towards AI in design.

Indeed, the possibility of adopting sceptical views at early stages may hinder an efficient collaboration, where the human agents grant an inappropriate or insufficient level of trust towards the non-human agent.

Trust is a crucial element within any team, particularly in groups involving non-human agents that are less familiar and more difficult to assess for humans, increasing the risk of trusting non-humans too much or too little. Over-trust can condition human agents into complacency and misuse of AI tools, leading to costly mistakes. On the other hand, under-trust can cause unbalanced workloads, leading to the disuse of a machine or the avoidance of a person [15]. A fair design process should limit the phenomenon of over-trust and under-trust as much as possible.

During the workshop, participants were stimulated to build their vision and improve their awareness of AI, as shown in Table 1. Here, some students have already developed a certain level of consciousness about the human-AI relationship, figuring out a possible role for the designer to judge AI-generated outputs, thus maintaining the full responsibility of the design process. This aspect is vital because it shows the capability to increase the students' awareness through design experiences, highlighting training as an effective solution to addressing human-AI challenges. Indeed, we want to stress the importance of providing a proper and gradual introduction for design students to disruptive technologies, including AI, allowing them to gradually understand the technology in a safe environment and through a period of familiarization.

Preparing novice designers for AI technologies means providing tools and knowledge to safely use them, still responsibly maintaining the design process under control. Assuming that AI systems and related human-AI collaboration are not infallible, it is up to the designer to evaluate the machine's work and choose whether to consider its output or discard it if it does not meet expectations. In this scenario, a new role for designers emerges. Indeed, if operational tasks are increasingly assigned to AI, designers could shift towards judging and supervising positions. Design arbiter is our way to define a figure who combines the skills and sensitivity of the designer with excellent critical analysis expertise, helpful in evaluating the outputs provided by AI systems and appropriately implementing them in the design process. Therefore, the designer arbiter will be less concerned about the operational responsibility and individual manual activities took on by AI, assuming a position more focused on managing and supervising design tasks. The designer arbiter more intensively applies her expertise at a higher level, such as the project's general direction, the understanding, and framing of the problem, infusing her sensitivity, intuition, and know-how into the design process. The ability to manage collaboration with AI systems or, more precisely, to design for AI [16] will be a crucial competence of the designer arbiter.

5 CONCLUSION

AI systems are capable of helping designers tackle increasingly complex design problems. However, introducing non-human agents into the design team can become a difficult task due to emerging specific criticalities, which we distinguish into "technical" and "sensitive". The workshop results made it possible to gain insights into students' perceptions of the introduction of AI systems in the early stages of the design process. The students' overall welcoming attitude towards the issue was tempered by their difficulty in trusting AI suggestions. Even if all students went through the same experience, they perceived the workshop personally. Indeed, after the design activity, most of them changed their view on AI towards more and less favourable positions. Moreover, a correlation between the direction and the intensity of the shift emerged, highlighting a greater susceptibility of participants to worsening their perception than improving it. Finally, during the workshop, participants improved their awareness of the issue, exposing practice as a valuable method to train students into professionals capable of optimizing human-AI collaboration through applied judgmental skills.

REFERENCES

[1] Churchman C. W. Guest Editorial: Wicked Problems. *Management Science*, 1967, *14*(4), pp. B141–B142.

[2] Rampino L. *Evolving Perspectives in Product Design: From Mass Production to Social Awareness*, 2018 (Franco Angeli, Milano).

[3] Tuarob S. and Tucker C. S. Quantifying product favourability and extracting notable product features using large scale social media data. *Journal of Computing and Information Science in Engineering*, 2015, 15(3), pp. 1–12.

[4] Wang L., Shen W., Xie H., Neelamkavil J. and Pardasani A. Collaborative conceptual design - State of the art and future trends. *CAD Computer Aided Design*, 2002, 34(13), pp. 981–996.

[5] Pandya R., Huang S. H., Hadfield-Menell D. and Dragan A. D. Human-AI Learning Performance in Multi-Armed Bandits. In *AAAI/ACM Conference on AI, Ethics, and Society (AIES '19)*, 2019, pp. 369–375.

[6] Zhang G., Raina A., Cagan J. and McComb C. A cautionary tale about the impact of AI on human design teams. *Design Studies*, 2021, 72(100990).

[7] Lopez C. E., Miller S. R. and Tucker C. S. Exploring Biases Between Human and Machine Generated Designs. *Journal of Mechanical Design, Transactions of the ASME*, 2019, 141(2).

[8] Bansal G., Zhou J., Fok R., Ribeiro M. T. and Weld D. S. Does the Whole Exceed its Parts? The Effect of AI Explanations on Complementary Team Performance. In *Proceedings of the Conference on Human Factors in Computing Systems, 2021 CHI*, Article 81, New York 2021, pp. 1-16 (Association for Computing Machinery).

[9] Cautela C., Mortati M., Dell'Era C. and Gastaldi L. The impact of artificial intelligence on design thinking practice: Insights from the ecosystem of startups. *Strategic Design Research Journal*, 2019, 12(1), pp. 114–134.

[10] McNeese N. J., Demir M., Cooke N. J. and She M. Team Situation Awareness and Conflict: A Study of Human-Machine Teaming. *Journal of Cognitive Engineering and Decision Making*, 2021.

[11] Rajpurohit N., Saxena M., Yadav R. and Chande P. K. Investigating Impact of Artificial Intelligence in Deployment of Effective Project Teams. *International Journal of Advanced Science and Technology*, 2020, 29(8), pp. 382–391.

[12] Mortati M. and Bertola P. Saperi indisciplinati nell'era digitale. In *Diid disegno industriale Vol. 70-71-72: Design 2030: saperi Formazione pratiche*, 2021, pp. 135–141.

[13] Torre D. la, Colapinto C., Durosini I. and Triberti S. Team Formation for Human-Artificial Intelligence Collaboration in the Workplace: A Goal Programming Model to Foster Organizational Change. *IEEE Transactions on Engineering Management*, 2021, pp. 1–11.

[14] Figoli F. A., Mattioli F. and Rampino L. *Artificial intelligence in the design process: The Impact on Creativity and Team Collaboration*. 2022 (Franco Angeli, Milano).

[15] de Visser E. J., Pak R., Shaw T. H., Peeters M. M. M., Neerincx M. A., Jung M. F. and Kohn S. Towards a Theory of Longitudinal Trust Calibration in Human-Robot Teams. *International Journal of Social Robotics*, 2020, 12(2), pp. 459-478.

[16] Verganti R., Vendraminelli L. and Iansiti M. Innovation and Design in the Age of Artificial Intelligence. *Journal of Product Innovation Management*, 2020, 37(3), pp. 212–227.

TOOLKIT THAT SUPPORTS THE DEVELOPMENT OF A SUSTAINABLE PRODUCT-SERVICE SYSTEM

Eline ALBERT and Ivo DEWIT
Faculty of Design Sciences, University of Antwerp, Belgium

ABSTRACT
This study results from a master thesis for the Department of Product Development of The University of Antwerp. The thesis focuses on a toolkit that provides support in the design process of a PSS, namely the product-service system design toolkit [1]. In this toolkit, there is hardly any focus on sustainability, but rather on the interaction with the end-user. To integrate this sustainability aspect - considering people, planet and profit - the Sustainable Innovation System (SIS) toolkit of OVAM [2] is used as input. The opportunity of this master thesis is to work out a possible synergy of both toolkits. This type of toolkit is hardly explored in the current market. This paper will first find out how both toolkits are used and what pitfalls there are. Various research methods have been used to map out the findings: a literature exploration, analysis of existing evaluations, in-depth interviews, a focus group, online questionnaires, a workshop, and project guidance. The triangulation ensures that the results are as close to reality as possible. This information is summarized and translated into drivers for the solution to be designed. After this, a proposal for the solution is being presented, which is a digital library of design tools. This study thus contributes to a concise human and economic analysis of design tools in general, and a proposal – specifically for the PSS design toolkit and the SIS toolkit – of automated project guidance for design students and practitioners. The online tool platform emerges as the best solution for the abovementioned problems and considers five design drivers that guide the design process, namely: design track support, autonomous use, reduced complexity, universal use, and easy integration.

Keywords: Tool, toolkit, design methodology, product service system and sustainable design

1 INTRODUCTION
This master thesis starts from an externally provided theme related to two design toolkits. On the one hand, the PSS design toolkit [1] supports users in the design process of a PSS using 31 different tools. A Product Service System (PSS) is an example of a sustainable solution on a systemic level. It is a system of products and services that together can fulfil the needs of a consumer through innovative cooperation between stakeholders. A PSS can bring about a shift from owning to consuming, which responds to the scarcity of our resources. Unfortunately, this toolkit has little regard for sustainability but instead focuses on the interaction with the end-user. This approach is being criticized today: if sustainability can be involved as early as possible in the design process, the impact is maximised [3]. To develop sustainably, designers need tools and methods that can guide them through the design process. This is where the second toolkit comes in: the Sustainable Innovation System (SIS) toolkit of OVAM [2]. The purpose of this toolkit is to implement innovations sustainably. The toolkit is provided by certified facilitators and consists of 30 individual tools divided into different capitals of sustainability. The main principles of this master thesis are: how can both toolkits reinforce each other and how to reduce the barriers for using the toolkits? Besides the fact that the solution must support the development of a PSS, sustainability must also be integrated as broadly as possible.

2 CONTEXTS
Today, sustainability is hardly ever included in design toolkits, as the analysis by José, Rui and Fernando [4] shows. Talal Rafi, a business council at Forbes magazine, indicates that companies struggle to concretise a sustainable approach [5]. Although 90% of executives recognise the importance of sustainability, only 60% of companies have a sustainability strategy. This also confirms the need for concrete applicable tools.

2.1 Competing toolkits

To start with, the current context of the toolkit market is being analysed. An overview is made of toolkits that support designers to realise developments in a sustainable manner. To make the inventory of existing toolkits, the following search terms were used: 'PSS development toolkit', 'design a sustainable PSS', 'sustainable design tools', 'instrument for sustainable design' and 'instrument for sustainable PSS'. The toolkits are then placed on a product & system axis. The result of this mapping is shown in figure 1. This overview is not complete but gives an indication of the sustainable toolkits available on the market.

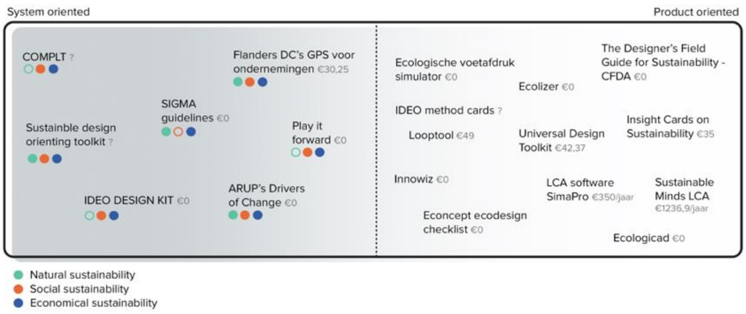


Figure 1. Competitive toolkits on a product/system axis

First of all, there are more toolkits available for designing products than for systems. When taking a closer look at the toolkits with a predominant system focus, it becomes apparent that most of them have a different ambition than the solution being developed. They do not help in the exploration or development of new Product-Service Systems. Furthermore, for the available toolkits with a predominant system focus, it is shown which aspects of sustainability are integrated. This shows that the broad spectrum of sustainability (people, profit and planet) is only included in a limited number of these toolkits. Finally, the price (if available) of the various toolkits is also placed in the overview. From a market perspective, this analysis shows that there is room for an immediately applicable tool that provides support in the design process of new sustainable product-service systems.

2.2 Business models of toolkits

The various business models used for toolkits are also examined. These can be divided into paying and free models for the users. The most traditional way in which a tool can be provided is through the sale of a physical product. This can take various forms, including a poster, cards, a book or a game. This usually involves a fixed price. Tools and instruments can also be incorporated in a software programme; the revenue model then often works based on one-off or annual licences. It is also possible that a tool is offered as a workshop with the necessary guidance. In this case, the tool itself is enhanced by the expertise and a high fee is often charged for that expertise. A tool can be downloaded online and thus be considered 'open source'. This often involves templates, maps or a manual that can be printed out yourself if desired. Another way of offering a tool for free is via a web page that the user can interact with. This way, there are online maps, completion templates, etc. Often different business models are combined into a hybrid toolkit.

3 RESEARCH METHODS

According to Conole and Oliver [6], a toolkit is judged by its usability. This results in the user being responsible for the assessment of a toolkit. Both toolkits are therefore submitted to a human analysis. This implies looking at how the users deal with the toolkits and what user problems are observed.

For the human analysis of the SIS toolkit, four different research methods were used. First, an analysis of the internal documentation provided by OVAM concerning the design process and the evaluations already carried out by OVAM and partners in 2013-2014. This includes an online survey on the SIS toolkit, completed by 19 out of 32 certified supervisors with questions mainly related to the support and dissemination of the toolkit. Furthermore, recommendations from Studio Spark, the study agency that piloted the SIS toolkit were also available. Finally, a general customer survey on the eco-design practices within OVAM was carried out by a former policy innovation team. As part of this survey, OVAM partners were questioned about various eco-design tools. Secondly, in-depth interviews were conducted with Philippe Vandenbroeck and Wim Van Den Hende, the two designers of the SIS toolkit, as well as with Filiep Dewitte and Thomas Vandenhaute, two facilitators certified for using the toolkit. Thirdly, a workshop concerning the SIS toolkit was organised for the 1st master students of product development as part of the Integral Product Design course. Information was collected during this workshop through observations and conversations with the students. Finally, an online survey was sent out to the users of the SIS toolkit. For this purpose, a mail was sent to 86 users. These are the people who have ordered the toolkit since January 2021. Since enough rich information had already been collected beforehand, this method is only used for verification. The results of the open-ended survey reflect the problems experienced by 7 of these users.

The PSS design toolkit has been analysed at the human level using the following three research methods. First, in-depth interviews were conducted with users of the toolkit in the field. These were Maksim Sayevitch, a product development alumnus who has been active in the industry for five years, and Bart Melort, an architect and lecturer in architecture at Ghent University. Next, a focus group was organised with four students who are in their 2nd master's year of product development and have chosen Strategic Design as major course. Each of them went through the PSS design toolkit - in a different project - during the Integral Product Design course. During the focus discussion, a template or short explanation of each tool was laid out on the table. First, the participants individually filled in the predefined evaluation form, giving each tool a score out of 10 and indicating which of the factors of the creativity support index [7] apply to it. These 6 factors are collaboration, fun, exploration, expressiveness, immersion and worthwhile results. After this, the group discusses the tools. The evaluation form is mainly used to form a personal opinion and to start the conversation afterwards. The scores on the form are indicative and are not processed as such. Finally, some general questions were asked. The final research method consists of the project supervision of the 1st master course Integral Product Design, which also provides insights in the use of the PSS design toolkit. In this course, 24 groups of 4 students systematically go through the PSS design toolkit, to support the design process of a PSS within the theme of student life experience. Students are not explicitly asked about this, but they do ask questions and spontaneously share their opinions about the different tools.

4 FINDINGS

The results are divided into 4 sections: results human analysis SIS toolkit, results human analysis PSS design toolkit, general results human analysis and design results. Obviously, both the SIS toolkit and the PSS design toolkit have their specific pitfalls. However, there are also overlapping issues that users experience with both toolkits, and that apply to toolkits in general. The section 'design results' covers the implications of these findings for the solution aiming at creating a synergy between both toolkits.

4.1 Results human analysis SIS toolkit

The interviewees notice in recent years a greater sense of urgency regarding sustainability among companies (Van Den Hende and Vandenbroeck, 4 November personal communication 2021; Filiep Dewitte, personal communication, 10 November; Thomas Vandenhaute, personal communication, 28 October). They are therefore often looking for concrete guidelines. Unfortunately, they cannot find these in the SIS toolkit. The toolkit is strong in content and theory, but poorly applicable in practice. Furthermore, users did not expect the toolkit to be so strategic and were often looking for something concrete to support them.

The toolkit overwhelms users with a multitude of information, partly due to its clumsy materialisation and huge manual. It requires a lot of preparation time to go through everything before users can get started. It is too complex to take the first steps and is therefore mainly used as a theoretical framework. The three large posters are inconvenient to use, for example, 70% of the surveyed supervisors score the user-friendliness only neutral.

The SIS toolkit requires a high level of general knowledge about sustainability. This statement is supported by the fact that 62.5% of the surveyed supervisors say that guidance is necessary. The toolkit was made available through certified facilitators. Van Den Hende and Vandenbroeck (personal communication, 4 November 2021) are not satisfied with the go-to-market strategy used. They see more potential in an open-source community with a low entry threshold instead of a protective marketing strategy with certified supervisors Another observation is that users' priorities are not equally distributed over the different capitals, e.g., intellectual capital is considered less important. Also, users need a value chain that can map the cooperation between partners and ensure a circular system. Finally, the content of the SIS toolkit needs to be updated, as the information dates to 2011 and many new sustainable strategies and tools exist in the meantime.

4.2 Results human analysis PSS design toolkit

For the tools of the PSS design toolkit, the added value and purpose is not always clearly defined. In some cases, the thought process behind a tool is useful, but the tool is not the right way to support this thought process. Some tools within the toolkit are less suitable than others. The PSS design toolkit can be applied more broadly than just for designing a PSS; Bart Melort made a small adaptation of the toolkit for an architecture assignment. In general, users do not always agree with the order in which the tools are described in the process. Some tools have a lot of overlap and the order in which the tools are presented needs to be changed. Also, the toolkit falls short in idea generation tools and the idea generation phase is often too short for users. They would like to see more tools implemented in the toolkit to be able to present the widest possible range of ideas. This feedback has led to the selection of the tools to be included in the solution.

4.3 General results human analysis

The interviewed experts point out that every design process is unique and needs flexible tools that can be easily implemented in a company's current design methodology. As both SIS and PSS design toolkit are physical toolkits, their flexibility is more limited.
The observations of the use of the tools showed that not every user has the same approach when it comes to toolkits. On the one hand there are users that like to take a lot of initiative; they start working with tools themselves with limited explanation. They interpret tools in their own way and dare to deviate from the prescribed tools. If necessary, they will also look for alternative tools themselves. On the other hand, there are also users who tend to wait; they ask more questions about the application of a tool and need clear guidelines and examples. These users are stricter with the imposed tools and do not like to deviate from the process. Yet both types of users need clear objectives: what is the overall purpose of the tool/toolkit and what kind of output can they expect.
Finally, within both toolkits, there are tools with various levels of abstraction. Some tools have a high level of abstraction, these are theoretically strong and more generic. The tools with a low abstraction level are concrete and directly applicable tools. Within a tool or toolkit, there is always a tension of the level of abstraction. Finding the right balance is essential here. Often examples or concrete business cases are missing, while these could help to lower the level of abstraction for users.

4.4 Design results

From the results of the human analysis, design drivers were determined. These describe the most important characteristics that guide the solutions to be designed in this master thesis. To start, the solution supports the design process of a sustainable product-service system. It is therefore not a loose collection of tools but focuses on guiding the process. Secondly, the solution is self-managing and can therefore be used fully independently by both initiative-taking users and users looking for more guidance. Thirdly, the complexity and level of abstraction are reduced. This means that even someone without expertise in strategic tools or sustainability can use it. Fourthly, the solution is flexible and can be used for any project theme. Finally, the tools must be easy to integrate into a company's current design methodology. Subsequently, the idea generation process resulted in four ideas for possible solutions. These should provide an answer to the question of how both toolkits can reinforce each other and how to reduce the barriers for using the toolkits?

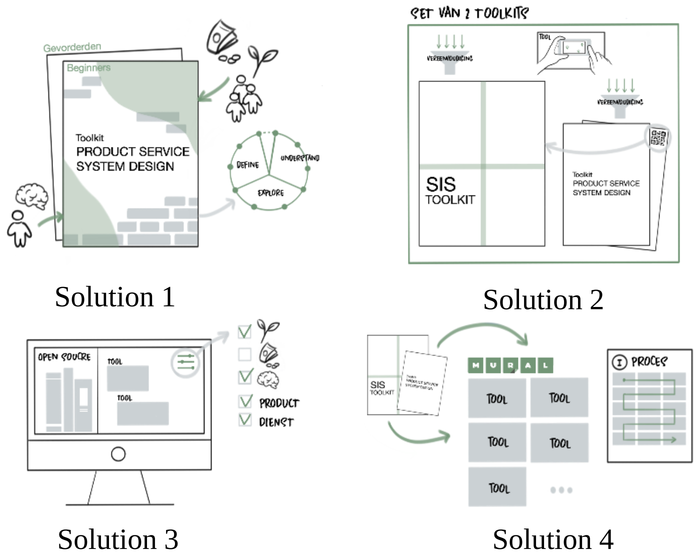


Figure 2. Solutions 1 to 4

These four solutions have each been evaluated based on the design drivers (Figure 2). The driver complexity has been left out of consideration, as it mainly influences the tool's content and less the way the synergy of both toolkits is made possible.

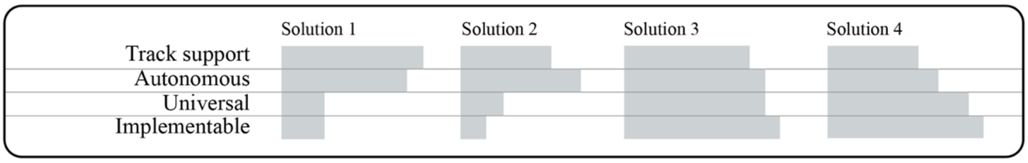


Figure 3. Trade-off of solutions 1 to 4

In this assessment, solution 3 emerges as the best (Figure 3). This proposal supports designers in a sustainable and balanced design process based on an online tool platform.

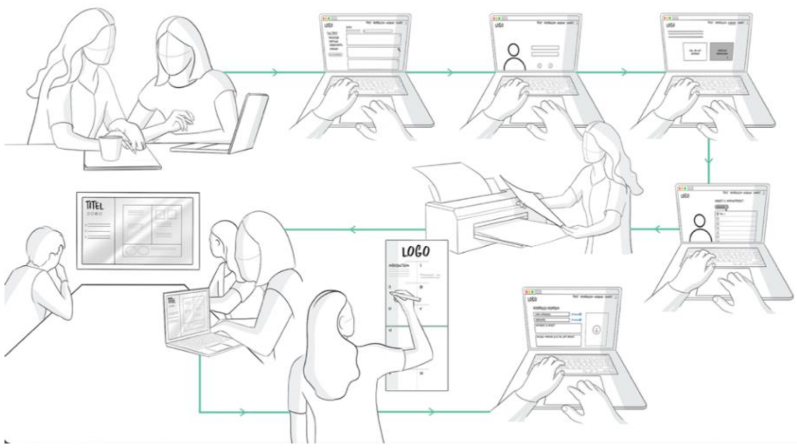


Figure 4. Visualisation of the user scenario

Hereby, users can search for tools by means of two search strategies. They can either select tools themselves by using different filters or they choose to get help from the platform. In the second option, they must answer some questions and the platform proposes one of the standard design trajectories. Users can then save tools or complete projects on a profile. They can also set personal branding to be applied on the tools. Before they get started, the facilitator of the workshop can find more information on the platform: about the purpose of the platform, the different components of the platform and tips on organising workshops. Users do not receive a physical toolkit but can download files for free. These downloads always contain the template of a tool (if present) and an overview of the selected tools. Users can print the overview, which contains information about each tool, and users can also supplement this with their own written conclusions. Finally, users can also upload example projects to inspire other users. There will be a LinkedIn link to the project and the designer or company concerned. In this way, a community is created in which users can ask questions and inspire each other. It's also a positive advertisement for the designer or company involved.

5 DISCUSSIONS

The results of this study would be more reliable if a larger population was surveyed. The PSS design toolkit is still actively used by students and in the field. However, this is not the case for the SIS toolkit. It was released in 2011 and has not quite taken off as expected. The sustainable mindset required for active use of the SIS toolkit was not sufficiently present among companies when it was launched in 2011. In addition, the toolkit was not delivered to companies that were already making efforts with regard to sustainability. Also, working with an external facilitator creates an extra barrier for companies, as it is difficult to deal with confidential information. Moreover, the use of an external facilitator often has an influence on the price and the accessibility of a toolkit. At this moment, the tools are hardly used. This timeframe and the lack of intensive use made it difficult to conduct in-depth interviews.
Interviewees According to Sayevitch's experience (personal communication, 26 October 2021), new tools in the corporate world are not always warmly welcomed by management. "The PSS design process is not that complex, but habits have been built up that are very difficult to break with something completely new. To break habits, one has to give something very handy to decision-makers". Meaning that there is a need for practical, immediately applicable tools that prove their added value in the short term. Moreover, they must be flexible and easy to apply per project. A toolkit should be approached as a circular or iterative process, whereby tools sometimes need to be repeated several times to achieve a good result.

6 CONCLUSIONS

The competitor analysis shows that there is therefore room for an immediately applicable tool that provides support in the design process of new sustainable product-service systems. The human analysis shows different problems for each individual toolkit and for toolkits in general. To work out the solution, these problems are taken into account by listing 5 design drivers that guide the design process, namely: design track support, autonomous use, reduced complexity, universal use and easy integration. After idea generation, the solution of the online tool platform emerges as the best.

REFERENCES

[1] Dewit I. et al. (2018) product service system design toolkit. *University Press Antwerp*.

[2] Van den Hende W. and Vandenbroeck P. (2011) *OVAM SIS toolkit.*

[3] Doualle B. et al. (2016) Design of Sustainable Product-service Systems (PSS): Towards an Incremental Stepwise Assessment Method, *Procedia CIRP*, 48, pp. 152–157. doi:10.1016/J.PROCIR.2016.04.074.

[4] José V., Rui F. and Fernando M. da S. (2016) (PDF) Ecodesign Tools: One basis to operationalize Sustainable Design. Available at *https://www.researchgate.net/publication/289236511_Ecodesign_Tools_ One_basis_to_operationalize_Sustainable_Design* (Accessed: October 14, 2021).

[5] Rafi T. (2021) Why Corporate Strategies Should be Focused on Sustainability, 10 February. Available at: *https://www.forbes.com/sites/forbesbusinesscouncil/2021/02/10/why-corporate-strategies-should-be-focused-on-sustainability/?sh=124a6cda7e9f* (Accessed: October 14, 2021).

[6] Conole G. C. and Oliver M. (2002) Embedding Theory into Learning Technology Practice with Toolkits, Journal of Interactive Media in Education, (1), p. 7. Available at: *https://www.academia.edu/274643/Embedding_Theory_Into_Learning_Technology_Practice_With_ Toolkits* (Accessed: November 21, 2021).

[7] Dewit I. (2019) Product -service system design, a synthesis approach, pp.137-138.

SOCIAL MEDIA: ENABLING INCONSPICUOUS BLENDED LEARNING IN DESIGN EDUCATION IN INDIA

Christy Vivek GOGU and Jyoti KUMAR
Indian Institute of Technology Delhi, India

ABSTRACT
Social media has penetrated all strata of society and educational levels and spheres, making it an important channel of communication and knowledge transfer. Even as the Covid-19 pandemic changed the education scenario across the globe, with the medium of instruction majorly shifting to online, things are slowly returning to 'normalcy'. Albeit the use of social media as a conduit for instruction, feedback and learning, which increased during the lockdowns, continues to grow and evolve. This study aims to trace and understand the relationships between online social networking, social connectedness and learning in design education, in online, offline and blended set-ups. This paper reports findings from quantitative studies, done across various design schools in India. Participants responded anonymously to the online survey using the Google Forms platform. This study assesses the amount of course material shared, discussed, and engaged with on various social media. Respondents also marked the amount of connectedness they perceived with peers through social media and whether it impacted their class interaction with each other. It was found that students used various platforms for online communication and exchange of information, though their feedback on online interactions revealed deeper insights into factors that affect their overall experience of design education and learning. Further analysis of data found significant correlation between felt connectedness and interaction on social media with peers and design creativity and learning.

Keywords: Social media, design education, Indian students, social connectedness, blended learning

1 INTRODUCTION
Scholarship on the relationship between social media and student experiences has gained prominence in recent years. Educational fields from medicine to language studies are investigating the impact of social media usage and internet penetration on student lives and motivations. With the recent global pandemic affecting all strata of education, students from kindergarten to higher education have been exposed to the online mode of education. Social media has been rather widely studied among web-based technologies popular today, especially in developed countries such as Australia, Canada, Germany, the United Kingdom, and the United States [1].
According to a recent article by The Global Statistics, on an average, Indians spend about 2.36 hours on social media per day. The number of social media users in India have been growing steadily at the rate of 467 million due to deep penetration of internet connectivity. Internet users in India have grown to a colossal 658 million, roughly 47% of the total population of India. Social media has now become an essential part of daily internet usage in India [2]. This study explores the impact of social media usage of design students in India on their social connectedness and design learning experience.

1.1 Social media and education
Social media sites and applications provide specific socio-technical systems [3], offering different services and functions. A study done to investigate individual motivation influence in virtual communities revealed a significant relationship between motivation factors and knowledge sharing. Consequently, students are making the most of social media for problem solving, course discussions, and group assignments [4]. This also highlights the functions of social media in ease of access, affordability, and speedy interaction [5]. A recent study also illustrates the 'affordances' coined by Don Norman, in understanding the features of social media and its application in learning experiences [6]. It further reports how students describe social media as their 'space', requiring a navigation of

appropriateness. These nuances of social media interactions need further research to understand their specific implications in different educational and cultural contexts.

1.2 Social media and social connectedness

Social interactions are key in maintaining the physical and psychological well-being of humans. Social connectedness, one of the main motivating principles behind social behaviour, is often considered a predictor of successful living and has been associated with many social and health benefits [7]. Laffey, et al [8] claim education and various learning interactions, whether traditional F2F or virtual, to be social practices. The extent to which students in online learning environments perceive themselves as being socially connected to their peers appears to be a key factor in predicting the success of online courses [9].

2 METHODOLOGIES

This study set out to answer the following research question: *How does (if at all) social media interaction of students impact their online design learning experience?*

To this effect a questionnaire was designed that consisted of (1) social media functions used by students and educators (i.e., kinds, usage frequency, effect on classroom learning), (2) items to measure the impact of social media interaction on felt social connectedness (such as, sense of authenticity, belonging, feeling understood), and (3) socio-demographic questions such as gender, age, design school, courses, etc.

2.1 Study design

An online google form was designed with 30 items to study student-student and educator-student interaction on social media and its perceived effect on social connectedness and online design learning. Online surveys gave the advantage of greater number of participants in a short time, and the flexibility to participate as per participants' convenience of place and time.

A 5-point Likert scale was employed, and students picked from a range of responses, such as 'Always' (5) to 'Never' (1) or 'Strongly agree' (5) to 'strongly disagree' (1). 50 students from more than 8 design schools across India responded to the survey. 92 percent of the students had attended online design classes for at least 6 months.

2.2 Data analysis

The quantitative data obtained using the online surveys was analysed by using the existing tools from the survey platform. This data was also statistically analysed to find significant correlation between the critical variables and group dynamics. The findings and analysis have been presented in the subsequent section, followed by discussion of some implications of the findings, conclusions, limitations and future scope.

3 RESULTS AND FINDINGS

The findings of the study are presented below in figurative and tabulation form.

3.1 Profile of respondents

The figure and table below show the sociodemographic profile of the respondents, with a majority of them in the age group of 21-25yrs and online class experience.

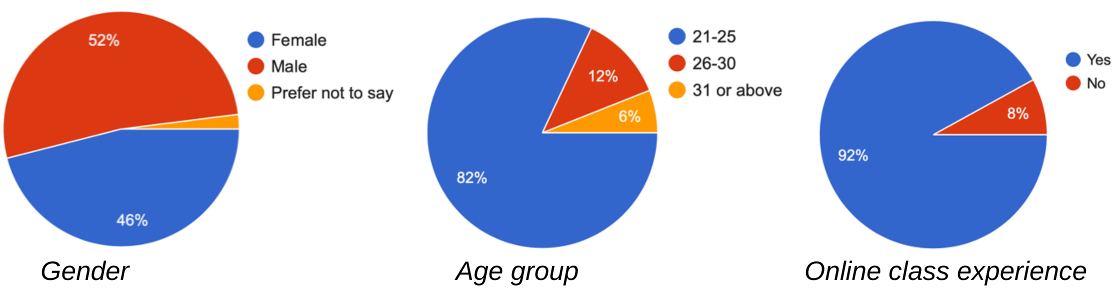


Figure 1. Sociodemographic Profile of Respondents

Table 1. Design schools represented in the study

Design Schools represented	%
DoD, IIT Delhi	32
ISDI, Mumbai	20
School of Design, UPES, Dehradun	16
CPDM, IISc Bangalore	10
Mumbai schools (Pearl, Raffles, anonymous)	10
NIFT, Delhi	4
Indira Gandhi DTU	4
Anonymous	4

3.2 Popular social media apps used by design students and educators

Below are listed some of the social media apps or websites most widely used by design students in India. 78% of the respondents were connected to most of their peers through social media, while 20% were connected to some of their peers.

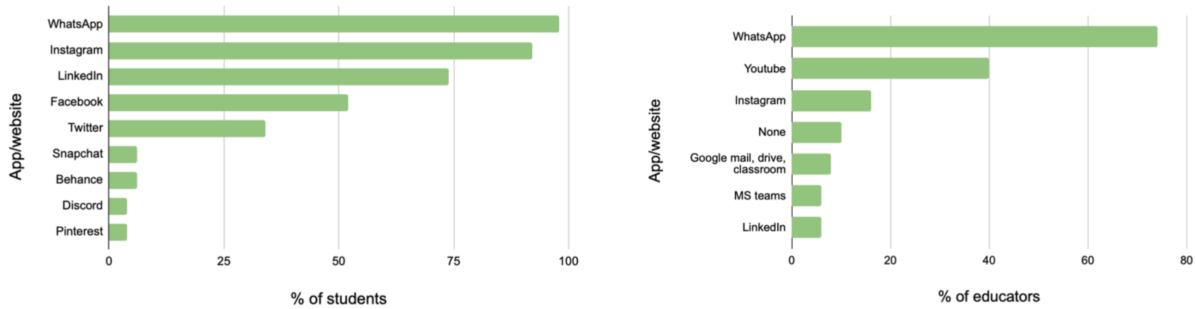
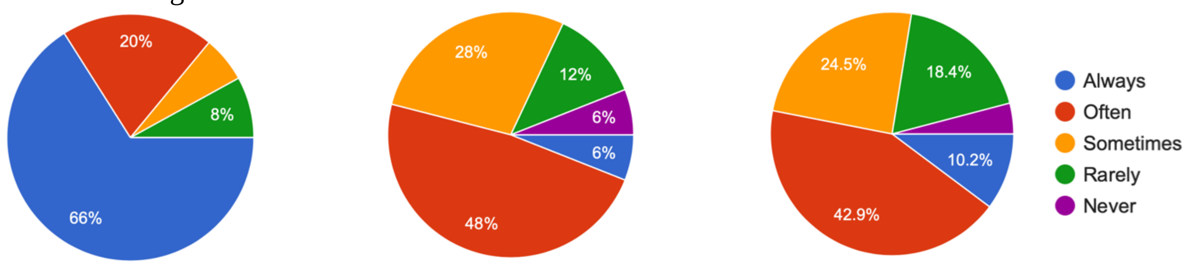


Figure 2. Popular social media apps used by design students and educators

3.3 Student-student and Educator-student interaction on social media

Respondents indicated how often they interacted with their peers and educators on social media as shown in the figure below.



Student-student *Student – student design content* *Educator - student design content*

Figure 3. Frequency of Interaction on social media

3.4 Effect of social media interaction on design learning factors

Respondents indicated from 'strongly agree' to 'strongly disagree' on the perceived effects of their social media interactions with their peers on their design learning experience.

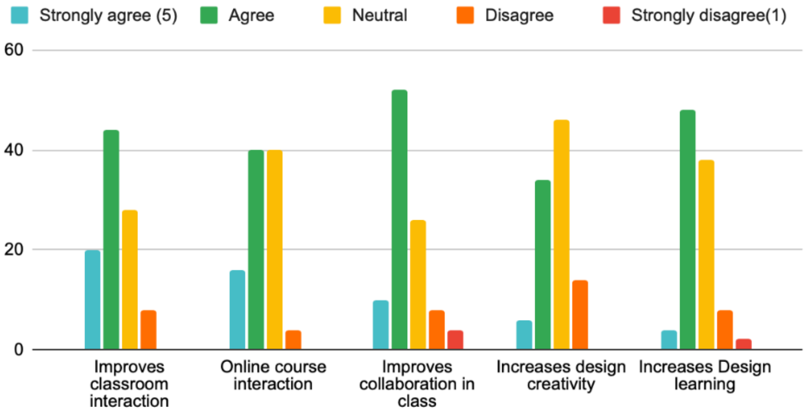


Figure 4. Effect of social media interaction on factors

3.5 Effect of social media interaction on social connectedness

Respondents indicated from 'strongly agree' to 'strongly disagree' on the perceived impact of their social media interactions on aspects of social connectedness.

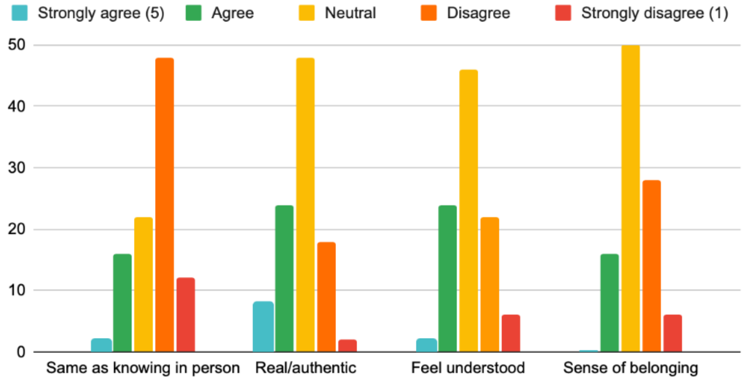


Figure 5. Effect of social media interaction on social connectedness

3.6 Correlation between social media interaction and other factors

Pearson's correlation was applied to see the relationship between social media, the felt connectedness and learning experience. Significant correlation was found between social media interaction of students and other factors.

Table 2. Correlation between social media interaction and other factors

Correlation of social media interaction on (r)	Increased online course interaction	Increased design learning	Being connected online is same as knowing in-person
Increased design knowledge sharing	0.412	-	-
Improved teamwork/collaboration	0.413	0.437	-
Real/authentic	-	-	0.413
Feel understood	-	-	0.434
Sense of belonging	-	-	0.519

4 DISCUSSIONS

The results show that a high percentage of students as well as educators were not only connected on used social media but also used it to share design knowledge. Even after many of these design schools having opened in-person, fully or partially, social media continues to be a convenient medium to share design content through private messages or public posts, making it an indispensable aspect of design education leading to blended learning.

Figure 4 indicates the significant impact of social media interaction among peers on their classroom interaction, design learning, creativity and collaboration, even though Figure 5 provides a dismal view of its effect on perceived social connectedness. Reiterating the findings that students lean more on in-person interaction to feel connected, authentic and understood in their relationship with their peers, as shown in prior research [10]. Interestingly, Table 2 exhibits significant correlations found between the effects of social media interaction (increased online course interaction and increase design learning) on 'increased collaboration' and 'knowledge sharing'. The social media interaction can therefore be seen as an extension of peer learning, feedback and critique to exchange and build on each other's ideas. Significant correlation was also seen between respondents who found social media interactions as real as in-person interactions, and their feeling a sense of belonging and connectedness online.

5 CONCLUSIONS

The benefits of social media interactions can be seen as design instructors and students successfully exchange knowledge, content and ideas to deliver and receive design education in both online and in-person setups resulting in continued blended learning. Thus, social media has become a tool that can support and supplement learning management systems for fostering virtual classroom experiences, wherein students across the globe can join in simultaneously to learn and share their ideas [11].

While felt social connectedness of design school instructors and students and its effect on pedagogy has been reported earlier [12], this study specifically focused on the role of social media interaction in the students' online design learning experience. Keeping this in mind, design instructors and course planners therefore need to continue to keep the channels open for online exchange of knowledge even as most design schools in India re-open to in-person classes. Educators can incorporate social media tools as add-ons to their online learning platforms or LMS, thereby inconspicuously and seamlessly incorporating blended learning to heighten the learning experience for both the students and themselves. Our result is consistent with research that relate that students share knowledge through social media to benefit from that sharing [13], and support prior investigations on influence of social media interaction on learning and knowledge exchange [14].

6 LIMITATIONS AND FUTURE SCOPE

One could say that the study is only partially complete without studying the impact of social media usage of students on their in-person or face-to-face classroom interaction and learning, and we'd have to agree with them. Therefore, the immediate future scope of this study includes studying this impact and then reporting a comparative analysis of social media usage on online and in-person classroom interaction and learning.

Perhaps, another study could involve listing parameters and scoring them to assess how particular features of social media specifically contribute to design learning, design creativity, or feeling understood, etc. considering the various limitations of social media as well as online mode of design education [15]. This research can be further corroborated by gaining inputs from design educators, as a next step.

REFERENCES

[1] Connolly T., Willis J. and Lloyd M. (2019). Evaluating teacher and learner readiness to use Facebook in an Australian vocational setting. *Studies in Continuing Education*, 41(1), 61–75. https://doi.org/10.1080/0158037X.2018.1461619 .

[2] India Social Media Statistics 2022 | Mobile & Internet Statistics. Available: *https://www.theglobalstatistics.com/india-social-media-statistics/* (2022, 11 March).

[3] (van Dijck, 2013)- van Dijck, J. (2013). The Culture of Connectivity: A Critical History of Social Media. The Culture of Connectivity: A Critical History of Social Media. *https://doi.org/10.1093/acprof:oso/9780199970773.001.0001*.

[4] Eid M. I. and Al-Jabri I. M. (2016). Social networking, knowledge sharing, and student learning: The case of university students. Computers & Education, 99, 14–27. *https://doi.org/10.1016/j.compedu.2016.04.007*.

[5] Lim W. M., Lim A. L. and Phang C. S. C. (2019). Toward a conceptual framework for social media adoption by non-urban communities for non-profit activities: Insights from an integration of grand theories of technology acceptance. Australasian Journal of Information Systems, 23. *https://doi.org/10.3127/ajis.v23i0.1835*.

[6] Lambton-Howard D., Kiaer J. and Kharrufa A. (2021).Social Media is Their Space: Student and Teacher Use and Perception of Features of Social Media in Lang Edu.
[7] Smith E. and Mackie D. *Social psychology* (2nd ed.), Psychology Press, NY (2000).
[8] Laffey J., Lin G. Y. and Lin Y. (2006). Assessing social ability in online learning environments. *Journal of Interactive Learning Research*, 17(2), 163 – 177.
[9] Kreijns K., Kirschner P. A., Jochems W. and van Buuren H. (2004). Determining sociability, social space, and social presence in (a)synchronous collaborative groups. *Cyber Psychology & Behaviour*, 7, 155–172. doi:10.1089/109493104323024429.
[10] Gogu C. V. and Kumar J. Social Connectedness and Online Design Learning Exp in the Indian Context. Design and Tech Education: an International Journal,[S.l.], v.26, n.3, p. 325-340, nov. 2021. Available at: <*https://ojs.lboro.ac.uk/DATE/article/view/3080*>.
[11] Tess P. A. (2013). The role of social media in HE classes (real and virtual) – a lit review. Comp. in Human Beh, 29, A60–A68. *https://doi.org/10.1016/j.chb.2012.12.032*.
[12] Gogu C. V. and Kumar J. (2021) Social Connectedness in Online versus Face to Face Design Education: A comparative study in India. In Design for Tomorrow-Volume 2, Smart Innovation, Sys and Tech 222, *https://doi.org/10.1007/978-981-16-0119-4_33.*
[13] Hung S. Y., Lai H. M. and Chang W. W. (2011). Knowledge-sharing motivations affecting R&D employees' acceptance of electronic knowledge repository. Beh & I T, 30(2), 213–230. *https://doi.org/10.1080/0144929X.2010. 545146.*
[14] Hosen M., Ogbeibu S., Giridharan B., Cham T. H., Lim W. M. and Paul J. (2021). Individual motivation and social media influence on student knowledge sharing and learning performance: Evidence from an emerging econ. *Comp & Edu*, 172, 104262.
[15] Pratap S., Dahiya A. and Kumar J. From Studios to Laptops: Challenges in Imparting Design Edu Virtually. In *Intl. Conference on HCI 2021* Jul 24 (pp. 507-516). Springer, Cham.

NEW COLLABORATIVE WORKFLOWS - IMMERSIVE CO-DESIGN FROM SKETCHING TO 3D CAD AND PRODUCTION

Mauricio NOVOA MUNOZ[1], Bryan F HOWELL[2], Jan Willem HOFTIJZER[3], José Manuel RODRÍGUEZ DÍAZ[4], Wendy ZHANG[5] and Nikolaj KRAMER[6]
[1]Western Sydney University, Australia
[2]Brigham Young University, United States of America
[3]Technical University of Delft, The Netherlands
[4]EUIPO Europa, Spain
[5]University of Canterbury, New Zealand
[6]VIA University College, Denmark

ABSTRACT
Digital technologies have enabled design sketching to expand into new applications and domains. Inevitably, these new forms of visualisation require re-evaluating how we use drawing to see, visualise, understand, and fabricate products and services in design education and the profession. This paper presents a selection of discoveries after the authors performed research, made presentations and mediated workshops when face-to-face collaborations and travel were impossible because of the Covid-19 epidemic restrictions. Findings add to work intending to build a modern taxonomy for design sketching and visual knowledge while accounting for immersive virtual collaboration and distributed workflows from sketching to 3D CAD and 3D printing. These are among the first indications of a drive towards synthesising historically demarked design process stages into a singularity of actions that merge and move simultaneously among ideation, design, and production. Participants in two international conference workshops shared ideas and discussed their local circumstances relating to the potential use and acceptance of new technologies already researched and adopted in other disciplines such as computer science and entertainment. A critical consensus was that the challenge of new technologies for our design education and profession is not as much about technology and its tools as the process and steps that enable change. Significantly, conversation pointed towards a strategy that enhances and augments habits in design education and the profession as the means to modify and transform culture and practice.

Keywords: Design sketching, immersive realities, technology diffusion, virtual reality, visualisation

1 INTRODUCTION
The authors are an international team who organically united in 2018 when they established the Design Sketching Special Interest Group (SIG) within the Design Society. There is broad interest in design sketching and research on visualisation as they are essential to design education, practice, and other disciplines. They believe that sketching and visualisation provide new ways to imagine, see, and solve problems. The Covid-19 pandemic, 2021, was an active period for the SIG. Members were invited to present as guest speakers at the plenary session of the 2021 Design Theory Symposium at Mines Tech Paris, France. They presented and chaired a track session at the 2021 International Design Education Research (IDER) Symposium: Explorations of Alternate Futures, Oslo Metropolitan University, Norway. They also chaired and edited a session, presented papers, and conducted workshops on “new collaborative workflows for sketching from immersive co-design to 3D CAD and production” at the 2021 Design Society (DS) 23rd International Conference on Engineering & Product Design Education (E&PDE), VIA University, Herning, Denmark, and the 2021 Design Research Society (DRS), Learn X Design International Conference, Shandong University, Jinan, China.

2 PROBLEM STATEMENT

Globalisation, a significant driver of the Industrial Age, weakened geopolitical and professional boundaries for productivity. Among this disruption, new technologies created gaps between the traditions of design education and advances made within the profession. Successful contemporary production is typically driven by interdisciplinary collaboration. At the same time, visual literacy is highlighted as one of the means for overcoming communication breakdowns and shortcomings presented by local languages (e.g., verbal, textual) and idiosyncratic specialist argot (e.g., professional jargon). Wide-ranging experts are now interested in visual knowledge as a natural next step following the adoption of design thinking methods established at the start of this century. Logically, we ought to investigate how we bridge the gap between tradition and the disruptive innovations that affect our discipline. How do we nurture a transformation in our education and practice after disruption? Design drawing and sketching (both called sketching here) are vital skills for designers and educators to develop their imagination, frame and problem-solve complex challenges, innovate and communicate better globally. This paper explores the impact of virtual reality (VR) sketching in design education.

3 METHODOLOGIES

The Sketching SIG's work utilises a methodological approach that conceives sketching and visualisation as a phenomenon with epistemological, technological, and practical implications. The group is progressively building a literature review that will help create an intellectual framework to facilitate their understanding of current use and future evolution. Some of that work is cited in this paper. The group is also dedicated to exploring the analogue and digital realities of sketching and visualisation and constructing new knowledge through collaboration and experimentation. On the latter, the two workshops held at international conferences in 2021 kept similar formats while considering variables, such as the different design education focus for each event. Characteristically, one event was dedicated to design engineering and product design, while the other event catered to a more expansive design audience.

The workshops were organised for up to twenty-five participants and comprised of two parts. They were conducted over Zoom by presenters from Australia, Netherlands, New Zealand, Spain, and the USA. Each presenter introduced their expertise and interest relating to design and sketching. Then, the background and aims of the workshop were explained. A quick overview followed on new technologies disrupting traditional ways of design, sketching and visualisation. Lastly, the team co-designed an artefact live and took the audience through each stage of the design process, ideation, design, and development which consisted of two-dimensional output (e.g., Photoshop), preparation for 3D CAD, repairing files, and converting them from virtual reality (VR) to 3D printing formats (e.g., OBJ, FBX, STL), representing new forms of production. Attendees viewed the process of multiple designers located in different countries simultaneously creating an artefact. Discussions about the process of building, communicating with each other, and the user interface were asked and answered during the demonstration. Attendees were invited to participate if they had access to a VR headset and controllers. Access to the immersive environment was available for free using Gravity Sketch and Landing Pad.

Participants from Asia, Europe, Asia Pacific, the Middle East, the Americas, and the United Kingdom were invited to discuss the workshop experience. Participants were asked to download the Miro online tool before the discussion session. Miro is an online whiteboard platform that helps groups co-create conceptual models through live ideation, hyperlinking, note-taking, sketching and visualisation. Attendees were asked to record comments, suggestions, and thoughts about their workshop experience. They could ideate visually with an analogue pen and paper (photo upload) or enter ideas through text or sketching or via digital touch screen devices or stylus and tablet.

A framework based on two interrelated and complementary theories for new technology and digitalisation were trialled for each contribution [1, 2]. A list of queries to trigger conversation and facilitate the group discussion was also provided.

- Do you use digital and immersive technologies? If so, what do you use them for?
- If you do not use digital and immersive technologies, do you see a need for them?
- If you are interested in using them, what would you need for their implementation?
- How can we reach educators, practitioners, and students to promote change?
- What activities can promote the redefinition of education and practice?

- What would it take for students and practitioners to change a habit and embrace digital transformation?

The framework was based first on the SAMR model [3] of substitution, augmentation, modification, and redefinition. These are the key factors that affect the introduction and use of new technology in education. This theoretical model proposes that the most significant impediment to introducing innovation in education is not technological but cultural. The challenge to evolve is a constant for education and innovation throughout history: how to persuade educators and students to try new things and modify and create a new vision and practice? The SAMR model identifies a process for technological change and implementation in two stages.

First is the substitution and augmentation of a group's tradition with new technology. That enhancement will be effective if the group reaches a point of modifying their habits. Ultimately, technological change will prove successful if the participants go through a cultural transformation utilising a practical process of reinterpretation, redefinition, and construction of a new vision for their future.

The second interrelated theory was based on the RACE model [4], which stands for reach, act, convert and engage. This structure was first used for digital marketing as a conscious effort by institutions or companies to implement new technologies. This was useful here as it helps unpack four key phases that start the promotion of digitalisation, engagement with it, and adoption of new technologies through effective behaviour change. The interrelated framework envisaged that participants would position themselves and their ideas on some areas of either or both sides of the habit transformation column or the digital transformation column. Workshop participants were invited to visualise their situation, annotate the pros and cons, ideate on them, cross-reference, place their textual and visual thinking in the most fitting cell and directly free sketch relationships among components in the framework (Fig. 1).

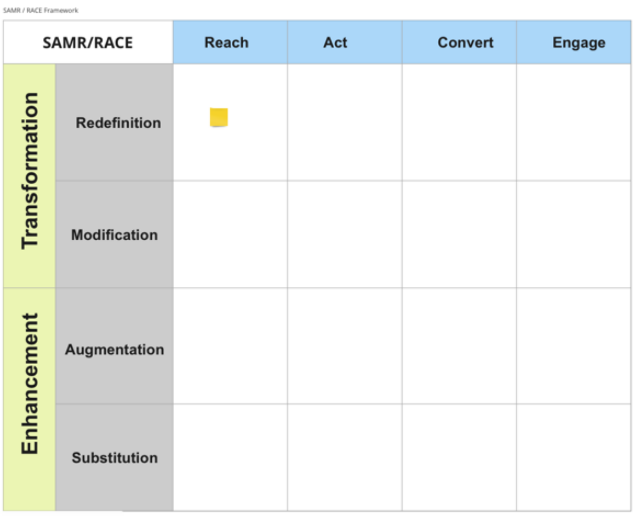


Figure 1. SAMR - RACE framework based on Puentedura [3] and Chaffey [4]

4 RESULTS AND DISCUSSION

The four events that our SIG members attended in 2021 were well received. Their approach kept a finger on the pulse of designers' and educators' concerns. There was a consensus that we need to reinterpret and redefine our tools of the trade and the competency skills for this century. In presentations at previous E&PDE conferences, research results demonstrated different steps in the evolution and extension from traditional physical design sketching taxonomies to more modern digital applications of these skills [5-7]. It was noticed that design sketching is also evolving into other domains, uses, and through new tools. Importantly, digital technologies today enable sketching for design workflows in ways never seen before. As a result, the conventional function and meaning of sketching have become more ample and undefined since it's expanded from traditional pen and paper to new know-how, such as user experience (UX), immersive experiences (e.g., VR) and new forms of distributed design and production. In parallel, sketching technology in these new platforms has become cheaper and more intuitive. Therefore, the focus is moving from cost and technicalities to prioritising concept and meaning-making, simulation, trialling of function and shaping within specific ecosystems, and testing for model failure and sustainability, before moving to physical outputs. The global Covid-19 pandemic is also influencing change in design sketching by accelerating the adoption of digitalisation and immersive technologies.

Both workshops showed similar interest and feedback from attendees. Most participants preferred to watch the demonstration instead of participating actively, while presenters worked collaboratively from their own countries. This was understandable since most attendees did not have experience in Gravity Sketch and Landing Pad collaborations.

The collaborative environment for the software was launched earlier in 2021. Several participants preferred to give opinions rather than work with the framework provided. The demonstration provided evidence to improve understanding and defined parameters with the audience. The sketching from ideation to VR, co-designing and production, and the post-workshop discussion using Miro were used to visualise similar problems, similarities and differences between traditional and new technologies and local circumstances in different parts of the globe. The VR prototypes assisted the discussion in developing a conceptual model as preliminary validation for a future cadastral model to implement transformational change and new technologies for design education and its profession. The feedback was positive concerning how easy it was to work in VR. However, there was a nuance about the time needed to adjust to a completely immersive environment. Some hesitations were pointed out, such as concentration and focus, length of time that the activity runs before one feels unsteady and a different sense of control over the work.

Traditionally there is a sense of total control when sketching with pen and paper in a two-dimensional environment and on the computer screen when working in 3D CAD. The sketcher depends on fingers, wrist, and forearm movements most of the time. In contrast, VR creates a feeling of being within the drawing. The former feels like working from the outside in, while the latter feels like working from the inside out. When sketching in VR, the designer needs to involve both arms and the whole body to draw an object. Then, the sketcher needs to keep walking around the object and through the virtual environment space to sort the sketch out. The feeling is closer to sculpting, minus the haptic feedback, rather than traditional sketching in two dimensions (Figure 2).

Figure 2. Highlights from workshops experience

During the second part of the workshop, the trigger queries given to the attendees were also answered in similar ways. On the side of the SAMR model, participants who shared the view that design education needs substitution of technology to augment habits and improve practice said that they suffered from financial shortcomings. Most design education is constantly cash-strapped, and there is not enough money to pay for things academics currently need. Most of the time, the technology they want is not approved in the yearly budget. Therefore, design education primarily works with traditional or simpler materials (e.g., pen and paper, 3D CAD).

On the side of the RACE model, comments were made that higher management above design schools and departments tend to be risk-averse in bringing in new technology. They are not experts on current and future trends in the design profession, its practice, and the industry. It can be that management looks after the business bottom line and cannot see or act on larger local, regional, or national implications. An old premise of *"if it's not broken, don't fix it"* has previously worked well for them. Besides, there is no assurance of a safe return on investment if they decide to support technology considered the domain of other disciplines (e.g., computer sciences, entertainment, gaming).

The attendees freely provided comments on technology and management issues. Several academics were open and upfront about their views and desires concerning the modifications needed in design education to keep up with changes. However, there was no clarity on what percentage of participants were willing to embrace and use immersive technologies in their day-to-day work in design education. Several participants from the industry contacted the first author afterwards to learn the steps and costs involved in implementing the technology in their professional practice as they saw potential value in it. On reflection, two significant differences observed between people in academia and the industry were in attitude and speed of adoption of new technology. Attitude dramatically comes down to the degree and level of control and decision-making power about what, when and how to accomplish goals. Typically, academics go from day to day, with workloads bursting at the seams. They have a high demand for their current specialisation and can only think of expanding to other areas of expertise if they are supported with time and training. The other difference, the speed to adopt technology between education and industry, is another example of how our SIG's work has shown that traditional designers can effectively use VR. However, we live in a time that technology mediates the generation and diffusion of knowledge unevenly through society and across the world. Economists say that the diffusion of technology favours a phenomenon of *"haves and have nots"*. Breakthrough technologies are generally expensive and stay for a long time with privileged clusters before they find a way to the periphery [8]. That was also the case with immersive technologies.

Visionaries promised that VR would be popular and affordable soon after its invention and sequential incremental innovations in the area. That has been an undelivered promise for more than seventy years. VR had a slow start in the 1930s with the description of *Stereopsis* [9], then in the 1950s with the invention of the first virtual reality (VR) experience theatre *Sensorama* [10] and the first headsets were introduced in the 1960s, such as *The Sword of Damocles* [11]. Now technology is catching up with the promise in the form of extended reality (XR), which includes augmented (AR), mixed (MR) and virtual (VR) environments [12].

These technologies seem closer to becoming a creative and communication tool for designers and people in general. One benefit of Covid-19 is that big digital and manufacturing corporations have invested heavily in technology that can be used during isolation and lockdowns. Meta (previously known as Facebook) bought the company Oculus and launched the first VR all-in-one headset kit for under US$1,000.00 at the start of the pandemic. Today, the same kit sells for US$299.00. Asian mobile phone companies are strategising to offer VR headsets with their phone plans as part of their marketing and sales wars. These price changes in two years have forced all previous forecasts to be recalculated; however, those still give a sense of the magnitude that immersive technologies will have on culture. At the start of Covid-19, Price Waterhouse Coopers [13] estimated that VR would increase at a rate of 18% growth per year and be used by at least 23 million professional jobs worldwide, an equivalent close to a US$2 trillion boost to the global economy by 2030. That was in addition to the then-current VR use for other purposes. In the United States of America alone, that was estimated as 52.1 million VR users in 2030.

This SIG's work has opened two opportunities for future research. One for mapping XR and other technology's role in the technology diffusion into design education and practice. The other is to research the knowledge translation inherent to technology diffusion and its effects on the new nature and division of labour in education and the industry. Representatively, we are already tracing the new landscape of design sketching that changed the minute it left two-dimensionality and moved into three-dimensions and later immersive realities. In its origin, sketching was a static mark on the walls of a cave. It was an artefact (Latin- *arte*: made with skill, artificial; *factum*: man-made) that presented a symbol and also represented animals, objects, and people in their natural environment as realistically as possible. Today, that artefact can be an abstract concept (drawn in your mind) and a physical or digital two-dimensional and three-dimensional object that requires an observer's gaze to travel around it to understand it. Immersive realities force the designer to do more. XR artefacts need the sketcher's physical involvement to experience it interactively within specific eco-systems. This artefact is an active narrative that asks designers to build a new visual grammar that considers time and a new physical-virtual space as influential variables.

Visual knowledge also needs to cover new methods and techniques for design and production. Exemplary, new software in development that fuses into one both old sequential design processes from ideation to development and new production methodologies that synthesise old industrial assembly and waterfall project management into agile manufacturing. Gravity Sketch and Shapr3D are light architecture programming examples that work towards the singularity of sketching, design, and production in one application. In contrast, older software like SolidWorks has grown big by the accumulation of components. Jon Hirschtick's OnShape, promises and compares well against SolidWorks, which he also founded in 1993. OnShape is a browser and cloud-based 3D CAD, data management, collaboration, workflow, and analytics application. What and how we learn, teach and work is already changing with the effect of technology. We already see that labour, once clear cut and divided into niches, is also coming into a singularity that will displace several old specialisations. New professionals are now mobile and work-together-apart in synchronous and asynchronous scenarios with increasing assistance from artificial intelligence and machine learning.

5 CONCLUSIONS

This paper talks about the VR presentations and workshops performed by the authors. Outcomes of these participatory activities helped forecast that upcoming immersive technologies will have a similar impact on design education and professional practice as home computing, accompanying software breakthroughs, and the internet had in the 1980s, 1990s and 2000s. The paper also shares views from participants that design education and professional practice may also suffer from a natural human reluctance to evolve like any other profession or social group. It also proposes that there are means to keep the principles of design and education paramount while embracing technological diffusion and its subsequent modification and transformation of professional education, habits, skills and practice.

REFERENCES

[1] Kramer N. S. Introduction to Emerging Sketching Technologies. In *International Conference on Engineering and Product Design Education E&PDE'20*, Herning, Denmark, September 2020.

[2] Novoa M. Framework for iPedising higher education: new makers culture for transformative industrial design education. In *ICERI2014 Proceedings: 7th International Conference of Education, Research and Innovation,* Seville, Spain.November 17th-19th, 2014.

[3] Puentedura R. *SAMR and TPCK: Intro to advanced practice*. 2010. Available http://hippasus.com/resources/sweden2010/SAMR_TPCK_IntroToAdvancedPractice.pdf. [Accessed on 2022, 22, May]

[4] Chaffey D. Applying capability models to assess the maturity of digital-marketing governance. *Journal of Marketing Management,* 2010. 26(3-4): p. 187-196.

[5] Corremans J. and Mulder-Nijkamp M. Towards an extended design sketch & taxonomy in industrial design education. In *Visual Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE'19),* Glasgow, UK, September 2019.

[6] Hoftijzer J.W., Sypesteyn M. and Kormelink S. A New Language For Sketching The Intangible; Building On A Mutual Fundament. In *Visual Proceedings of the 22nd International Conference on Engineering and Product Design Education, E&PDE'20*. Herning, Denmark, September 2020.

[7] Novoa M. Basis for a new theory of drawing framework from traditional handmade to modern virtual simulation. In *Proceedings of the 22nd International Conference on Engineering and Product Design Education, E&PDE'20.* Herning, Denmark, September 2020.

[8] Tarde G. *The laws of imitation*, (E.C. Parsons Trans.). New York: Henry, Holt, 1903.

[9] Bowers B. *Sir Charles Wheatstone FRS: 1802-1875*. IET, 2001.

[10] Heilig M. L. Sensorama simulator (1962). 2018, Available *http://www.freepatentsonline.com/3050870.html,* [Accessed 2022, 22, May]

[11] Sutherland I. E. A head-mounted three dimensional display. In *Proceedings AFIPS, fall joint computer conference, part I*. San Fransico, California, USA, 1968.

[12] Milgram P., Takemura H., Utsumi A. and Kishino F. Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and telepresence technologies,* Boston MA, USA, 1995.

[13] Price Waterhouse Coopers. *Seeing is Believing*. Available: https://www.pwc.co.uk/issues/intelligent-digital/virtual-reality-vr-augmented-reality-ar.html. [Acessed 2022, 22, May].

THE APPLICATION OF A DIGITAL PROTOTYPING SUPPORT TOOL IN A GLOBAL DESIGN STUDENT PROJECT

Konstantinos PETRAKIS[1], Andrew WODEHOUSE[1], Hilary GRIERSON[1], Euan COUTTS[2], Jussi LIIKKANEN[3] and Hannu PARKKAMÄKI[3]
[1]Department of Design, Manufacturing and Engineering Management, University of Strathclyde, Glasgow, United Kingdom
[2]School of Product Design, University of Canterbury, Christchurch, New Zealand
[3]Unit of Engineering and Business, Turku University of Applied Sciences, Turku, Finland

ABSTRACT
Prototyping is an inseparable part of product development in industrial and academic settings and a major theme of design education. However, it is still regarded as a design activity which is poorly implemented by students due to their limited prototyping scope; a challenge that is raising the need for the development of structured guidelines. Since distributed design projects are becoming popular in design education, research highlights the necessity for digital tools which ensure efficient collaboration and communication between globally dispersed students. The intention of this study is to explore students' usage of the prototyping support tool (PST) which aims to assist with planning, documentation and evaluation of their prototyping activities. Insights show that the tool's digital version (e-PST) enables students to communicate efficiently and present higher competency when documenting their design process, providing justification to their decisions and illustration as to how their outcomes have been informed through design iterations. Suggestions for further improvement of the e-PST are provided through surveys and interviews of participant students.

Keywords: prototyping tool, design education, prototyping purpose, student design projects

1 INTRODUCTION AND LITERATURE REVIEW

Prototyping is one of the most prominent design methods and represents an inseparable aspect of product development processes in both professional and academic settings. Prototypes represent physical or digital manifestations of design concepts and can encompass multiple features according to designers' needs who apply them for exploration or learning purposes, to inform their decision-making and improve communication between project stakeholders [1]. Especially in engineering design university courses, students have to build a wide range of different prototypes in order to support their learning objectives. Relevant research has emphasised prototyping's cognitive benefits to students, i.e., the reasoning and understanding of a design problem during the early stages, as well as the advantages offered through learning by reflection, learning by thinking and learning by making during prototyping-based exercises [2], [3].

Nevertheless, although prototyping constitutes a major theme of design education, it is still regarded as an underexplored activity which is inadequately understood and implemented by students [4], [5]. Our previous work is built on the importance of prototypes having pre-defined purposes, as an explicit purpose to be achieved by a prototype can ensure higher quality outcomes and better inform decision-making. Still, the task of constituting this purpose requires reflective thinking which comes less naturally to inexperienced designers. Investigation of students' prototyping reasoning has shown that their limited prototyping scope prevents them from realising prototyping's maximum benefits and raised the need for strategic guidelines that would improve learning and enhance their academic performance [4].

Relevant research has focused on the development of several tools for assisting students with their prototyping activities. Such means intend to structure prototyping into systematic step-by-step processes and have been introduced in the form of platforms containing photo- or video-based resources [2] or consist of questions which force conscious decision-making and are included in canvases [5] or planning-based templates [6]. However, the recent shift towards online and blended learning environments due to COVID-19 restrictions and globalisation, has raised the need for additional online design tools that can ensure the successful delivery of distributed design activities [7]. Efficient collaboration in particular, is a key requirement of global design projects as it ensures the sharing of knowledge and expertise between dispersed stakeholders. Collaborative team projects are becoming more popular in the field of design education, as they facilitate the delivery of innovative solutions, enhance design coordination and represent real-world design scenarios found in professional settings [8]. At the same time, distant collaboration includes a number of challenges due to the participation of students of multiple disciplines, diverse cultures and different design practices as well as due to the obstacles in efficiently allocating tasks amongst team members [8]. All these barriers are even more evident in the case of students working in different time-zones, which consequently require asynchronous communication and collaboration for overcoming resource mismanagement which can lead to unsuccessful design outcomes. The evolvement of technology has significantly contributed to tackling these types of challenges by integrating appropriate digital tools which ensure collaboration and communication. They include functionalities such as messaging and video conferencing, collaborative document editing, electronic whiteboards, cloud storage platforms and shared calendars involving task distribution modes [9]. Yet, due to issues related to students' unawareness and inadequate experience, design educators should also ensure their integration into curricula by ensuring their availability and inform students about the appropriate selection of such practices.

Therefore, the aim of this paper is to present a study on students' usage of a digital tool including aspects of the aforementioned functionalities, which supports them during their prototyping activities by providing a shared, dynamic environment for collaboration. In detail, through exploration of students' engagement with the tool, we will examine if it has contributed to the development of prototyping-driven mindsets or if it disrupts the design process in any undesirable way. Followed by surveys and interviews, the students had the opportunity to reflect on their usage and provide valuable suggestions for its future improvement.

2 STUDY DESIGN

2.1 The "Global Design" module

This study has been conducted on design projects of "DM503 Global Design", a postgraduate level module at the University of Strathclyde which aims to provide 5th year students with appropriate understanding of the nature and management of distributed design practices. The team projects run for 7 weeks and involve a collaborative design task between co-located and distributed members of 8 teams, across 3 regions: University of Strathclyde (Scotland), University of Canterbury (New Zealand) and Turku University of Applied Sciences (Finland). Students have to apply necessary tools for producing, sharing and storing design information with the aim of delivering a product solution that prevents COVID-19 transmission in aircraft cabins.

2.2 The requirements and key steps of the Prototyping Support Tool (PST)

The Prototyping Support Tool (PST) aims to guide designers by assisting in the planning, documentation and evaluation of prototyping activities. Previous studies on novice and professional designers' practices [4], [10] have contributed to the elicitation of the underlying foundations of the PST; its essential requirements and the key steps of its structured supporting process. In detail, the PST comprises of a decision-making guide which minimises prototyping risks and encourages prototype assessment and refinement according to the quality of acquired insights. It facilitates efficient communication by encouraging designers to build context around their ideas and effectively articulate them to stakeholders. Given the diverse nature of each design project, PST ensures a modular process, the steps and tasks of which can be re-designed and integrate project risks and critical factors, while sticking to the underlying supporting process. Based on Design Thinking and Human-Centred Design principles, PST aims towards the development of a prototyping-driven mindset and adoption of a holistic design approach as well as the involvement of people across all decisions.

The current, online version of the tool (e-PST) has been created by taking the requirements and learning objectives of the "Global Design" module into consideration. A digital template has been developed on Mural (Mural.co), a digital workspace platform for visual collaboration which enables remote teamwork synchronously or asynchronously through a virtual environment. The project objectives were aligned with Mural's delivery format as all team members were able to input information in the form of text, post-it notes, visuals and graphs, or even create their own personalised templates to support communication, sharing and management of their design work. As shown in Figures 1 and 2, e-PST comprises of 4 main Sections which include specific tasks, and its core is the provided built-in list of prototyping purposes which has been adapted from previous work and tailored to the project brief. This study is based on prototypes' emerging role as information prompts in supporting learning, communication and decision-making, regardless of their fidelity [1]; therefore, sketches, storyboards, role-playing, physical mock-ups, CAD models and functional models are all considered as prototypes.

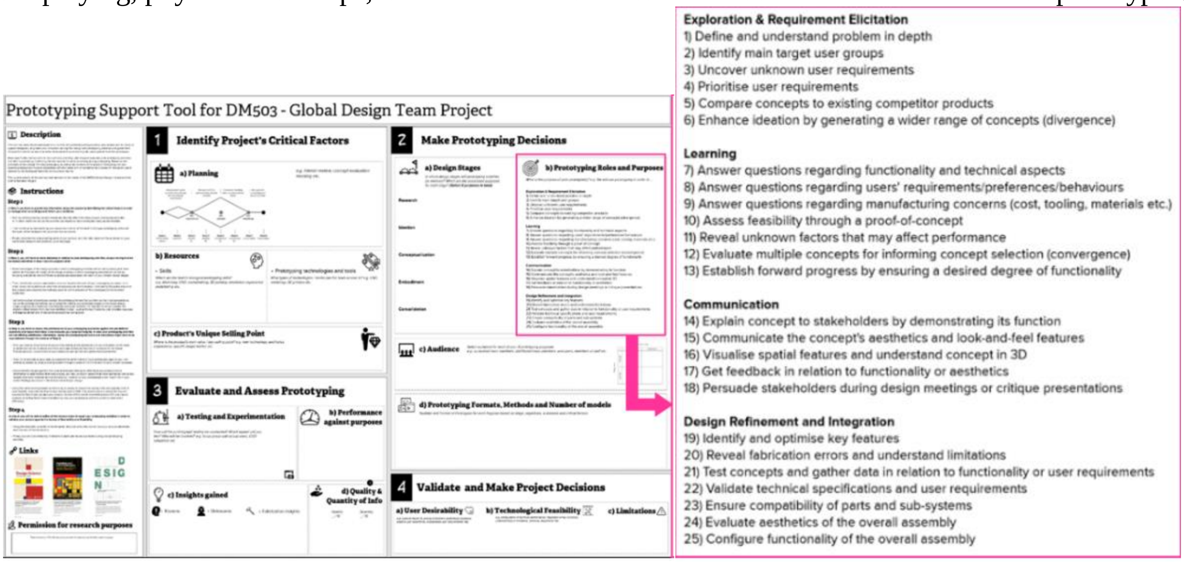


Figure 1. Mural template of e-PST with built-in list of prototyping purposes being highlighted

Section 1 – Identify Project's Critical Factors
• Provide information by defining key project or prototyping milestones • Document resources in terms of members' prototyping skills and access to available prototyping technologies • Describe product's unique selling point
Section 2 – Make Prototyping Decisions
• Recognise when prototyping is needed and associate prototyping purposes from built-in list to the according design stages • For the purpose of this exercise, select up to 8 explicit purposes • Consider types of audiences to which prototypes are communicated • Define prototyping formats, methods and numbers according to above inputs i.e., design stage, purpose, audience
Section 3 – Evaluate and Assess Prototyping
• Document and describe the conducted testing and experimentation methods • List the insights gained from testing and prototyping building process • Assess performance of prototyping outcomes by scoring them against their pre-defined purposes • In case of underperforming prototypes, consider the revision of Section 2 and explore prototype refinement
Section 4 – Validate and Make Project Decisions
• Utilise the total of lessons learnt through prototyping activities and combine with findings acquired through other design tools • Validate product against the factors of user desirability and technical feasibility • Highlight any prototyping challenges or limitations and document your reflection remarks

Figure 2. e-PST Sections and instructions on included tasks

2.3 Methodology

Once the project brief was released, students were introduced to the e-PST. Explicit instructions were provided within the template, and a video demonstration of its usage was presented during the class. Also, researchers were supervising the usage of the e-PST during the project. After the projects' conclusion, students were asked to complete an online survey comprising of 40 multiple choice Likert scale questions in relation to the e-PST's usage, complexity, effectiveness and design. In order to capture a mixture of quantitative and qualitative feedback, semi-structured interviews were also conducted with 3 of the students to get in-depth feedback and suggestions for further development. Lastly, we gathered the completed e-PST Mural templates from all teams, and we tried to relate the levels of their engagement to their marks, prototypes and final design solutions.

3 RESULTS AND DISCUSSION

3.1 Students' usage and degree of engagement with the e-PST

With regards to the teams' usage of the e-PST, we classified their templates according to the degree of engagement as shown in the examples included in Figure 3. Although we can recognise significant relationship patterns between engagement and their associated marks, as highest marked teams showed higher levels of e-PST usage and templates filled with information, we should also mention that their assessment is based on their overall design work and process management. Nevertheless, although teams with little or no engagement show fair consistency in the quality of prototyping outcomes, a valuable observation has to do with their process documentation. Teams which demonstrated adequate or good usage of the e-PST, managed to justify and document their design process more effectively. They also exhibited higher competency in relation to providing rationale behind their decisions and better illustrate how their outcomes informed iteration and development processes. Furthermore, these teams conveyed a stronger sense of collaboration and interaction across their members and clearer structure in terms of project management. Finally, it is evident that higher engagement with the e-PST facilitated the application of mixed prototyping methods, informed problem definition and considerably enhanced ideation and concept generation in relation to spatial and feature exploration. As a result, these teams were more capable in evaluating their prototypes based on ergonomics and functional aspects, while offering manufacturing considerations and providing realistic conclusions on feasibility and desirability.

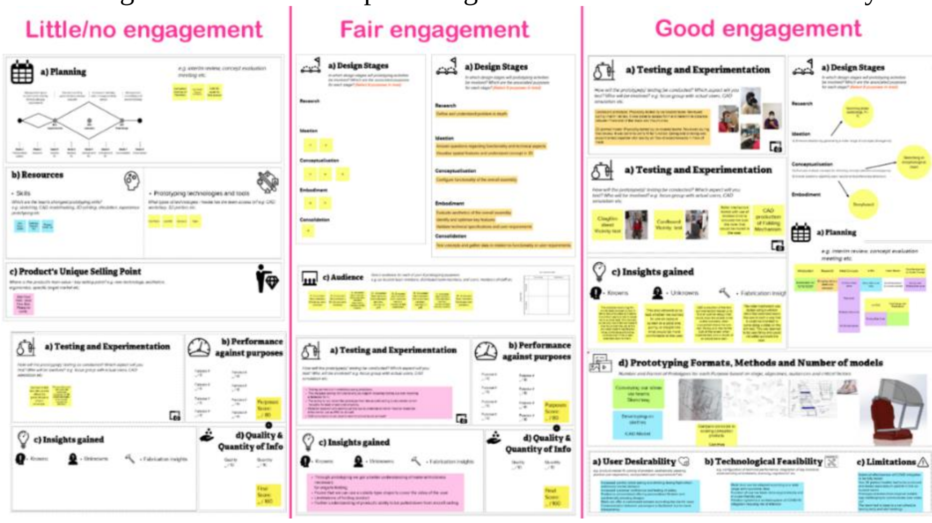


Figure 3. Examples of completed e-PST template Sections, based on level of student engagement

3.2 Feedback on different e-PST aspects through surveys and interviews with students

Initially, a noteworthy finding concerns students' previous exposure to similar prototyping guidelines and tools. In detail, 82% of them had never employed any comparable support, even despite the fact that they are all part of a postgraduate level design course. As far as complexity is concerned, while the majority was satisfied with the provided instructions, students reported that the execution of the e-PST can be moderately (66%) or significantly (11%) challenging. Additional interview insights indicated that instructions were skipped, and e-PST was completed through simply following the natural flow between Sections, and that the provided video demonstration was more useful; results that feed back to students' experience in analogous support tools. e-PST integration was also regarded as fairly (44%) or significantly (11%) time-consuming, a finding that may be related to students' retrospective approaches, i.e., inputting information after they had already completed the related tasks. Nevertheless, disruption of process was insignificant, as the e-PST did not significantly interfere with their actual design or prototyping activities. The e-PST facilitated students to appropriately address the assessment criteria of the project's brief, and consequently achieve the module's learning objectives, an important finding for the modularity and adaptability of the tool. Interestingly, e-PST achieved similar rates of effectiveness in terms of communication of concepts among dispersed and co-located team members, showing that while digital template-based tools can enable efficient distributed design practices, they also ensure successful communication between local design teams in which synchronous or asynchronous collaboration modes may be required. In terms of their overall e-PST experience, 66% of students rated it as very or moderately useful, whereas 11% were extremely satisfied with the value it added to their projects. This novel approach of project management based on prototypes was considered as "new and really interesting" and students were pleased with the breakdown of different prototyping phases.

Students seemed satisfied with the level of support provided in Section 1 (Identify Project's Critical Factors) for planning prototyping activities and managing the project, as the latter was also among the two highest ranked useful attributes of the e-PST by 56%. Definition of key milestones was also deemed as valuable, along with the focus on the identification of the product's unique selling point, aspects significantly assisting in Section 2 (Make Prototyping Decisions) decision-making. All students acknowledged the e-PST in relation to managing their resources, whereas 73% of them highlighted that it enabled them to realise and appreciate their skills in different prototyping methods. These conclusions are notable due to the relatively little amount of time students had to complete the project, meaning that resource management and risk reduction had to play an important role in successful delivery.

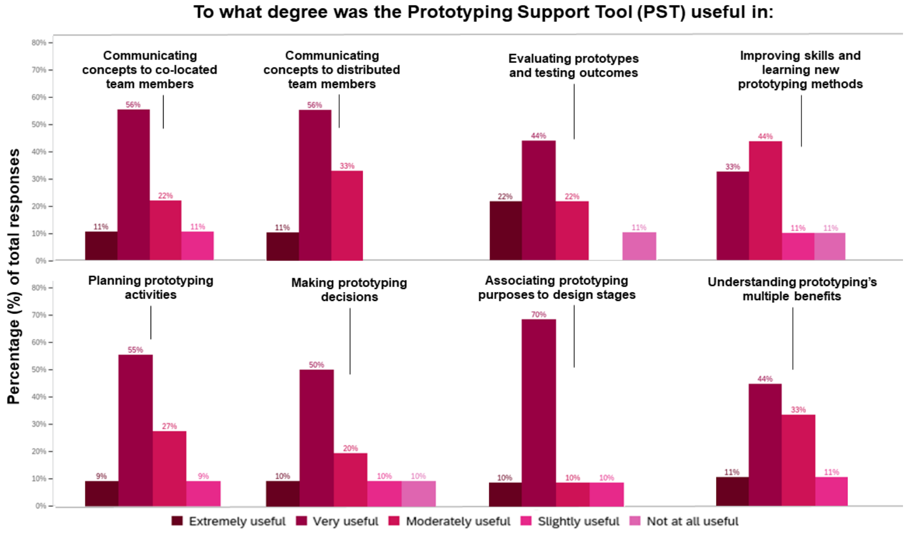


Figure 4. Survey results on different utility aspects of e-PST

Prototyping decisions and assessment of prototyping outcomes, which embody the core of the PST, were also the most acknowledged. Section 2 was really beneficial in recognising when prototyping is needed, as well as associating purpose to the corresponding design stage. The built-in purpose list was rated as the most useful aspect of the e-PST as it regularly acted as a reference and turned out to be more useful than the actual instructions provided for the project's overall goals. Students were generally impressed with the wide variety of roles prototyping can serve, stating that e-PST facilitated the learning of prototyping's multiple capabilities and enhanced their creativity. They specified that past experiences were mainly limited to technical requirements and did not actively involve the task of pre-defining a purpose, a finding that verifies the narrow prototyping scope exhibited. The aforementioned findings are strongly related to exploration and ideation enabling attributes of prototyping, which are not widely used, and massively affect students' adoption of a Design Thinking mindset, one of the key PST aims. The tool's implementation was also useful in correlating prototype purposes and features to the associated type of audience. Ideally, future e-PST versions should be able to provide bespoke prototyping format guidelines according to the inputs in previous Sections; however, students stated that although suggestions and examples would be welcome, they would prefer some degree of freedom.

In relation to Section 3 (Evaluate and Assess Prototyping) and Section 4 (Validate and Make Project Decisions), particular mention was made to the capacity of the e-PST in documenting lessons and assessing testing outcomes, as this practice may not be normally done. This process provided them with reassurance and enabled them to translate insights into user or product requirements. Section 3 in particular facilitated the prototypes' iterative refinement and ensured that they were exploited to their maximum potential, as 89% of students were able to revisit Section 2 and make appropriate prototype alterations, while 55% of them used the e-PST to predict potential prototyping issues. The distinction made between prototyping insights (Section 3) and project decisions (Section 4), enabled students to combine the lessons learnt from prototyping with information acquired through other design tools, to make "bigger picture" decisions in relation to desirability and feasibility such as ergonomics, product lifecycle and manufacturability.

Finally, the template's design was considered as "visually attractive" and a "fun addition" to the module, while the efficient interface and the intuitive flow between Sections were emphasised. The digital e-PST was preferred over a paper sheet version due to its easier access and storage, and the presence of information on a single template; consequently, the majority are willing to apply it to future projects. Highlighting the importance of the user-friendly and modular aesthetics, students were ensured that bespoke, personalised versions can be developed for their design projects, a fact that also verifies the specifications realised during PST's development.

4 CONCLUSIONS AND FUTURE WORK

This paper documents the development and evaluation of a digital prototyping support tool (e-PST) through its application in an academic, distributed design project. The need for the e-PST was established through literature findings on students limited prototyping competencies as well as the requirements of design projects of global nature which necessitate efficient communication, collaboration and sharing of design information. Exploration of students' tool usage on the web-based platform Mural, showed that it can enhance their prototyping activities, boost their decision reasoning and enable them to justify their design processes effectively while ensuring efficient communication.

Future work includes the ongoing development of the tool to align with design education practices, to ensure that prototypes are exploited to their ultimate capabilities and improve students' skillsets. Since the effortless execution and smooth integration of the tool into the design process is one of its key requirements, findings from this study will be considered towards its future refinement. Such modifications include, ensuring that disruption from actual design and prototyping tasks is kept to a minimum, integration of visual instructions within its template and the more efficient allocation of space, which would allow more detailed documentation and greater number of visual inputs. Also, refined versions of the e-PST tool will be used in future team or individual academic projects for the purpose of validating their use and compare their application with this study's findings.

REFERENCES

[1] Lauff C., Kotys-Schwartz D. and Rentschler M. E. What is a Prototype? What Are the Roles of Prototypes in Companies? *Journal of Mechanical Design 140 (6): 061102. doi:10.1115/1.4039340,* 2018.

[2] Ramos J. D. and Wallace D. R. Designy: a multimedia platform for supporting student prototyping in product design education. *In Proceedings of the ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (IDETC/CIE2019), Anaheim, CA, USA, August 18–21, ASME,* 2019.

[3] Böhmer A. I., Kayser L., Sheppard S. and Lindemann U. Prototyping as a Thinking Approach in Design: Insights of Problem-Solving Activities While Designing a Product. *International Conference on Engineering, Technology and Innovation (ICE/ITMC), 955–963*, 2017.

[4] Petrakis K., Wodehouse A. and Hird A. Physical Prototyping Rationale in Design Student Projects: An Analysis Based on the Concept of Purposeful Prototyping. *Design Science 7* e7. *doi:10.1017/dsj.2021.6.*, 2021.

[5] Lauff C., Menold J. and Wood K. L. Prototyping Canvas: Design Tool for Planning Purposeful Prototypes. *Proceedings of the Design Society: International Conference on Engineering Design 1, no. 1 1563–72. doi:10.1017/dsi.2019.162*, 2019.

[6] Hansen C. A., Jensen L. S., Özkil A. G. and Martins Pacheco N. M. Fostering Prototyping Mindsets in Novice Designers with the Prototyping Planner. *Proceedings of the Design Society: DESIGN Conference 1, 1725–34. doi:10.1017/dsd.2020.132.*, 2020.

[7] Brisco R., Grierson H. and Lynn A. Lessons learned in the development of an online 6-3-5 digital design tool for distributed idea generation. *DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), VIA Design, VIA University in Herning, Denmark. 9th-10th September* 2021.

[8] Mamo J., Farrugia P., Borg J., Wodehouse A., Grierson H. and Kovacevic A. Using engineering design tools in multidisciplinary distributed student teams. *DS 82: Proceedings of the 17th International Conference on Engineering and Product Design Education (E&PDE15), Loughborough, UK, 03-04.09. (pp. 099-104)*, 2015.

[9] Brisco R., Whitfield R.I., Grierson H. and Bohemia E. Overcoming the challenges of global collaboration through design education. *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019), University of Strathclyde, Glasgow. 12th-13th September* 2019.

[10] Petrakis K., Wodehouse A. and Hird A. Prototyping-Driven Entrepreneurship: Towards a Prototyping Support Tool Based on Design Thinking Principles, *The Design Journal, 24:5, 761-781, DOI: 10.1080/14606925.2021.1957531,* 2021.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

DESIGN EDUCATION DOES NOT EXIST IN A VACUUM

Paul MAGEE[1], Andree WOODCOCK[2] and Sinead OUILLON[3]
[1]Centre for Intelligent Healthcare, Coventry University, United Kingdom
[2]Centre for Arts, Memories and Community, Coventry University, United Kingdom
[3]Centre for Trust, Peace and Reconciliation, Coventry University, United Kingdom

ABSTRACT
There is no advantage to designers in perpetuating outdated modes of thinking. Graduates of such an approach would be disadvantaged in comparison to their peers regarding their ability to design within the constraints of the real world. Not something students would choose or something that educators would actively impose. <Future> Design education does not exist in a vacuum; therefore, the teaching model needs disruption in order to support the development of empathic, sensitive and entrepreneurial, future game-changers. Furthermore, disruption of this nature within design education has the potential to derive wider societal benefits, through improving young people's agency and ability to address issues beyond their own professions and experiences.
Our work is leading us to a new educational paradigm, although this was not our original intention. This paper aims to explain how we engaged with a large-scale multi partner, multi country Research and Innovation project – the Transport Innovation Gender Observatory (TinnGO)[1] - to approach our disruption to a typical, outdated method of design education using design internships informed by citizen social science. In this paper, we explore the barriers and opportunities experienced in combining citizen and stakeholder engagement with design education focused on gender smart mobility. To conclude, we will propose ways to move the paradigm forward.

Keywords: Empathic education, disruption, diversity, citizen social science, new thinking modes

1 INTRODUCTION
The environment in which graduates will be 'employed' is multi-faceted, complex and influenced by over-arching economic barriers that prevent many conceptual solutions from reaching the market, and into the hand of users. Following the COVID-19 crises, it is evident that perception of the world of work for new design graduates is also unstable (Wong, 2021) [2]. A UK focused industry trend report based on young designers entering the profession (Dribble, 2021) [3] even suggests that the route to becoming a designer has started to change to a less formalised route, perhaps initiated by the greater flexibility of remote training aligned to a higher current-technology literacy that enables new designers to explore different routes. Education is an ever-changing entity but clearly, recipients are beginning to question the way that they acquire knowledge. A dangerous route? Does working in isolation, a silo, remove objectivity and inhibit those new designers from understanding the real needs of users? We have addressed the importance of empathy (Woodcock, 2020) [4] in design and the value for immersive strategies (Magee, 2021) [5] that engage with citizens from marginalised backgrounds in an equitable way (Mudyarabikwa, Regmi, Ouillon 2021) [6] and to respectfully learn to walk in the shoes of others in previous publications, and indeed at E&PDE (Woodcock et al, 2019 [7] to Magee et al, 2021) [5].
Following our lockdown and remote working period, we have found that a number of things have changed.
Change is ongoing, and needed, not least in training graduates to challenge the validity of a given design challenge; to challenge the notion that problems can be 'known' without really 'knowing.' Previously, we have undertaken a number of tasks focused on embedding empathy, discursive techniques to improve communication with hard-to-reach groups (Woodcock, 2019) [7] and fundamentally attempted to dissipate the barriers to involvement that so often impacts the effectiveness of silo-solutions. We have had micro-success, but we see that this remains relatively tokenistic in the bigger picture of design at scale. We are yet to be convinced that design education carries the notion of this democratic,

compassionate approach through to its climax – nor that it had become a common thread, through which the next generation of creatives frame their thinking. This is not the fault of the education system behind it, but rather a symptom of the repeated assessment process that makes it difficult for educators to embed new, somewhat abstract, techniques that have no immediate comparison against which to score performance.

An approach that might have the potential to enhance design students' empathy and expose them to wider and more complex design challenges was implemented by Magee, Ouillon and Woodcock. The approach involved the design students in an immersive design internship programme whereby ideas for concept designs or design challenges related to gender and diversity sensitive smart mobility were informed by action research intelligence from citizen social scientists.

2 RESEARCH METHODS

TInnGO and Coventry FabLab [8] implemented an action research approach by training local people in ten countries as Citizen Social Scientists. Our definition of citizen social science is social or community-based research, conducted by members of the public, with the support of professional researchers for the benefit of citizens, scientists and the community/society. It is associated with other terms such as Community Participatory Action Research (PAR) and peer research. While the term has a broad meaning, it is underpinned by an approach that seeks to engage the collaboration of the public in a dialogue about science and society (Clark and Illman, 2001) [9]. Citizen social science recognises that the citizens are experts on the communities from which they come. Therefore, they can play an important role in exploring complex phenomena from behavioural science.

Early on in the project, Magee, Ouillon and Woodcock tested combining citizen social science with the design studio experience for product design students at Coventry University. To achieve this, they recruited eleven local elder women, as Citizen Social Scientists to co-design with 30 product design students over a period of four, four-hour sessions, culminating in a presentation of design concepts to tutors and a panel of the local elders. The experience was mutually beneficial, supporting students to address their design ideas in an inclusive and empathetic way by enabling direct input and feedback from potential consumers. When the Covid-19 pandemic hit, it was no longer possible to deliver the citizen social science programme as planned in the design studio. Therefore, the co-design experience was expanded to engage interns in a programme that reframes the relationship between knowledge gain and creative endeavour. An approach where citizen and stakeholder contributions at varied levels are valued and lead policy change, product or service design; upskilling stakeholders as citizen social scientists and co-designers so that their lived experience enhances the depth of understanding within young design teams, during internship.

To begin with, consider the term; '*interns*'- who tend not to be formally employed (i.e., typically without remuneration and not contracted other than an informal agreement), but rather invited to volunteer for externally funded, multi-disciplinary projects with a variety of ambitions but with a common goal – of widening the skill and knowledge base of a given community. We already have the traditional notion of people engaged primarily in taught education, taking some time out to work in consultancy, research or similar external activity. Perhaps with the hope that this improves their own employability. Yet, the same term might be applied to citizens who have sought a new start in Coventry and have been willing to learn new skills provided by our living lab (ENoLL, 2016) [10]. Within this bubble, we have highly skilled, experienced citizens who are willing to share their knowledge, and years of learning, for the benefit of others (Fablab); and 'in turn' for the economic benefit of the region. And perhaps beyond; those who possess wider experience have a sought-after mind-set and tend to be more capable with addressing others, in short, their world experience better enables them to engage with a world of requirements other than their own typically narrow life experience (Woodcock et al, 2020) [11].

To address the limitations resulting from the COVID-19 pandemic, a group of transport design students were recruited as design interns to work within a virtual living lab environment (a space where researchers, citizens, designers and stakeholders can come together). This environment aimed to get close to the lived experience of citizens, to better understand their mobility needs whilst also providing the design interns with information from citizen driven action research. This involved the following mixed methods approach. The students came from, and operated in, different geographical locations, including Malaysia, India, Spain and the UK. Whilst existing in multiple time zones may seem to be a disadvantage, in practice it was managed smoothly, we operated flexibly and as a quirk of these arrangements were able to meet weekly as a large group, regularly throughout the week for short

discussions and frequently on an 'ad hoc' basis. Although we hadn't expected to do so, we met up for a variety of discussions – many more than we may have been able to had we been co-located and perhaps more so than would normally be anticipated for an internship. Despite the challenges for our students to rapidly and unexpectedly relocate to their home places, the experience was positive and rich.
The TInnGO project was built around hubs in ten European countries which communicated citizen and stakeholder identified smart mobility challenges to the intern designers from their own citizen social science activities. It was important to include research methods that are capable of collecting data 'from below,' especially from social groups whose perspectives are usually overseen. This is to support local citizens and stakeholders' ability to shape the process of problem setting and the quest for realistic solutions, e.g., with the involvement of citizen (social) science (Kythreotis et al., 2019) [12]. The citizen social science activities involved a number of methodologies such as interviews, focus groups and Participatory Design Walks described by Bertelsen et al (2017) [13] as a citizen driven approach that can provide valuable insights for design (Morrison et al, 2019) [14].
In addition to action research, citizens/stakeholders could collect and upload their own images to provoke a design discussion. These were posted on an online whiteboard (Mural) where individuals could comment, anonymously if desired. Using the information from the Mural board as well as the citizen social science activities the intern designers set about co-developing concept designs with the project hubs. Design activities lasted over 18 months, generating over 50 design provocations, some of which may be found on TInnGO's Open Innovation Platform (OIP) https://oip.transportgenderobservatory.eu/ideas-lab. A number of design and engineering students worked on concept designs (or provocations) using internally generated and submitted ideas from the ten National hubs. These related to current, context specific, mobility related challenges (Woodcock et al, 2021) [15] whereby the concept designs aimed to provoke further discussion and ideas for policy and service change as well as new products or adaptations to existing infrastructure. This process involved weekly meetings with the wider Coventry University team as well as regular contact with and input from the ten European Hubs.
The Hubs would also use the designs to run labs with citizen social scientists/stakeholders to co-create the next phase. This typically involved additional citizen and stakeholder engaged workshops for example as well as feedback on each concept design directly by citizens and stakeholders on the Open Innovation Platform.

3 RESULTS

The citizen social science approach combined with the design intern programme, resulted in the development of over 50 concept designs (or design provocations) and nearly 300 discussions (from citizens and stakeholders about the gender smart mobility solutions). The conversations continue on the Platform. Combining active engagement of citizens into the design process through citizen social science informed internships helped to bring the lived experience closer to the design process and helped to improve the design intern's ability to design for a wide range of needs.
"I'm back on the course and everyone is talking about fast cars and aesthetics, and I can't stand it I keep thinking is it accessible, is it inclusive etc. This is changing designer's perspective before they eyed the market! (Transport Design student/TInnGO intern, Coventry University).
Using an asynchronous feedback and discussion platform (Open Innovation Platform) can support student designers to obtain direct input from citizens into their design process in a low resource intensive way. The process specifically helped further the design interns understanding of the specific transport requirements and needs of different groups of women, such as older women and women with care responsibilities. The experience of the students has undoubtedly changed them as designers who will soon go out into the workforce with newly acquired empathic design skills.
Combining an approach to design pedagogy with a large-scale European research and innovation project had its challenges. However, the research project partners and their tentacles out to local citizens meant that the interns could experience a variety of input into their design process from people with very different ages, nationalities, cultures and backgrounds.
"A nice well thought-through idea. I like the protection for the child's legs but need to think about the dimensions as their legs can get very thick when all wrapped up in padded trousers or onesuits "(feedback provided by a hub citizen/stakeholder on a design interns child seating solution).

"It was really useful to allow our students to experience working within a much larger research project whilst still having the freedom to exercise their design ideas on quite a broad topic. We liked the design challenges brought forward by the TInnGO team – they were often simple problems to understand but often required complicated solutions" (Lecturer, Coventry University).

4 DISCUSSIONS

TInnGO in particular introduced a gender shift in terms of the wider project delivery. Perhaps therefore there is a difference in the thinking of the project and in certain outputs, which represent a willingness to include the emotional and societal aspects of lived experience applied to transport systems. The project was not just about designing new modes of transport but about understanding how the existing system leads to inequity. Bringing in a team of intern designers to the process of bringing the lived experience to life through future gender smart mobility concept designs merits further investigation. Design does not exist in a vacuum (whimsically nor does it solely exist in a Hoover…), isolation of the design process disadvantages the method for the detriment of the resulting designs. The future of socially responsible, citizen engaged design remains a tension between economic drivers and social barriers - we must change our way of looking at the users within the lens of the producers, we must change the way that users see themselves as excluded from solving interwoven problems. Our work is leading us to a new paradigm - and embedding this in education.

How does such a new paradigm make impact, ultimately as a learned legacy of design education? Surely, the best way to know is to ask those whom have experienced it. To co-create that knowledge so to speak. However, how long is needed to elapse until their professional reflection indicates how well their knowledge has improved their ability over that of their peers? 1 year? 10?

The Design Council's 'design differently' campaign [16] findings emphasised the value of relationship building and trust, citing 3 C's (Communicate! Capability! and Convene!) as themes around which to categorise collaboration experience. Participants used these themes to engage with local challenges across the UK, nicely slotting into the DC's democratic design values. Whilst (user) Experience businesses can provide vast amounts of corporate transport data and work closely with 'clients,' how often are they willing to fundamentally disagree? How do we know that their insight is ethical? Moral? Real? They are in business after all, and ultimately economic factors drive decisions. But then, integrity keeps business afloat and clients coming back. Why, then, are vehicles still not addressing the needs 50% of the population whose gender remains at a deficit, for instance in impacts?

This question challenges the potential of a design pedagogy that builds a more direct connection between people's lived experience and the designer/design process. Given that, UX companies exist and yet the gender issues remain.

5 CONCLUSIONS

Experience of the citizen social science informed design intern programme has informed thinking about the potential for a new educational paradigm; one where the student is critically engaged in dialogue with wider society and where the design process is directly linked to and influenced by the lived experience and needs of potential users. Evidence from the citizens, stakeholders, students, researchers and teaching staff involved suggests that all have derived benefits from the experience. For example, the interns developed more empathetic design skills and experience of discursive techniques with wide ranging communities and the citizens and stakeholders benefited from the visual concept/design solutions and opportunity to bring their own experience into the design process. In this respect, the experiment has had small-scale success.

There are, however, many challenges to scale the approach to achieve a paradigm shift. For example, the research and teaching team involved were fortunate to have access to large-scale research and innovation project and the associated resources that that brings. Would the approach be achievable without the resources? The original engagement of 11 local elder women and 30 product design students within the design studio might be more replicable in the short term. In the longer term, the potential for online collaboration spaces linked to audiences outside of the academy and immediate geography such as, the Open Innovation Platform and living lab approach merit further investigation.

REFERENCES

[1] Transport Innovation Gender Observtory (TInnGO). https://www.tinngo.eu Accessed 221221.

[2] Wong H., (202). Young designers battle with job instability and remote work challenges in 2021. https://www.designweek.co.uk/career-survey/ Accessed 221221.
[3] Dribble 2021 Design Industry Trends Report. https://www.industry-trends.dribbble.com Accessed 221221.
[4] Woodcock A., McDonagh D., Magee P. and Tovey M. (2020) The Value and Place for Empathy in Designing for Older People. In: Woodcock A., Moody L., McDonagh D., Jain A., Jain L. (eds) Design of Assistive Technology for Ageing Populations. Intelligent Systems Reference Library, vol 167. Springer, Cham. https://doi.org/10.1007/978-3-030-26292-1_4
[5] Magee P., Woodcock A., Gut K., Saunders J., Atkinson P. and Bridgman J., (2021). In pursuit of meaningful insight; covid remote collaboration and design as provocation. In *DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), VIA Design, VIA University in Herning, Denmark. 9th-10th September 2021*.
[6] Mudyarabikwa O., Regmi K., Ouillon S. and Simmonds R. Opportunities and Challenges in Designing a Public Health Knowledge and Skills Curriculum for Refugee and Migrant Community Health Champions in the West Midlands, England (UK). *Pedagogy in Health Promotion* 7.1 (2021): 71-81. Web.
[7] Woodcock A., McDonagh D., Magee P., Ball T. and Iqbal S. (2019). Expanding horizons: Engaging students with empathic thinking. In *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019), University of Strathclyde, Glasgow. 12th-13th September 2019*.
[8] Learn With Us. https://fablabcov.coventry.ac.uk Accessed 221221
[9] Clark F. and Illman D. (2001). "Dimensions of Civic Science." *Science Communication* 23.1: 5-27. Web.
[10] Introducing ENoLL and its Living Lab community. 02022016. https://issuu.com/enoll/docs/enoll-print/64 Accessed 221221.
[11] Woodcock A., Ball T., Gut K., Magee P., McDonagh D., Moody L., Moreira F. and Ouillon S. (2020). Fostering design literacy, empathy and awareness in codesign. In *22nd International Conference on Engineering and Product Design Education, E and PDE 2020*. The Design Society.
[12] Kythreotis A. P. et al., (2019). Citizen Social Science for More Integrative and Effective Climate Action: A Science-Policy Perspective. *Frontiers in Environmental Science,* 7(10). 1-10.
[13] Bertelsen P., Kanstrup A. and Madsen J. (2017). Steps Toward Technology Design to Beat Health Inequality - Participatory Design Walks in a Neighbourhood with High Health Risks. *Participatory Design & Health Information Technology, 233,* 158-172.
[14] Morrison A., Ola Erstad O., Liestøl G., Pinfold N., Snaddon B., Hemmersam P. and Grant-Broom A. (2019) Investigating agentive urban learning: an assembly of situated experiences for sustainable futures, Oxford Review of Education, 45:2, 204
223, DOI: 10.1080/03054985.2018.1556627
[15] Woodcock A., Magee P. and Gut K. 2021, September. Realising gender and diversity sensitive smart mobility futures during the Covid pandemic: the TInnGO experience. In *Design Thinking Research Symposium 13 (DTRS13): Expanding the frontiers of design: A blessing or a curse?*
[16] Design, differently. https://www.design-differently.com/6/ Accessed 221221.

DESIGN FOR PUBLIC ENGAGEMENT AND AWARENESS: EQUIPPING DESIGN STUDENTS WITH EMPATHY AND SOCIAL RESPONSIBILITY SKILLS

Susana SOARES and Alison ALVAREZ
London South Bank University, United Kingdom

ABSTRACT

Public engagement has become a crucial process of democratic societies. It broadens knowledge, brings a diversity of views and voices, and widens participation in decision-making activities. Design as a discipline has been shifting from making finite goods to collaborating with different disciplines, generating dialogue, highlighting ethical questions, and engaging different users and/or communities to understand complex issues.

The primary aim of this project was to develop learning and teaching content with real world impact that prepares design students to address societal challenges, including an array of global citizenship competencies that equips students with empathy and social responsibility. 'Vaccination: increasing trust and awareness' project targeted second year product design students, and initially originated from the UK's loss of 'measles-free' status since August 2019 with the World Health Organization. Over the past decade, an increasing number of studies have documented a rising number of people who seem to be losing confidence in vaccines.

Within this context, students were asked to develop a service design intervention to inform, raise awareness and ultimately increase public trust in vaccines. Students were also encouraged to take a holistic and inclusive approach to the design of the intervention. The project was supported by a lecturer from applied sciences which helped to understand the challenge from a scientific perspective. The paper includes examples of these design proposals, student feedback and results that illustrates the importance of design for public engagement that addresses societal challenges with real world impact, promotes the understanding of complex issues and fosters collaborations with other disciplines.

Keywords: Public engagement, empathy, societal challenges, real world impact

1 INTRODUCTION

1.1 The importance of public engagement

Public engagement and awareness have been embedded in policymaking, to understand the impact of higher education and research in the wider society and empower communities. A definition of public engagement by the National Co-ordinating Centre for Public Engagement states that 'Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is, by definition, a two-way process, involving interaction and listening, with the goal of generating mutual benefit' [1]. Some of the ways in which we can engage a particular user / community range from learning, developing new skills, gaining insight, access information to being inspired. In regard to why public engagement matters, it stems from the idea that low levels of scientific literacy are often linked to a loss of public trust in scientists [2]. This is particularly relevant when engaging with some of the more controversial, but important scientific and social challenging topics. Therefore, since 2008 the major UK funders of HE and research actively started to encourage ways of engaging the wider public in the understanding of research. By establishing the increasingly importance of public engagement institutions can build trust, strengthen the relevance of research and its applications, be responsive to wider public needs, be accountable and transparent on how they used public funds and increase the value and purpose by committing to wider social benefit [3].

1.2 Design for public engagement

Design has a wealth of methods and expertise in creating engaging experiences, facilitating dialogue, and translating complex insights into tangible outputs that the wider public can understand. As explained by Teal & French, design can be used to generate 'thought-provoking public engagement experiences to stimulate creative dialogue and explore new ways of addressing societal challenges [4].

Design has the capacity to gather in depth understanding of user / community needs by using human centred design and / or empathy tools, engage a variety of stakeholders through creativity and innovation and jumpstart action and constructive change by working with different disciplines, expertise, and community to address a specific challenge. Design is becoming 'an engine for social transformation through increased capacity and resource for communities to change themselves' [5]. Design is increasingly being seen as a strategy for addressing social change, as it uses approaches that provide the ideal conditions for new communicative spaces and experiential learning, that enable scientific fluency, increase trust, and support constructive change. In this context, it is essential to equip design students with global citizen competencies [6] that include empathy, social responsibility, critical thinking, and recognition of global issues.

2 ADDRESSING SOCIETAL CHALLENGES

2.1 Addressing societal challenges at London South Bank University

Since 2016, second year students on the Product Design course at LSBU have been exposed to a series of project briefs that envisaged addressing societal challenges such as *Design for Dementia* and *Citizen Participation.* These projects have aligned with the university strategic goals concerning Real World Impact, related to research, and teaching that tackles global and societal challenges, generates critical insights and sustainable solutions that transform the lives of individuals and communities. The project enabled product design students to develop their collaborative skills benefiting cross disciplinary work. It also gave students the opportunity broadens their perspective of design by shifting semantics of design from creating finite goods that end up in land fill to addressing societal challenges. As referred by Cope and Kalantzis, this transformational agenda for the design professions is crucial to strengthen the importance of design within the creative economy and knowledge society and increase product design students' employability towards empowering constructive change [7].

2.2 'Vaccination: increasing trust and awareness'

2.2.1 The brief

The primary aim of this project was to develop learning and teaching content with real-world impact that prepares design students to address societal challenges and cover an array of the global citizenship competencies as identified by the UNESCO framework [5] namely: empathy, critical thinking (underlying assumptions), ability to communicate with other, shared universal values, respect for diversity and recognition of global issues.

Vaccination: increasing trust and awareness project targeted second year product design students and the first iteration of the brief was launched in February 2019. Students have 4 weeks of approximately 45h contact time and 155h of self-managed time to develop the project. The brief initially originated from a 2018 Wellcome Trust study into global attitudes on immunisation. The study showed that confidence in vaccination was low in some regions [8], further reinforced by UK's loss of 'measles-free' status since August 2019. Over the past decade, an increasing number of studies have documented a rising number of people in both high-income and low-income countries who seem to be losing confidence in vaccines [8], this has been termed vaccine hesitancy. The World Health Organization listed vaccine hesitancy as one of the top 10 threats to global health [9]. Unfortunately, global vaccination coverage dropped from 86% in 2019 to 83% in 2020. Moreover, the current COVID -19 pandemic highlighted the importance of vaccines as one of the most effective ways to prevent disease spreading. However, and despite the evidence of the effectiveness of covid 19 vaccines in providing protection against infection, prevention, serious illness, and death, there is still an ongoing debate on acceptance and refusal.

Within this context, students were asked to develop a service design intervention to inform, raise awareness, engage, and ultimately increase public trust in vaccines. Students were encouraged to

take a holistic and inclusive approach to the design of the intervention and the proposal would need to cover a digital tool, a product(s) and a public engagement strategy.
Although this was an individual project, students were put in smaller study bubbles of groups of 3 to 4, so they could apply creative techniques and bounce back ideas with each other due to the complexity of the brief.

2.2.2 The importance of including expertise

The project is supported by a lecturer from applied sciences which addresses the challenge from a scientific perspective and gives and overview on how vaccines and immunity work, types of vaccines, how vaccines are produced and why public complacency is problematic to any vaccination programme. On top of this, students also get expert support at specific project milestones to verify the scientific veracity of their proposals.
Conveying scientific knowledge to a non-scientist audience required deliberate thought. Careful attention was given to the language chosen, replacing scientific jargon with language that was more accessible. Analogies, visuals and video excerpts were used to illustrate the more complex concepts thus increasing accessibility. The materials were grounded in a historical context, with the purpose of contextualising the topic and promoting engagement. Students were asked open-ended questions to engage them in a debate in a subject they were initially not comfortable contributing to. This stimulated critical thinking, which in some cases, resulted in a shift in knowledge and attitudes on the topic. Figure 1 shows student feedback before and after the project on how much they learnt about vaccination in general, vaccine hesitancy, levels of trust and public complacency (the darker the column colour the more knowledge students were able to gain).

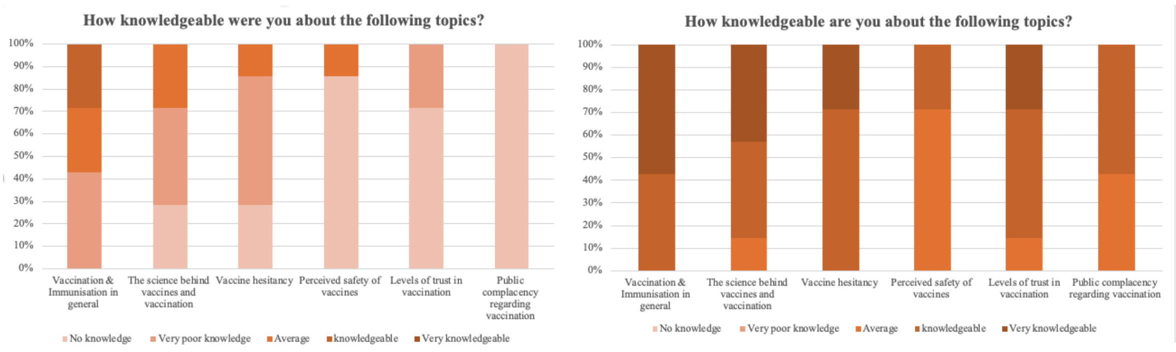


Figure 1. Comparison feedback on student knowledge regarding the vaccination topic before (left) and after (right) vaccination project

The project design gave an opportunity for non-specialist students to improve their perception of science and empower students to make a positive contribution to tackling a complex challenge. Crucially, the project gave an opportunity to address misinformation regarding vaccinations, allowing students to find ways of stopping misinformation and improving vaccine uptake.

2.2.3 Transformative service design methods

The project uses a transformative service design method. It adapts the Design Council's Double Diamond method to include service design tools such as service safari, user profiling and journey, empathy map to define user needs, system map, service blueprint and experience prototyping.
Services focuses are less on the design of objects but rather on providing an experience and a means of supporting a more collaborative, sustainable, and creative society. As per Sangiorgi, transformative service design can be applied to radically change public and community services and has been associated with work for socially progressive ends, but also can trigger change within organisations to introduce a human-centred design culture [10].
Therefore, this approach is relevant to the aims of the project and learning outcomes of the module such as drawing knowledge from other disciplines, generate design outputs that increase dialogue and engagement and use service design to generate digital tools to address societal challenges. Furthermore, service design methods allow for a more holistic and inclusive approach as it is looking into both social and organisational change, whilst also enables a quicker exchange of communication between all partners of the process – coined the enabling model centred on co-creation and active citizenship [10].

2.2.4 Project stages

After the brief launch, the scientific perspective lecture and an explanation of the projects aims, and methods, students were asked to get research insights. First, they were given an array of academic studies on vaccine hesitancy and each student was asked to do a literature review of 1 or 2 papers that was shared with the whole class. Followed by employing empathy design tools, such as user profiling and empathy maps, to identify vaccine hesitant individuals' demographics and determinants (Figure 2). After identifying a variety of factors associated with vaccine hesitancy students were encouraged to use research methods such as surveys, interviews, focus groups and web forums to gather primary research on the subject. The results were presented to the group so everyone could benefit from the various insights.

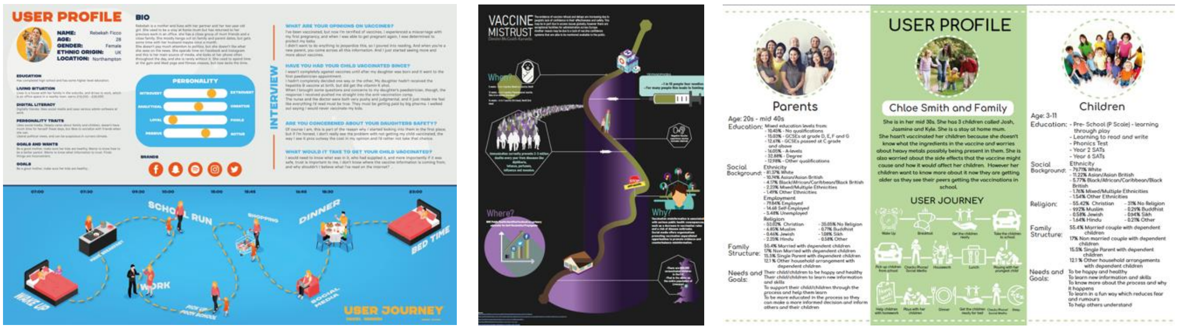


Figure 2. Use of empathy tools to profile determinants of vaccine hesitancy

The project moved into ideation and generation of concepts stage in which students were introduced to service design methods with an emphasis on the enabling model. Outcomes of this stage include service system maps (Figure 3) and a project brief containing a clear rationale on how the service design proposal would address vaccine hesitancy and increase trust.

Finally, students presented a service design proposal that included a digital tool, a product(s) and a public engagement strategy (Figure 3) To this end usability principles and basic user experience laws were imparted to students along with an introduction to digital prototyping tool software (Adobe XD). This was followed by user experience and interaction development such as flow charts, wireframes, service blueprint and user interface.

Figure 3. Vaccination project system maps and service design proposal

Project outcomes are of high standard and well considered. Student feedback was very positive stating that 'I thought product design was essentially designing objects, but I have gained a new perspective on design', 'it was challenging to grasp vaccine hesitancy, but the lecture given by Alison was really useful', 'I really enjoyed learning how to prototype an app, it made it easier to create an outcome for the project' [13]. However, projects can much improve on the evaluation and testing of the proposals with chosen users. In addition, a bigger emphasis in co creation will be necessary in project outcomes. Also, some students prioritised the digital tool in detriment of the rationale.

3 VALIDATION, RESULTS & FEEDBACK

In order to validate the project as being appropriate for addressing societal challenges using a design for public engagement framework, we have analysed overall student projects against the core of engagement processes from Escobar, O., Faulkner, W., J Rea, H. [2], which are:1. inform and inspire wider publics about a certain topic; 2. converse about ethical or other issues arising from topic; 3. involve groups / communities in the project and 4. collaborate to 'co-produce' the project. The multidisciplinary nature of the project and the teaching and learning methods described in Section 2 presented opportunities for students to develop all 4 engagement processes as showed in Table 1. Inform and inspire was the core engagement process of choice, 40% of the projects included all processes within their final proposal and 80% of the projects included at least 3 core engagement processes.

Table 1. Analysis of core engagement processes against processes covered by student's design proposals

	Projects										Total per core process
Core engagement processes	1	2	3	4	5	6	7	8	9	10	
1. inform and inspire	1	1	1	1	1	1	1	1	1	1	**10**
2. converse about ethical or other issues	1	1	1	1			1	1	1	1	**8**
3. involve groups / communities	1		1	1	1	1	1	1	1	1	**9**
4. collaborate to 'co-produce'	1	1		1					1	1	**5**
Total Engagement score per project	**4**	**3**	**3**	**4**	**2**	**2**	**3**	**3**	**4**	**4**	

As for equipping the students with global citizen competencies including empathy tools and social responsibility skills by embedding empathy tools [14], students were able to identify challenges and understand user needs towards vaccine acceptability. The discussions generated within the research stage were valuable and insightful as students were able to get a local and global perspective of vaccination, avoid assumptions, engage with different opinions and perspectives from different demographics and collaborate amongst themselves and with others to do both secondary and primary research. Figure 4, from student feedback, shows that students agreed and strongly agreed that the project allowed them to increase recognition of local and global issues, empathy skills, respect for different opinions and critical thinking.

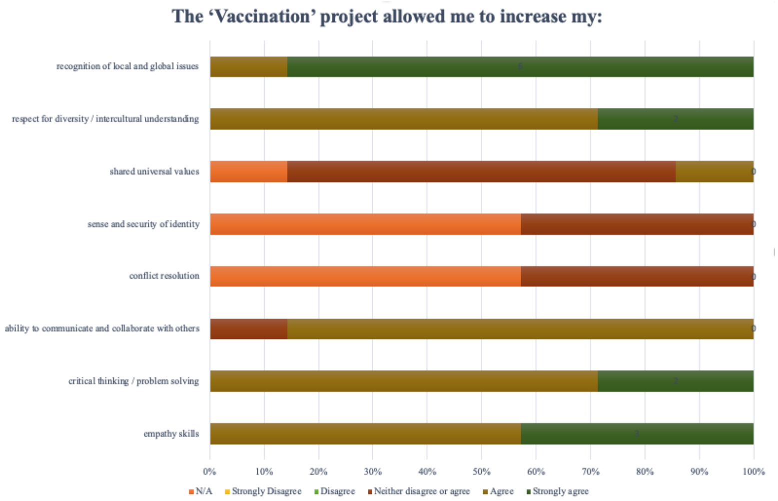


Figure 4. Student feedback on the skills that the Vaccination project allowed them to increase

Through the project they were able to develop transferable skills such as being able to do literature review, identify service design principles and create a digital prototype that students can apply within their placement and final year projects. However, evaluating long term impact of the project would require a longitudinal research study.

4 CONCLUSIONS

The paper started by demonstrating the importance of design for public engagement as having a wealth of methods to generate meaningful dialogue and address societal challenges. The authors highlighted the capacity that design has to use empathy tools, to gather in depth understanding of a group/

community; engage a variety of stakeholders and start constructive change. The paper subsequently describes Vaccination: increasing trust and awareness, a second-year project that requires students to develop a service design intervention to inform, raise awareness, engage, and ultimately increase public trust in vaccines. The main aim of the project was to develop learning and teaching content with real world impact that prepares design students to address societal challenges and equips them with global citizen competencies including empathy tools and social responsibility skills. It shows the importance of expertise support in terms of gaining understanding and knowledge of local and global issues regarding vaccination and immunisation including vaccine hesitancy and complacency (Figure 1). In section 2.2.3 it explains why a transformative service design method is relevant as it enables co-creation and active citizenship. In section 2. 2.4 outlines the stages of the project and shows examples of student work. In section 3 an analysis of core engagement processes against processes covered by student's design proposals shows that 80% of the projects included at least 3 core public engagement processes evidencing a high success rate on embedding engagement in the design process. Moreover, student feedback on global citizenship competencies shows an increased ability to: recognise local and global issues (90% strongly agreeing), gain empathy skills, respect for diversity, critically think as well as communicate with others. Finally, student perceptions on how well their projects covered global citizenship domains reveal an excellent coverage of increasing trust in vaccination, and a good coverage of including different viewpoints and avoid assumptions [13]. However, improvements need to be made at evaluation and testing phase of proposals to emphasise co-production as the least used core engagement process has shown in Table 1. Measuring long-term impact and legacy will require a longitudinal study. The project validation shows appropriateness of methods and valuable insights.

REFERENCES

[1] National Co-ordinating Centre for Public Engagement. *What is public engagement?* Available: https://www.publicengagement.ac.uk/about-engagement/what-public-engagement [Accessed on 2021, November].

[2] Escobar O., Faulkner W. and Rea H. (2014) *Building Capacity for Dialogue Facilitation in Public Engagement Around Research*, Journal of Dialogue Studies Volume 2 Number 1, 90-114.

[3] Bates S. R., Faulkner W., Parry S. and Cunningham-Burley S. (2010) *How do we know it's not been done yet?! Trust, trust building and regulation in stem cell research,* Science and Public Policy, 37(9), 703-718.

[4] Teal G., and French T. (2016) *Designed Engagement*, in Lloyd, P. and Bohemia, E. (eds.), Future Focused Thinking - DRS International Conference 2016, 27 - 30 June, Brighton, United Kingdom. https://doi.org/ 10.21606/drs.2016.263.

[5] Innes J. E. and Booher D. E. (2000). *Public Participation in Planning: New Strategies for the 21st Century*. UC Berkeley: Institute of Urban and Regional Development. Retrieved from https://escholarship.org/uc/item/3r34r38h.

[6] UNESCO (2016) *Education 2030: Incheon Declaration and Framework for Action for the implementation of Sustainable Development Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.* Available at https://unesdoc.unesco.org/ark:/48223/pf0000245656 [Accessed on 2022, March].

[7] Cope B. and Kalantzis M. (2011) 'Design' in Principle and Practice: A Reconsideration of the Terms of Design Engagement, The Design Journal, 14:1, 45-63.

[8] Wellcome.org. (2019). *Chapter 5: Attitudes to vaccines | Wellcome Global Monitor 2018*. [online] Available at: https://wellcome.org/reports/wellcome-global-monitor/2018/chapter-5-attitudes-vaccines. [accessed November 2021].

[9] World Health Organisation (2019). Ten threats to global health in 2019.

[10] Sangiorgi, D. (2011). Transformative services and transformation design. International Journal of Design, 5(2), 29-40.

[13] Excerpts taken from Vaccination project student survey and feedback 2021.

[14] OXFAM (2015), *Global Citizenship in the Classroom – A guide for teachers.* Available at oxfam.org.uk/education [Accessed on 2022, March].

CREATIVE DESIGN ACTIVITIES TO SUPPORT THE COMPLEX LEARNING ENVIROMENT OF THE CLASSROOM FOR CHILDREN WITH AUTISM SPECTURM DISORDER (ASD)

Nesrin ELMARAKBI, Heather ROBSON and Lucy CURRIE
Northumbria University, Newcastle, United Kingdom

ABSTRACT
Creating inclusive and effective learning environments for all children can be extremely challenging. How do teachers recognize the needs of their different children, the dynamics between them and adapt in response? This paper presents work from a doctoral study and aims to investigate the integration of multidisciplinary fields (design, art therapy, and education) to create a design thinking-based framework and toolkit, which can be applied in the classroom setting to enhance teaching and learning experiences for autistic children (children with autism spectrum disorder (ASD)).This paper reports on initial fieldwork (case study) that investigates the design thinking of teachers applying arts practices to support the learning of autistic children, aged 5-6 years old. The case study has been carried out at Marine Park Primary School in the Northeast of England. This paper presents an initial cycle of the case study, which is researcher-driven. Further in the doctoral study ownership transitions from the researcher to the teacher and autistic children. This initial cycle resulted in the development of an arts therapy informed toolkit applied to create immersive learning experiences to address inattention and engagement with instructions and story-based tasks. The toolkit breaks down the lesson plans into more readily comprehensible components and translates tasks and worksheets into an immersive 3D learning experience. Reflections from teacher-research dialogues are presented that indicate an initial framework for day-to-day design thinking for more inclusive learning.

Keywords: Autistic children, social communication, emotional, sensory sensitives, design thinking, participatory design, art therapy, toolkit, and visual attention

1 INTRODUCTION
Autism spectrum disorder (ASD) refers to a neurodevelopmental condition, which manifests in a range of discrepancies [1], causing problems in communication and social skills. ASD impacts on over half a million people in the UK [2] and is also thought to affect 1-2% of individuals around the globe [3]. Incidence rates of ASD have been progressively increasing as the disorder has become more common and the awareness of the condition has been increased. ASD is deemed to be a hidden disability, especially for those individuals who are educationally capable, indicating that their demand for additional support is not instantly apparent. There are presently various educational, emotional, and medical interventions that aid the difficulties that individuals with ASD may face [2]. These kinds of assistance give the ultimate benefit if they are utilized throughout childhood [4] and art and design activities are being seen as an essential part of the intervention strategy.

There are several kinds of intervention with a range of different objectives. Some emphasise certain behavioural problems, while others may be driven by concepts of autism and focus on the core shortfalls of the condition [5]. As there is no one single solution to be offered by effective interventions to fit all children, the choice of the intervention strategy mainly relies on each child's specific requirements [2]. Educational interventions are vital for autistic children as they may have an imbalanced profile of knowledge and skills, being especially able in some areas and having struggles in others. Hence, education is regarded as the most successful therapeutic approach for autistic children [6] and is realized as essential to allowing autistic children to live a happy life [7].

This paper will apply qualitative ethnographic research in the complex classroom setting to improve the quality of practice, focusing on the adaptation of teaching styles to suit the support needs of the students.

It will also investigate the integration of multidisciplinary fields (design, art therapy, and education) to create a unified theoretical framework which can be applied in the classroom setting to enhance teaching and learning. Using design thinking (DT), participatory design (PD), and art therapy (AT), we intend to develop a new toolkit which presents and explains tasks in a manner which is more compatible with the learning style of autistic children, employing a variety of visual and auditory aids. The toolkit will break down lesson plans into more readily comprehensible components and translate tasks and worksheets into an immersive 3D learning experience. Inspired by theatre production, the toolkit will employ appropriate imagery, textures, music, etc. to bring the lesson to life in a way which autistic children can actively engage with the material at hand, whilst also ensuring that the visual, auditory, and tactile experience is not overwhelming to the students.

2 CREATIVE DESIGN APPROACH INTEGRATION

Autistic children often struggle with poor social skills, languages difficulties, sensory issues, attention problems, executive functioning difficulties, and emotion dysregulation [8]. Such difficulties can result in a gap in communication between teachers and students, feelings of frustration for the children, and can significantly hinder the learning process. There is a growing challenge to meet the requirements of autistic children enrolled in schools as they have ongoing difficulties with social interaction (e.g. eye contact, facial expression, and emotional signals), communication skills (e.g. verbal and non-verbal), and repetitive behaviours (e.g. focus on parts or pieces and need for routines) as well as often display restricted and repetitive patterns of activities or interests since early childhood, which limit and impair everyday functioning, and are often referred to art therapy sessions [9-10]. Such problems require careful attention and development of a new design approach to support learning in the classroom. Complementing the learning process with creative activities (such as using art therapy, problem-solving, and decision-making) in the classroom provides an alternative medium of communication and expression for autistic children (especially useful for non-verbal students) and can help create an environment of controlled stimuli, helping to prevent children from becoming overwhelmed.

Addressing the complex classroom situation in schools requires full consideration of how autistic children interact with their environment.

Hence, this paper integrates DT, PD and AT approaches to develop a new model of design practice to enhance social perception, communication skills, and sensory sensitives challenges of autistic children and to support classroom teachers working with them. The model is conceptualised as a learning environment design-led practical sessions and toolkit (e.g., a tool for data collection, analysis, and interpretation; engagement materials and practices) to assist teachers in making informed choices about the planning and implementation of learning experiences for this student group. The research method considers participation of teachers, teaching assistants and students in the implementation process.

The research model and case study will be created and formulated developing ways via the DT approach, in which autistic children are well engaged in the PD processes as co-designers and contributed and participated in the designed practical sessions and used the devolved techniques and models toolkits comfortably. The methodology links to principal approaches (integrated with DT and PD), role of design in this complex context as a design-led approach and its principals are established.

We aim to assist teachers in modifying their traditional teaching style to incorporate new design-based practices through the adoption of this toolkit, and thus help autistic children to understand and take part in classroom activities more easily. Additionally, the applications of the toolkit that will be developed have the potential to be extended beyond the classroom environment.

The toolkit can be used to teach autistic children how to approach various key social interactions, communicate more effectively, and filter their environment in a way which is more understandable and manageable to them. Such skills can be transferred to their home environment and can greatly assist them in daily life. The education and development of autistic children can thus continue to flourish outside the classroom, and teachers can more easily cooperate to ensure the best outcomes for the children, as well as to increase their overall confidence and self-esteem.

3 RESEARCH MODEL

This study will follow the five-step of the DT approach [11], including: i) Emphasis (to watch, listen, observe, and engage); Define (statements of problem, views); Ideate (to identify problems and seek solutions); Prototype (building, problem-solving, testing, monitoring, and developing solutions); and Test (enhancing prototypes, optimising solutions, and liaising with end-users). The PD will also be adapted to carry out the design research process, investigate the problem with autistic children and their teachers in the classroom setting, research the problems and provide solutions to help them in their learning and development and to support teachers and teaching assistants while interacting with them. The relationship between the design process and the process of research have been highlighted [12] as showed that the commonalities are apparent in that both look through a method of determining a problem, commencing a sequence of steps to examine it and offer a practical solution. In all steps, there is a process of knowledge exploration to identify the design process. They are mainly emphasised on the process of searching for understanding, creating ideas, and providing solutions [12]. A new approach to enhance the learning outcomes of autistic children through a range of DT processes will be developed emphasising on the impact of PD on their social, communication, and sensory processing, which have not been profoundly considered using robust learning environment tool (as shown in Figure 1).

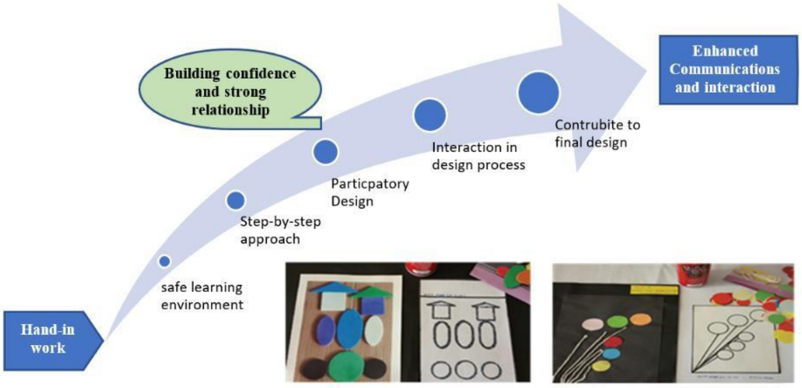


Figure 1. Enhanced learning environment- hand-in work and interaction in the DT process

Via several practical sessions, a new toolkit based-design will be developed and used by the autistic children as well as their teachers. The design process via the toolkit provided to autistic children will be a main source of practice once the practical sessions are completed. The main purpose of the toolkit is to serve as an easy tool to deal with problems and challenges those autistic children may face during the settings. The stimulating challenge of this study is to develop ways via the DT approach, in which autistic children will be engaged in PD as co-designers and can contribute and participate in the designed practical sessions and use the devolved toolkits easily. In addition, Figure 2 shows the main principles and approaches to be integrated within the research model.

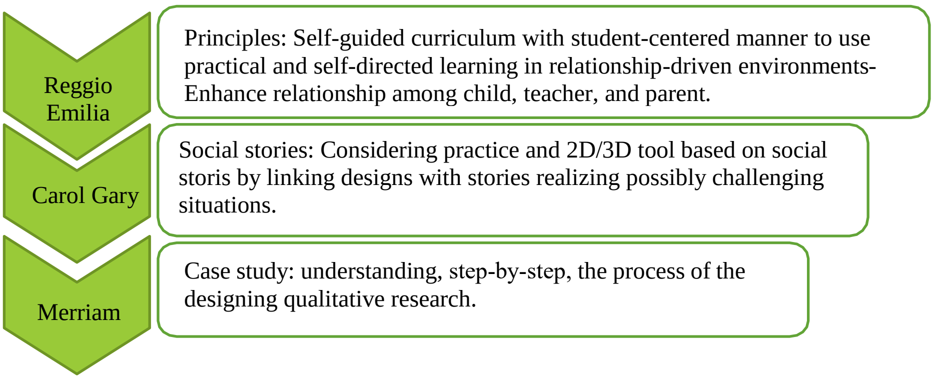


Figure 2. Methodology links to principal approaches (to be integrated with DT and PD approaches)

Reggio Emilia's main principles of enhancing the relationship between autistic children, teachers and partners will be considered [13]. Moreover, Social Stories will be used, inspired by Carol Gary's technique [14] to build the practical sessions and the toolkit's structure. Finally, the case study to be developed in the school will follow Merriam's principles on PD and educational theory [15].

4 INTEGRATED TOOLKIT

There are several strategies and skills which can help them to focus on paying attention, for instances choosing interesting activities (e.g., LEGO, 3D designs, and painting), providing efficient guidelines (e.g., limit the word numbers to be used, repeat key words, and break up instructions), creating model tasks, talking and playing while preparing the tasks as well as preparing them for transitions. Following both Reggio Emilia's approach as well as Carol Gary's writing Social Stories technique mentioned in previous sections, creating creative design process and tools are developed to support autistic children and their teachers in the complex learning environment of the classroom setting.

In this work, toolkits of several design elements are developed that are crucial to successful implementation of full virtual construction with visual stories, including how to design activities with vital elements to create secure and effective shapes and designs for autistic children. This will also allow separate steps and spaces to withdraw if sensory inputs become overwhelming, without the need to reinitiate the previous steps (e.g., provide opportunities for autistic children to do what they can to feel relaxed and happy). This provided an alternative strategy to the usual method of interaction and create dialogues between autistic children and their teachers by using tailored 3D models instead as a starting point for a more familiar language. The design of the toolkit is intended to be used by autistic children and their teaching assistants at primary schools as a case study to test its efficacy.

The applications of the toolkit have the potential to extend beyond the classroom environment. It highlights the need for an improved interchange between teachers and autistic children and encourage employing 3D models to communicate their ideas and expertise when designing. It is vital to understand that they have various potentials, which are all equally important. Visual interaction is a good way of helping them, allowing easy communication and interactions with teachers and teaching assistants.

The 3D toolkit design creative activities approach steps are as follows: Introduction the toolkit to the class teachers and teaching assistants in the classroom setting; Preparation stage (e.g. observe, engage, watch, and listen); Planned activity based on the school curriculum to support class teachers in the classroom setting; Test to fine prototypes and solutions and to learn about the users' needs; Observation and monitoring the outcomes; and Evaluation, reflection, feedback, and recommendations.

5 CASE STUDY DESIGN

This study will follow the case study methodology and the principles of Merriam [15] to integrate the participatory design, art therapy and educational theory approaches during complex classroom situations. The design and methods of the qualitative research and case study focus on understanding, step-by-step, the process of designing qualitative research, including i) Beginning with a detailed literature review to conceptualize the inquiry, to steer the development of a new theoretical framework; ii) Identifying the research problems and motivation; iii) Constructing and sharpening clear research questions; and iv) Selecting purposive and theoretical sampling [15].

<u>Educational Context:</u> This activity was undertaken at Marine Park Primary School, which included specialist ASD classrooms. The school is located in South Shields, Northeast of England, UK, and provides special classes to autistic children aged 3-11 years in different key stages. The school's related data is as follows: A large proportion of autistic children are from minority ethnic groups (70%); Gender of entry: mixed; School capacity: 238; Number of pupils: 198; Pupils with SEN support: 23.2%; English is not the first language: 59.1%; Ofsted rating: good. The head teacher was provided by relevant documents and letters describing the overall research study.

<u>Research Samples:</u> The number and size of the potential groups are a typical class size of the designated classroom in the selected school. Participants are autistic children, in primary schools, aged between (5-6 years old; boys). It is anticipated that, approximately, there will be around 2-4 children in the classroom setting, in addition to their class teachers, and teaching assistants who will also be involved. Critical peer review and experience mapping with a set of experience teaching practitioners. The experience teaching practitioners who have dealt with autistic children for several years and guided learning through classroom interactions. They have also adopted problem-solving techniques to their teaching and learning activities, monitored problems, and assessed levels of understanding and progress of their students. They mainly can attend to affective attributes and influence student outcomes.

A set of around 4 (average size) experienced teachers and academic experts in the school will be consulted to review the data generated in the case study passing critical commentary and mapping it out against their own experiences and challenges. This will generate the core features and properties of an enhanced PD to support teachers to adapt their classroom to the dynamic needs of their children.

6 PRACTICAL SESSION

Teaching styles with KS1 children with and without special education needs (SEN) in a classroom setting. Two different teaching styles are presented, as examples using a short story from KS1 curriculum, in Figures 3 and 4, respectively. In Figure 3, a traditional teaching style was presented by the class teacher with children without SEN as they can easily understand, copy work, and write their story based on their imagination. On the other hand, a new teaching style was presented by the practitioner, which was designed for autistic children, who cannot comprehend the traditional teaching style as they need tailored strategies encouraging visual attention using (e.g., 3D toolkit).

The KSI short story involves The Little Scared Bird: "Once upon a time, there were a happy couple women and man living together. One day they were walking slowly through the big forest. When they found three golden eggs! They carefully carried them back to their cosy home and gently put them in a brown basket. Suddenly, a tiny chick cracked out of the egg and ran away from home. The scared little bird was afraid to fly and tried to find a friend who doesn't fly like himself but found he doesn't really fit in with any of the other animals he stumbled upon. He found a mouse who cannot fly but also cannot get out of a hole. Then, he found a cat who cannot fly but also cannot get out of a box. Finally, as the little bird tried to help his new friends, he got over his fear and learned to fly!". The End!

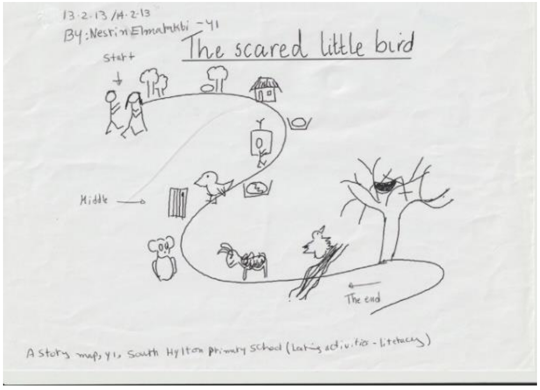


Figure 3. Traditional teaching style in a classroom setting- children without ASD

Figure 4. Creative design activities (3D toolkit) in a classroom setting - autistic children

The aim of the 3D toolkit (Figure 4) is to break down the lesson plans into more readily comprehensible components and translate tasks and worksheets into an immersive 3D learning experience. Inspired by theatre production, the toolkit will employ appropriate imagery, textures, music, etc. to bring the lesson to life in a way which autistic children can actively engage with the material at hand whilst also ensure that the visual, auditory, and tactile experience are not overwhelming to the students. In addition, we aim to assist teachers in modifying their traditional teaching style to incorporate new design-based practice through the adoption of such toolkits (to be developed for different cases and scenarios to accommodate a wide range of lessons and teaching style), and thus help autistic children to understand and take part in classroom activities more easily.

7 FINDINGS

Autistic children need extra help, time, and different teaching strategies in the learning environment using the developed methodology such as active production (e.g., images, numbers, texture, colours, letters, light, and music). The aim of the toolkit is to enhance visual attention, thinking and imagination skills, and provide opportunities for autistic children to encourage their self-esteem, self-confidence, self-express, and self-acceptance. In addition, the visual materials used by both schools (mainstream and special educational needs) are good but not as good enough for autistic children to make them independent, fully understand information and knowledge, follow the class teacher and teaching assistants, and interact with other children. In this case, the using of the 3D toolkit could help teachers, teaching assistants, and autistic children to cope with the classroom setting challenges such as social perception, communication skills, and sensory sensitives.

Addressing the complex classroom situation requires consideration of how autistic children interact with their environment, process visual information, communicate with peers and teachers, and how the curriculum can be delivered in an inclusive manner. Knowledge of the specific barriers faced by teachers in terms of understanding and accommodating to their students' needs is also imperative.

The DT process and PD will allow for such knowledge to be gained and thus help ensure the successful implementation of new creative thinking methods in the classroom setting. Despite the challenges faced in the complex classroom situation, positive changes made using the DT approach with the participation of autistic children in the PD process stimulated their engagements and interactions. The optimum balance between developed DT approach and real encouragement to autistic children to participate confidently is a major milestone towards enhancing their visual communications and social interactions.

Autistic children learned, through a variety of techniques, strategies, and basic elements of design, which helped them to open their mind, think visually, and enhance their problem-solving skills. The availability of regular classroom education techniques and materials as well as trained teachers can make a noticeable difference in how autistic children work and interact.

The integrated research models of DT, PD, and AT offered a holistic way to tackle the complex learning environment in the classroom setting of autistic children. Involving autistic children in the design process enhance social communication between autistic children, researcher, teachers, and teaching assistants, encourage their self-esteem, self-confidence, self-expression, self-acceptance, memory skills, problem-solving skills, and visual attention. In addition, the main idea of using the toolkit is to encourage the class teacher and teaching assistants to adopt a new teaching strategy in their classroom settings with autistic children. It allows them to actively practice and make decisions and choices, make mistakes, think creatively and imaginatively. Hence, they embraced their variety of creative interactions and were able to distinguish that they were in control of the learning process, giving them confidence and self-esteem. Teachers also adapted to the developed research model, making their classrooms more comfortable and enjoyable.

ACKNOWLEDGEMENT

The authors acknowledge the active collaboration provided by the Marine Park Primary School, UK.

REFERENCES

[1] Pfeiffer B., Koenig K., Kinnealey M., Sheppard M. and Henderson L. (2011). Effectiveness of Sensory Integration Interventions in Children with Autism Spectrum Disorders: A Pilot Study. *The American Journal of Occupational Therapy*, 65(1), 76-85.

[2] National Autistic Society. (2019). Communicating and interacting.

[3] Roman-Urrestarazu A., van Kessel R., Allison C., Matthews F., Brayne C. and Baron-Cohen S. (2021). Association of Race/Ethnicity and Social Disadvantage with Autism Prevalence in 7 Million School Children in England. *JAMA Predictions*, 175(6): e210054, 1-11.

[4] Goldsmith T. and Leblanc L. (2004). Use of technology in interventions for children with autism. *Journal of Early and Intensive Behaviour Intervention*, 1, 166-178.

[5] Mesibov G., Shea V. and Schopler E. (2007). *The TEACCH approach to autism spectrum disorders*, New York, Springer.

[6] Konstantinidis E., Luneski A., Frantzidis C., Nikolaidou M., Hitoglou-Antoniadou M. and Bamidis P. (2009). Information and Communication Technologies (ICT) for Enhanced Education of Autistic children. *Information Technology in Healthcare*, 7, 284-292.

[7] Moore D., Mcgrath P. and Thorpe J. (2000). Computer-Aided Learning for People with Autism - a Framework for Research and Development. *Innovations in Education & Training*,37,218-228.

[8] Miller H., Caçola P., Sherrod G., Patterson R., Bugnariu N. *Children with Autism Spectrum Disorder, Developmental Coordination Disorder, and typical development differ in characteristics of dynamic postural control*: A preliminary study. Gait Posture. 2019; 67:9-11.

[9] National Autistic Society. (2020). *Autism facts & history:how many people in the UK are autistic?*

[10] Schweizer C., Knorth E. J., Van Yperen T. A. and Spreen M. (2019). Consensus-based typical elements of art therapy with children with an autism spectrum disorder: Results of a Delphi study and a Focus Group discussion. *International Journal of Art Therapy*, 24(4), 181-191.

[11] Plattner H. Meinel C. and Weinberg U. (2009). *Design Thinking-Innovation* Lerner, Ideenwelten offnen. mi-Wirtschaftsbuch, München 2009, Gebundene Ausgabe, 240, ISBN-10: 3868800131.

[12] Press M. and Cooper R. (2003). *The Design Experience: The Role of Design and Designers in the Twenty-first Century* (Aldershot: Ashgate), 102.

[13] Arseven A. (2014). The Reggio Emilia approach and curriculum development process. *International Journal of Academic Research Part B,* 6(1), 166-171.

[14] Gray C. (2010). *The New Social Story Book: Revised & Expanded*. 10^{th} Anniversary Edition Paperback. Future Horizons Incorporated Publisher. ISBN: 978-1935274056.

[15] Merriam S. (1998). *Qualitative Research and Case Study Application in Education*. 2^{nd} Edition, San Francisco, CA: Jossey-Bass; 275 pages, ISBN: 9780787910099.

TOWARDS RE-IMAGINING INDUSTRIAL DESIGN EDUCATION FOR THE CONTEMPORARY PERIOD

William DIM[1], Ian de VERE[1,2] and Jacob SHEAHAN[1,2]
[1]RMIT University, Australia
[2]University of Lincoln, Australia

ABSTRACT
It is proposed that a progressive Industrial Design education should focus on supporting students in learning to self-manage ambiguity and bolster their agile independence throughout the tentative undergraduate years of growth [1]. As the field of Industrial Design moves beyond its industrial manufacturing roots, exploration of curricula that anticipates contemporary issues such as decolonisation, diverse participation and complexity in creative innovation is still not prevalent in this contemporary period [2]. Such a context necessitates an accelerated disruption to traditional design pedagogical practices [3], as seen in the RMIT University Industrial Design programme My First Six Months (MF6M) - a first-year learner-centred initiative situated around capacity development, student agency, self-efficacy, and disruption of expectations about the power dynamics in learning and teaching. This paper outlines the adoption of the RMIT University, My First 6 Months (MF6M) first-year learner-centred pedagogical alignment into the 2nd and 3rd year *vertically integrated* studio environment, through the case study 'Safeness by Design (SbD)– Enabling an Ageing Workforce' – a collaborative partnership with the Innovation Centre of WorkSafe Victoria, a state government safety regulatory body.
In curating the studio's outcomes, it became evident that the embedded predispositions developed throughout their MF6M experience, activated the diversity of students' thinking and acting in situations resembling real-world design practice, which achieved our SbD studio's pedagogical ambitions.
We found this model to be highly transferable, requiring less teaching staff intervention and giving more flexibility to students, by reinforcing notions of independence, trust and self-efficacy in learning. Students are scaffolded as they dynamically explore and frame their own inquiry questions and continue developing their professional identity throughout their studies. In doing so, the classroom is firmly situated as a safe and democratic creative space, whereby teaching staff adopt a coaching role to establish a collaborative partnership, to further support student capacity and confidence.

Keywords: Design pedagogy, design education, design learning, future perspectives, project based learning, self-efficacy, capacity development, industrial design education

1 INTRODUCTION
Industrial Design as we know it, is currently experiencing a divergent shift from 'old world' manufacturing based outputs, to diverse explorative futures where design is an agile skillset, being applied [2] to increasingly complex wicked problems [4]. In fact, the World Design Organisation [2] expands the definition of industrial design, well beyond its industrial manufacturing roots to "*a more optimistic way of looking at the future by reframing problems as opportunities"*. Linking *"innovation, technology, research, business, and customers to provide new value and competitive advantage across economic, social, and environmental spheres."* The context of which clearly extends the project focus from artefact based industrial outputs to that of information-driven ones. The ever increasing presence of technology [5], diverse arrays of non-traditional and multidisciplinary stakeholders [6], and the complex structures of emerging project forms, all make profound changes to the ways in which the profession operates. As design methodologies become employed more broadly, Industrial Designers are increasingly utilised for their capability to negotiate complex problems within cross-functional and multidisciplinary environments.
Even though there will always be a need for traditional Industrial Design artefact-based outputs [7], this contemporary focus places intensified pressure on education providers to innovate suitable pedagogy [8] to deal with the ambiguity and uncertainty of this contemporary space. The challenge will be in the

provision of relevant skills needed in an information society, emphasising an information, socio-cultural and technological focus, rather than a production-based one [9].
To this point, it appears that most educational systems still operate much as they did at the beginning of the twentieth century [9], delivering a standardised, content rich curriculum, that addresses traditional industrial production-based outputs [10]. In the design field, it heavily relies on a teacher-led approach through a master/apprentice crafts-based model, descended from the Bauhaus/Ulm schools, and delivered through abstracted design practice [3]. Its end goal is achieving a level of proficiency to be professional designers practicing through discrete vocational skills such as drawing, drafting, and engineering, etc. [11; 12].
However, in order to address the future facing needs of the profession, a relevant change in design education will not arise from a steady refinement of this traditional approach, but that the "*context change necessitates an accelerated disruption by breaking the lineage from artefact-based curricula and pedagogies and placing focus on intellectual flexibility and concern for human values*" [3]. Exploration of curricula that anticipates contemporary issues such as decolonisation, diverse participation and complexity in creative innovation is still not prevalent in this contemporary period. It is proposed that a progressive Industrial Design education should focus on supporting students in learning to self-manage ambiguity, strengthen their independence, and promote agility throughout their undergraduate years of growth [1].

2 PROGRESSIVE APPROACHES TO PEDAGOGY

Given the increasingly uncertain environment that design exists within, there seems to be no one right way to design, and by proxy, no one right way to teach it. This in turn, creates complexity in how we define a progressive approach to industrial design pedagogy and how we could address future needs of the profession in an educational setting.
Reflecting on this uncertainty, we seek to capture and distil the essence of a progressive pedagogy, by gathering and integrating some key characteristics from the field of learner-centred educational theories:

- Active engagement in the "*hard, messy work of learning"* [13].
- Motivation to take ownership of learning by shifting the locus of control over learning processes [14].
- Encouraging collaboration, and social construction of knowledge where the learning agenda is shared by all [3].
- And the reflection on learning outcomes and how learning takes place [29; 30].

In selecting these elements, an attempt at a framework or the philosophy of an approach is made, grounding practice and instructional decision making through the notions of deep / transformative learning, self-efficacy [14], and the learner's innate ability in problem-solving [15].
By leveraging authentic tasks and scenarios [18] at the heart of "doing" the subject [15], projects are purposefully situated in ill-defined and ambiguous environments [16], which require an emphasis on multilateral integration of knowledge, skills, and attitudes, with a performance-oriented capability [17]. Power relations in the classroom are aligned to embody partnering dispositions, and the role of the educator is reimagined to work alongside students in supporting and prompting, but not leading their learning [22]. Then practically applying the approach, through the notion of Shulman's signature pedagogies, (Shreeve [19] lists as: studio, project, brief, materiality, dialogue, presentation and the crit.), coupled with guidance from deep pedagogical content knowledge [20], steers learners toward connections with its Community of Practice [21], by privileging the notion of "Design is what Designers Do" [19].
Furthermore, challenging and assessing outcomes, heavily incorporate the practice of reflection and self-assessment [29; 30], reinforcing the learners sense of self-efficacy to channel authentic understanding of curriculum and assessment.

3 CASES FOR CHANGE

Against this changing context for the Industrial Design discipline, the Industrial Design programme at RMIT University plunges students into a research-intensive trajectory that provides opportunities through multiple pathways of design practice including product design for manufacture, interaction design, vehicle design, service design and various art aligned creative practice pathways - all culminating in a significant final year project.

Beyond the foundation year, the pedagogy of the design studio typically uses a vertically integrated model from the second year of the programme, whereby 2nd/3rd year students are combined to learn in studios of their choice. Students are not within their specific year level in studio settings, which requires them to be agile, collaborative, able to self-manage ambiguity within their studio projects, and have high levels of independence to successfully engage.

The need to build capacity in our students from day one, sparked a series of questions concerned with the nature of appropriate 21st century design education, which led to an in-depth assessment of abilities that first year University students needed to function expertly in their second year and beyond.

3.1 Response to change – My First 6 Months (MF6M)

The outcomes of the assessment surrounding student capacity, formed a progressive learner-centred pedagogical approach, across a series of foundation year courses titled *My First Six Months* (MF6M). The aim is to shift the delivery approach, by incorporating "*learning and teaching practices that would encourage students to engage in learning that was personal and socially constructed through their interactions, negotiations and collaboration with peers and teachers, privileging the notion of 'students as partners'*" [22].

These outcomes also drive how the pedagogy and assessment practices of the first-year courses within MF6M were designed. Our intention is to cultivate students' independence and self-regulation as learners [14], fostering their individual development and confidence *"by shifting the locus of control from teacher to learner [23] rather than default to teaching as a performative representation of an assumed or unconscious habitus in design [24]."[22]*.

As a team, we acknowledge that there is no one specific way of '*doing'* design. We draw on constructivist theory and development discourse [25; 27] to then visualise the semester as a 'container' of social, cultural, and work practices rooted in a project-based mode of delivery [18]. This practice attributes learning as staged or performative in the '*act*' of designing. By incorporating a pedagogical approach that privileges students' prior learning, we are therefore open to the ways of the '*doing'* or the '*practising'* of design [19] which embraces diversity and acknowledges authenticity in a space that is student-oriented, and focussed upon the educating event [3].

3.2 Gauging success

Having focussed upon capacity development in the individual student and disrupting expectations about the power dynamics of learning, we found the first-year initiative successfully establishes student's agency and self-efficacy, through application of:

Project-based learning models to encourage practice culture - we observe that students work in tighter peer groups, build more agile teams, with higher levels of self-reliance, and independence. They share and construct knowledge though dynamically engaging in-class discussion and activated peer to peer exchanges.

Modelling professional practice - we regularly invite industry and academic colleagues to sit in on 'glass box' studio presentations, to make connections with the community of practice and stimulate collaboration within the cohort. This often leads to industry acknowledging the quality of students work, and has led to development opportunities, internships, and entrepreneurial outcomes.

Regular formal and informal presentations - privileging the student's voice to build formative and constructive critique, and authentically engage their own critical articulation. We see the success of the approach manifest through high achieving project outcomes where students have developed sophisticated presentations, pitch decks, posters, and various visual media.

Collaborative design of learning and assessment tasks - they work through situations where they must think fast and slow and take responsibility as 'business owners' to reach project outcomes. They do not have imposed benchmarks but feel confident to independently set their own solutions and standards in developing responses to ambiguous design briefs.

Building reflective practice into the studio - students actively engage in, and demonstrate a deep understanding of self-assessment, enabling self-regulation, and sophisticated integration of learning.

Adopt a coaching role or collaborative partnership – we see students take the lead in their own learning, by readily following their own and their peers' intuitive responses to creative problem solving.

The success of this model is highly transferable as it enables us to 'wrap' thematic and agile approaches around student learning every semester. As the diverse nature of projects, classrooms, and associated modes of delivery can vary every semester, we successively shift and align with whatever learning and teaching context best suits each cohort, and then each individual students' needs within that.

4 BUILDING ON CHANGE

As MF6M has been conducted for several years, its graduates are firmly embedded throughout all year levels of the programme. Appropriating the model beyond the foundation year, provides an opportunity to build on already activated learner agency and their sense of self-efficacy. As students' progress through the vertically integrated studio system, we seek to adopt, adapt and determine the impact of the MF6M model, by observing students' development, agency, work practices, and outcomes in the Safeness by Design (SbD) studio space.

4.1 Safeness by Design (SbD) - studio

Since 2019, the SbD studio has been using research and design innovation to provoke conversations that may direct the creation of safer environments and demonstrate the power of design to make a positive contribution to society.

In late 2021, 'Enabling an Ageing Workforce' was the first collaborative project between RMIT University's SbD initiative and the Innovation Centre of WorkSafe Victoria, providing an opportunity for SbD researchers and RMIT Industrial Design students to develop innovative and future-focused design interventions aligned to WorkSafe's current areas of priority.

Specifically, it is a collaborative themed studio exploration (with an external partner) in which students are introduced to the broad topic areas of ageing, wellbeing, and workplace safeness. As they immerse themselves within that proposed space, the intent is to provide a broad scope for students to connect with authentic areas of interest. Working in small design teams, students instigate their own research enquiry responses to complex problems, supported by peers and expertise from tutors and industry.

4.2 Safeness by Design (SbD) – pedagogical approach

This studio uses MF6M as an exemplar learning and teaching model and incorporates two further dimensions of future facing professional practice: *extensive exploratory research through comprehensive review of literature,* (and to reposition the studio from abstract or representational, to a real-world inquiry) *a relevant industry specific investigation with appropriate stakeholders*.

Facilitating the approach, we divide the engagement into several short, accessible, and 'intensive' milestones, iteratively spread over the longer complex project. The 'intensives' are designed to provide opportunities for continuous formative feedback, thereby reassuring the anxieties associated with navigating the complexities of ill-defined and ambiguous problems. Supporting the process further, the provision of all rubrics and measures, up-front, ensures a completely transparent process for students to match or push their comfort zones, as desired. We want students to feel free to explore their own understanding and language of design concepts, nurtured through emerging and ongoing dialogues with peers, teachers and external partners about the quality and standards of their work [29; 30].

Throughout the semester students intensively explore their self-directed investigation, initially by immersing themselves in the relevant discourse of the field and then engaging in a studio wide dialogue. The aim is for students to collaboratively transition from a 'liminal state' [28], iteratively progressing through outcomes, to form clear problem definitions. Students are framed as critical thinkers who can creatively explore problems and ideas, developing confidence to do this self-reliantly and away from the approval of teachers. We advocate that student designers examine their own understanding of user behaviour and situational contexts, relative to others, by responding authentically to safety concerns through their own unique design proposals and/or interventions. Rather than a design specialisation, exploring a socially constructed understanding around user-centred design, accompanied by behavioural considerations and a broad production knowledge base, the process seeks to form a generalist and multidisciplinary approach in realising social impact through a safeness agenda.

Augmenting the research investigation, we concurrently look to the industry partners expertise with consultation and feedback on progress outcomes of the real-world studio engagement, to scaffold the space around students, and kindle their professional identity development from the outset of their studies. By validating their capacity and confidence as designers [3; 19], students are all called on to form the backbone of the review process and give feedback to peers throughout the semester - this is intended to also support students to find their voice, constructively critique peers and openly listen to feedback about their own work. This is enacted at the conclusion of each intensive, in a whole class review comprising industry representatives, academic staff, and peers as an extended sharing and reflection event. We design this activity to model professional practice and stimulate collaboration between students, thus enhancing engagement and rapid capability acquisition. The sessions are recorded to produce a collective and participatory account of achievements and individual learnings from each intensive stage.

5 CONCLUSIONS

Lecturers observed and confirmed - that the progressive learner-centred framework proposed and conducted in the MF6M context, is a highly transferable approach across studio contexts and was an appropriate exemplar to adopt, validating our pedagogical ambitions.

Student behaviours were demonstrative of notions within constructivist theory and development discourse which supposes that there is no one specific way of ‘doing’ or ‘practicing’ of design. Instead, the enhanced student agency has revealed research outcomes that reflected the high participant diversity in the complex creative innovation requirements of this project.

In curating the studio’s project outcomes, it became evident that the diversity of students’ thinking and acting in situations resembling real-world design practice, led to intersections which are innovative, and highly appropriate to the industries and context for which they are proposed.

This pedagogical approach required considerably less direct intervention from teaching staff, affording students greater creative freedom and flexibility, thus reinforcing notions of independence, trust, and self-efficacy. In doing so, the classroom is firmly situated as a safe and democratic creative space, whereby teaching staff adopt a coaching role to establish a collaborative partnership, to further support student capacity and confidence.

The iterative ‘intensives’ achieved intent, to socialise students’ knowledge over compressed periods and created an immediacy in their ability to implement their learnings. As a result, we noticed that the depth of their content response was nuanced, their communication was more concise, posters were arranged more cohesively, videos were better quality, and their presentations wholly more "professional".

We found that students were enthusiastically engaged and readily gave each other feedback during the presentations, which we collated electronically. This meant that students received all feedback in a permanent format, unlike the spoken word, and were able to reflect on specific recommendations about their work to independently assess their capabilities, concurrently develop their ‘critical eye’ and understand the gap between what they know and where they want to be. We saw this happening through multiple iterations of their projects as they presented each week, and then in the building blocks of each next phase in their project.

For the researchers - we conducted a simultaneous and comprehensive investigation into the literature on the studio topic, which offered a large scope for inquiry across multiple industries and contexts. We found the students research responses greatly assisted in building a knowledge repository, which flowed back and forth fluidly, refining the studio collective's understanding and direction.

The studio partner - was surprised by the deeply engaged pace of the studio, the range of the design proposals and the quality of outputs. Students delivered solutions attuned to both the physiological and psychological needs of workers, but also effectively imagining and anticipating the future cultural, behavioural, environmental, and technical challenges.

Specifically noting that *“…the outcome for us is a combination of many things - high quality work, innovative desirable concepts, inspiring dialogue, the experience of collaborating with students, and the new connections we’ve made - which we bring back to our workplace as motivation and reference for our future practice”*. The studio partner also noted that “*some of the concepts are ‘accelerator ready’ - even in this early stage, there is a clear line-of-sight to tangible impact and benefit pools*” which are now being explored for entrepreneurial opportunities and further development.

ACKNOWLEDGEMENTS

The authors acknowledge the contribution of the My First 6 Months creators, Soumitri Varadarajan and Helen McLean for their learning and teaching expertise within the University’s pedagogical ecosystem. We also pay tribute to the extraordinary efforts of the students who, during a prolonged pandemic lockdown, responded to the project brief with enthusiasm and dedication, achieving insightful and impactful outcomes.

REFERENCES

[1] Novoa M. 2018. Innovating Industrial Design Curriculum in a Knowledge-Based, Participatory and Digital Era, *Design and Technology Education*, vol. 23, no. 3, pp. 154-204.

[2] WDO 2020, *Definition of Industrial Design - Expanded*, viewed Retrieved October 19, 2020,

<https://wdo.org/about/definition/>.

[3] Davis M. 2017. *Teaching design : a guide to curriculum and pedagogy for college design faculty and teachers who use design in their classrooms*, Allworth Press, New York, NY.

[4] Buchanan R. 1992. Wicked Problems in Design Thinking, *Design Issues*, vol. 8, no. 2, pp. 5-21.

[5] Trilling B. and Fadel C. 2009. *21st Century Skills: Learning for Life in Our Times*, 1. Aufl.1st ed. edn, Hoboken: Jossey-Bass, Hoboken.

[6] Meyer M. W. and Norman D. 2020. Changing Design Education for the 21st Century, *She Ji: The Journal of Design, Economics, and Innovation*, vol. 6, no. 1, pp. 13-49.

[7] Norman D. A. 2016. When You Come to a Fork in the Road, Take It: The Future of Design, *She ji*, vol. 2, no. 4, pp. 343-348.

[8] Bast G. and Carayannis E. G. 2019. *The Future of Education and Labor*, 1st ed. 2019. edn, Arts, Research, Innovation and Society, Springer International Publishing, Cham.

[9] Griffin P., McGaw B. and Care E. 2012. *Assessment and Teaching of 21st Century Skills*, 1st ed. 2012. edn, Springer Netherlands : Imprint: Springer, Dordrecht.

[10] Barr R. B. and Tagg J. 1995. From Teaching to Learning — A New Paradigm For Undergraduate Education, *Change (New Rochelle, N.Y.)*, vol. 27, no. 6, pp. 12-26.

[11] DeVere I. and Fennessy L. 2019. *REDEFINING INDUSTRIAL DESIGN: RESPONDING TO EMERGING MODES OF PRACTICE*.

[12] Raman A. and Rathakrishnan M. 2019. The Future of Product Design Education Industry 4.0, in, IGI Global, pp. 164-182.

[13] Weimer M. 2013. *Learner-Centered Teaching: Five Key Changes to Practice*, 2. Aufl. edn, Somerset: Jossey-Bass, Somerset.

[14] Bandura A. 1997. *Self-efficacy : the exercise of control*, W.H. Freeman, New York.

[15] Wiggins G. P. and McTighe J. 2005, *Understanding by design*, 2nd expanded ed. edn, Hawker Brownlow Education, Heatherton, Vic.

[16] Baartman L. K. J. and Bruijn E. 2011. Integrating knowledge, skills and attitudes: Conceptualising learning processes towards vocational competence, *Educational Research Review*, vol. 6.

[17] Rotherham A. J. and Willingham D. 2009. 21st CENTURY SKILLS: The Challenges Ahead, *Educational leadership.*, vol. 67, no. 1, p. 16.

[18] Bell S. 2010. Project-Based Learning for the 21st Century: Skills for the Future, *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, vol. 83, no. 2, pp. 39-43.

[19] Tovey M. 2016. *Design pedagogy: Developments in art and design education,* Routledge, London, [England] New York, New York.

[20] Kenneth R. P., Michael A. D. M. and Jinseup T. S. 2009. Pedagogical Content Knowledge and Industrial Design Education, *The Journal of technology studies*, vol. 35, no. 2, pp. 47-55.

[21] Lave J. and Wenger E 1991, *Situated learning : legitimate peripheral participation*, Learning in doing, Cambridge University Press, Cambridge [England].

[22] McLean H. and Varadarajan S. 2020. My First Six Months: Students' Perceptions of Learner-Centred Design Studios, in, Springer Singapore, Singapore, pp. 143-153.

[23] Goodyear P.and Dimitriadis Y. 2013. In medias res: reframing design for learning, *Research in learning technology*, vol. 21, no. 2013, pp. 1-13.

[24] Webster H. 2005. The Architectural Review: A study of ritual, acculturation and reproduction in architectural education, *Arts and humanities in higher education*, vol. 4, no. 3, pp. 265-282.

[25] Dewey J. 2012. *Democracy and Education*, Start Publishing LLC, <http://ebookcentral.proquest.com/lib/rmit/detail.action?docID=1078477>.

[26] Freire P., Ramos M. B, Macedo D. P. and Shor I 2018. *Pedagogy of the oppressed*, 50 anniversary edition. edn, Bloomsbury Academic, New York.

[27] Postman N. and Weingartner C 1971. *Teaching as a subversive activity*, Delacorte Press, NY.

[28] Land R., Meyer J. H. F. and Flanagan M. T. 2016. *Threshold concepts in practice*, Educational Futures, Rethinking Theory and Practice, Sense Publishers, Rotterdam.

[29] Boud D. 2000. Sustainable Assessment: Rethinking assessment for the learning society, *Studies in continuing education*, vol. 22, no. 2, pp. 151-167.

[30] Sambell K., McDowell L. and Montgomery C. 2012. *Assessment for Learning in Higher Education*, Taylor & Francis Group, London, UNITED KINGDOM, <http://ebookcentral.proquest.com/lib/rmit/detail.action?docID=1020266>.

DESIGN FOR SENTIMENT-ANCY: CONCEPTUAL FRAMEWORK TO IMPROVE USER'S WELL-BEING THROUGH FOSTERING EMOTIONAL ATTACHMENT IN THE USER EXPERIENCE WITH THEIR ASSISTIVE DEVICES

Saiba QUQANDI[1], Paul LIGHTERNESS[2] and Leon WILLIAMS[2]
[1]Immam Abdulrahman Bin Faisal University, Saudi Arabia
[2]Cranfield Centre for Competitive Creative Design, Cranfield University, United Kingdom

ABSTRACT
This study investigates how the ageing population interact with objects, what kind of bond individuals form using their assistive devices, and what methods are applied during the product design process to help improve the user experience leading to a long-term product relationship? This research aims to conduct a longitudinal study involving/discussing the interplay between end-user, designer and product. By developing an evaluation tool with which to describe and analyse the bond people form with their assistive devices and integrate the human emotions as a factor during the development of the product design process. The focus will be on the assistive technology market, namely, the aid-for-daily-living market targeting the seniors in the UK, to increase the quality of wellbeing. Findings will enable a better understanding of the real issues of the product experience relating to individuals' interaction throughout the product performance, establishing awareness of the emotional effects of fostering the product attachment, and help product developers and future designers create a connection between users and their assistive devices. The research concludes by discussing the implications of these findings for professionals and academics to identify new areas that can stimulate new /or developed design directions. The result of this paper will define plans for further investigation as part of a current PhD research project. Framework and evaluation tools are currently being developed and will soon follow this publication.

Keywords: Experience design, interaction design, emotional attachment, social science, assistive technology, inclusive design, user-centred design

1 INTRODUCTION
Ageing or impairments should not restrict people's lifestyle, so why should people with less ability be excluded from a simple routine task when the tools and technology exist in the marketplace to overcome these obstacles [7]. Having an impairment in our society today has many implications, as many cases of individuals being overlooked and missing a great deal of attention in some areas. The societal stigma of being viewed as a disability due to weakness in the abilities, whether visual, hearing or mobility impaired, excludes individuals from taking part in basic life activities, thus restricting them from equal access to social, leisure and routine-al activities. Over time, we all get older, and we are subjected to experience age-related changes of physical, sensory, or cognitive decline. Opportunities and services for the ageing population across the globe are growing fast, and this change touches every aspect of our life, extending from career living to health. There is an extensive investment in research to understand how and why we age as well as the undergoing developments in independent living [2]. Yet, there is little attention and limited understanding has been paid to the "missing market": assistive devices [3]. Assistive technology (AT); has a significant role in improving people's life quality, especially for individuals who are challenging age-related changes or with special needs. According to the Assistive Technology Act 1998, AT is defined as; any item, piece of equipment, product or service used to perform activities and compensate for functional decline [10]. It can vary in the shape of a mobility aid such as a wheelchair, a walking stick, accessibility aid such as bathroom bars, ramps, or performance aids such as dressing or feeding tools (which will be explored more comprehensively later in the literature). It has

been claimed that AT is meant to fulfil user needs, enhance life quality, decrease disability and promote equal social status. Despite all the advantages, concerns have been documented since the 1970s about individuals' responses towards the technology. There are still some barriers that cause users to reject or abandon this technology. AT is considered a medical device often designed based on the medical model of disability or ageing whilst ignoring the social model. It follows an inclusive design approach that mainly focuses on usability and functional aspects, neglecting user-product interaction in terms of desirability and meaning [3].

2 LITERATURE REVIEW

There are numerous arguments addressed by several researchers [28], [20], [19], [17], [12], these arguments show that users' cultural background, emotions and psychological needs can affect their perception and expectations of products; still, manufacturers and designers have been trying to standardize this perception. Standardizing User-experience-design (UX) helps in the short term; however, it ties the future of UX innovation to the standard/traditional value [20]. And the drawback of standardizing the design for a large variety of user segmentation can cause danger of complication and ambiguity, which may frustrate users rather than facilitate the desired experience [21].

2.1 Ageing and assistive technology (AT)

The demographic of the ageing population across the whole world continues to increase as part of a global phenomenon. According to the latest statistics in 2018 from the office of national statistics, there are 11.9 million resident’s over-65 in the UK, representing 18.2% of the total population. This is predicted to increase to 20.7% of the total population between 2018 and 2028 [8]. This increase highlights the importance of assistive technology as an essential tool to maintain independence and live regular life independently. Ageing is a natural part of the human experience, and as we all are going to age with a sort of physical changes or functional decline, inevitable these changes touch every aspect of our lives. We are entitled to continue to be integrated into society without any limitation, wondering how we will live now with all the challenges related to ageing and how we expect to live in the future? This fact highlights the importance of AT as a fundamental life aid to empower the individual’s abilities, enabling continued independence in daily functioning. Individuals who use assistive devices in the home form a complex bond, either by accepting or abandoning their devices regardless of the reason, as they end up in the closet or under the bed or damaged, broken or lost. Although AT is valued for improving daily life and supporting older people with functional decline and/or impairments, many AT devices and services are abandoned after experiencing their use [9]. The process underlying the decision to adopt or reject any given AT is a complex process that requires further exploration in examining how individuals perceive AT and react to the user experience in daily life. Several theoretical models have been developed to explain technology adaptation; however, these studies emphasize the functional and instrumental nature of such acceptance and have not captured all the aspects of cognition and behaviours [4]. The exclusive perspective on designing products and services centred around age or impairments relates ageing to deficiency and incapability. The target users usually reject products and services designed based on the medical model, which may stigmatise them and reduce self-esteem [3]. The acceptance of ATs by older users is essential in both industry and research. Despite the benefits of using AT, the need for AT is still lagging in terms of the utilization rate and has not yet translated into a willingness to use it [4].

2.2 User experience (UX)

Product design and User-experience-design (UX) emphasize the role of product function and usability in creating an effective/compelling user experience and increasing the product life span. However, the coming arguments have been agreed that product usability is not the only factor that impacts the user experience. In fact, many products have been abandoned or replaced because they fail to keep an emotional and psychological bond with their users. Forlizzi and Battarbee [28] debated emotion as the heart of any UX and the essential component of product interaction; emotion can be shaped by two standpoints: psychology and design, where emotion plays a crucial motive in what users experience to understand and interact with a product. Diehl & Christiaans [24] claimed that users' psychological and sociocultural backgrounds were denied in the design process, where the market drive is built for consumption. In a long-term study, Roto [20] noticed that when users give feedback, they tend not only to explain the utility and usability of the system but also social and emotional aspects. Also, Hassenzahl

[19] questioned; why someone owns and uses a particular product? Then argued that utility and usability should relate to potential tasks that acquire an evaluation of pleasure (hedonics) that focus on the Self. Mahlke [22] defined usability as a traditional quality to measure one aspect of UX and reach the ideal UX; it should involve three qualities: instrumental interaction, non-instrumental perception, and emotional user reaction. Fenko and Schifferstein [17] advised UX theoretical models' design direction to take integrative processes that combine all sensory properties of products and emotional and cognitive contents to get an effective product interaction. Inconsistent with the previous studies, Partala and Saari [12] reported a high emotional experience in product use, as emotion plays a dominant role in UX. Other fields categorize UX approaches into three groups: one direction takes the user as a perspective, others attempt to understand experience through the product, and a tertiary group defines user experience as an interaction between user and product. However, Forlizzi and Battarbee [28] have argued that an interaction-centred view is the most practical approach for understanding how a user can experience a product. Hassenzahl and Tractinsky [25] took a brief look at three prominent perspectives, as each view contributes to understanding users' interactions. Nevertheless, none of these perspectives fully captures UX as the UX perspective took a severe shift, from designing for pleasure rather than for the absence of pain. This perspective is based on creating an outstanding quality experience rather than merely preventing usability problems and can happen by aiming for experiential and emotional user-experience beyond the functionality. Focusing on the positive aspects mirrors a new trend in psychology which has been argued to deal with human strengths and promote well-being rather than aiming at human weaknesses and healing [25], adapted from; [37]. Existing literature from Hassenzahl [25], Chen [4] and Yoon et al. [1] all conclude their discussion that the current design approach adopts "problem-driven", "absence of pain", and "curing disease" to avoid/reduce negative emotion rather than implementing positive emotions and pleasurable experience. Hassenzahl [25] explained how the new future direction in psychology contributes to the quality of life and promotes positivity by designing, on the contrary, for pleasure (Hedonic) rather than preventing function and usability problems. Hancock et al. [26] pointed out that it is essential to consider both directions by promoting positive, pleasurable experiences and avoiding frustration, pain, and stress associated with product usage. According to Ko, Ramirez, and Ward [11], users need to obtain pleasing and satisfactory interactions to become attached to their possessions; this pleasure can be fulfilled by the four key elements of pleasure experience (physiological, sociological, psychological, and ideological).

2.3 Emotional attachment

In the late 19th to early 20th century, architect Sullivan's concept of "form follows function" [15] was dominant. Based on the idea that the shape of an object or building should be designed to follow mostly its purpose and function, not its aesthetic appeal. On the other hand, Don Norman [27], the inventor of the term "user experience" and the founder of "Emotional Design", argued that attractive things work better in creating the experience because a pleasantly appealing design creates a positive emotional response in the brain and thus improves human cognitive abilities, which is reflecting positively on the user-experience.

Desmet and Hekkert [21] argued that "product experience" refers to three aspects of interaction; that trigger certain emotions upon using a specific product. These emotions can be shaped by the user's characteristics (physical actions, cognitive processes, and emotions), the product's specifications, and human behaviours, in addition to the context. Each of these components has its own ability to affect the relationship between the user and the physical item (product) at every stage, beginning from when the users make the purchase and ending up owning it. They conclude by the three components of the user-experience design process: aesthetics, meaning, and emotional response, to be designed satisfactorily. Accordingly, discussing Norman's work [27], "Human Action Cycle" from a social science perspective, and incorporating it into the "Product Creation Process" [20] from a product design perspective will lead this research to a narrative perspective for the attachment experience. This cycle starts firstly by observing a product and then getting attracted to its aesthetic appeal/novelty, whether it is colour, shape or material. Then, attach a specific meaning to it, according to a place, memory, association, or familiarity. Afterwards, engagement with it according to the type of emotion this product triggers, which depends on its use, whether negative or positive.

(Product) is the external stimulus that provokes an internal response (emotions), processed by the brain to shape the physical action (attachment). Emotion is the cognitive system that plays an essential part in every decision-making process; emotions influence our actions and control our thoughts in shaping our memories [5]. On the other hand, attachment is driven by a behavioural system common among all mammals and humans, which is programmed to keep infants close to their caregiver, in reference to John Bowlby's evolutionary theory. Emotional attachment happens when emotional actions accrue to form a bond with other humans, a pet, or an object which has the characteristics of social relationships, which consists of; (physical presence, autonomy, and ability to adapt and communicate) [16]. Product emotional attachment; is an emotional bond that a consumer experiences with a significant object [29]. Researchers suggested that in order to design meaningful products, it requires collaborating with various disciplines, taking into consideration human needs, emotions, capabilities, and values as new areas when designing AT. Referring to a recent study by Chen [4] shows positive emotions along with negative emotions play an important role directly or indirectly in AT usage. Emotional bonds develop over a period of time, so only through a comprehensive understanding of emotional relationships, designers can create products that bring positive emotional responses during ownership. Fayazi and Frankel [3] indicate that there is an opportunity in the market for AT to be designed to not only alleviate the stigma associated with devices but also sustain long-term-product attachment. Likewise, Chen [4] claimed that supporting older individuals in pursuit of well-being through AT is by combining theories on technology acceptance, constructs in emotional experience, and theory on psychology. He also emphasized that not focusing on product usability only, but also on psychological needs and positive experience must be considered from design and development to the implementation processes. Nevertheless, emotional, and psychological concerns for the ageing population should be reflected as a critical factor in the process of AT design and development [4].

Optimizing the product-owning period through strengthening emotional bonding between users and their possessions, has been found to be effective in postponing the psychological abandoning of a product. In this regard, several design strategies have been proposed to trigger emotional attachment toward products; this has been studied through concepts like "emotionally durable design" [23] and "product attachment" [18]. Design practitioners and researchers have identified product-emotional attachment as a design strategy for postponing premature product disposal. However, limited research has been conducted to support this strategy for promoting sustainable consumption [11]. In order to influence users' behaviour toward the product through the design and development process, designers need to consider the emotional attachment between users and their possessions. Such strategies have been suggested to avoid or postpone product abandonment [4].

3 DISCUSSION AND FOLLOW-UP STUDY

Addressing human needs is a fundamental mission for a successful design; human needs and interaction are the core concepts designers tend to follow when starting any invention or making even minor design developments. Lupton [15] defined people from a design perspective; people are the gear that makes any design function, where people can be classified as users, customers, vendors, and designers. Users play the primary role in the design process and the product's use thereafter. So, what force can drive a particular design? Forces can range from the economic interest of firms and manufacturers to the personal belief of the designer, or a request by a client, and can also relate to the most common way for a manufacturer, or simply because this is how things have always been. Fayazi and Frankel [3] argued that advanced technology often drives design innovations rather than sensitivity to human needs, abilities, motivation, and cultural values.

User-experiences with their assistive devices can elicit significant emotional responses to form the product bond; however, existing products do not meet the criteria to form a healthy emotional attachment and most users struggle to achieve a long-term product relationship. Further exploration and in-depth study are required on this subject, as some barriers that cause users to reject or abandon their assistive devices remain not fully captured. Ultimately, findings indicate that emotional experiences have not been examined in the context of ATs acceptance by older people, which is mainly left unexplored [14], [13]. Existing methods, approaches, perspectives, and the underlying theories cannot deliver the new change required in UX; however, some researchers point out empirical studies are needed to link all the experience attributes [30]. Longitudinal research needs to be performed to get tangible facts to create the user-product bond. As Mugge et al. [18] believed, the more consumers could act as co-designers of their product, the more effort they will invest in the product; thus, the more likely to create a stronger emotional bond. The focus on user-centred design has inspired a shift from behaviour and cognition only to human involvement; this shift means building an effective user experience where various disciplines are involved. Social science offers a clear basis for experimental theories that can structure some of the discussion in the design education and design process, so the multidisciplinary approaches of; product design user experience will be incorporated along with ideas from social science, particularly “attachment theory.” This will positively incorporate a combined design, social and health needs that will help deliver a better experience for AT users and eventually increase well-being [6].

Based on much of the literature reviewed to date, the focus has been on the qualitative literature only, of the current approaches and frameworks about the design of emotionally engaging products. Yet, this research focuses on both quantitative and qualitative data to investigate the employment of emotions to overcome ageing difficulties in the user experience with their assistive devices by encouraging attachment. This study does not seek to develop a particular product but to develop a conceptual framework to guide the new design direction and develop a simple solution to add value to the future/existing market. This doctoral research will follow the methodologies and measures used by post studies, with alterations to fit the purpose of this research. This study aims to explore the subjective feelings towards AT among seniors. It begins by reviewing the literature concerning assistive devices and older adults' attachment to AT, introducing the most relevant theories on UX and concepts from anthropology, psychology, and neuroscience to be combined as research tools. This tool was designed carefully to suit the sample group. As people cannot express how exactly they feel, they can show it in the shape of evocative tasks, which follows the user-centric design approach (UCD), also known as 'Empathic design ", and can be flexibly constructed. Then, pursue investigating seniors' difficulties, interactions, and behaviours while using AT. That will be performed through three sequential stages of three size sample groups. The data should help define the scope of this research and construct a clear work-frame to influence the next stage of the primary research process. Due to the size of the sample group, the research tool will evolve to shape a set of evocative tasks using a web-based template to obtain inspirational responses from people and get an asymptotic clue about their thoughts and emotions. The results should address all the influencing aspects, which will be analysed to define the significant key issues that impact the attachment.

This research will focus on the assistive technology market and, specifically, the Aid-For-Daily-Living market for situational impairments (ageing and life situation impairments). This is because the nature of the relationship between the user and the assistive device demands a high degree of emotional bonding. Based on the researchers’ experience, literature, and initial observation of the problem, this research argues that, if this attachment occurs successfully, it will help serve several other aspects of the main goal that operating the assistive-device function; It motivates regular use, increases independence, and improves psychological and physical functionality, it also leads to a long-term product relationship and ultimately increases the quality of life. As an outcome of this research, the suggested evaluation tool seeks to identify previously unexplored areas in the future design of the AT market. It will provide product designers, design academics, and professionals with a new method of developing an effective product, along with opening up opportunities for market and business owners to expand their business, thus meeting a previously unmet demand. This may lead the design decision toward an emotional experience, resulting in a long-term relationship with the user and eventually maintaining users' well-being, pleasure, and satisfaction.

REFERENCES

[1] Yoon J., Pohlmeyer E., Desmet P. and Kim C. (2021). *Designing for Positive Emotions: Issues and Emerging Research Directions*. The Design Journal, 24:2, 167-187.

[2] NIH. National Institutes of Health. *Rehabilitative and Assistive Technology*. Available at: https://www.nichd.nih.gov/ [Accessed on 2022, 24 February], (2018) 24 October.

[3] Fayazi N. and Franke L. (2020). *Creating Emotional Attachment with Assistive Wearables*.

[4] Chen K. (2020). *Why do older people love and hate assistive technology? – an emotional experience perspective*. Ergonomics, 63, 1463 - 1474.

[5] Puchalska A. J. *Emotional Design: how to improve products with emotions*. available at: https://uxdesign.cc/ [Accessed on 2022, 24 February], (2020) 16 March.

[6] Sarsby S. The importance of assistive technology in feeding. Available at: http://attoday.co.uk /the-importance-of-assistive-technology [accessed on 2022, 24 February], (2020) 11 May.

[7] Disabled World. *Disabilities: Definition, Types and Models of Disability.* Available at: http://www.disabled-world.com/ [Accessed on 2022, 24 February], (2021) 8 August.

[8] Office of National Statistics. *Subnational population projections for England: 2018-based.* Available at: https://www.ons.gov.uk [Accessed on 2022, 24 February], (2020) 24 March.

[9] Petrie H., Carmien S. and Lewis A. (2018). *Assistive Technology Abandonment: Research Realities and Potentials.* 10.1007/978-3-319-94274-2_77.
[10] Chenel V., Auger C., Gore P., Johnson G., Guay M., Jutai J. andMortenson W. (2016). *Reliability and acceptability of an online decision support system for the self-selection of assistive technologies by older Canadians: a research protocol*. 1-7. 10.1109.
[11] Ko K., Ramirez M. and Ward S. (2015). *A framework for understanding the role of product attachment in enabling sustainable consumption of household furniture*.
[12] Partala T. and Saari T. (2015). *Understanding the Most Influential User Experiences in Successful and Unsuccessful Technology Adoptions.* Computers in Human Behaviour, 53: 381–395.
[13] Xu W. (2014). *Enhanced ergonomics approaches for product design: A user experience ecosystem perspective and case studies. Ergonomics.*
[14] Mallin S. and Carvalho H. (2015). *Assistive Technology and User-Centred Design: Emotion as Element for Innovation*. Procedia Manufacturing, Volume 3, Pages 5570-5578.
[15] Lupton E., Carpentier T. and Lambert T. (2014). *Beautiful users.* 1st ed. China: Cooper Hewitt, Smithsonian Design Museum.
[16] Emily C., Millings A. and Prescott T. (2013). *Attachment to Assistive Technology: A New Conceptualisation.*
[17] Fenko A. and Schifferstein H. (2012). *The influence of sensory product properties on affective and symbolic product experience*. 8th International Design and Emotion Conference, London UK.
[18] Mugge R., Schoormans J. and Schifferstein H. (2009). *Emotional bonding with personalised products. Journal of Engineering Design*, 20:5, 467-476.
[19] Hassenzahl M. (2007). *The hedonic/pragmatic model of user experience.* Towards a UX.
[20] Roto V. (2007). *User Experience from Product Creation Perspective.*
[21] Desmet P. and Hekkert P. (2007*). Framework of Product Experience.* International Journal of Design, 1(1), 13-23.
[22] Thüring M. and Mahlke S. (2007*). Usability, aesthetics and emotions in human–technology interaction*. International Journal of Psychology, 42(4), pp.253-264.
[23] Chapman J. (2006). *Emotionally durable design; objects, experiences and empathy* (Vol. 30).
[24] Diehl J. C. and Christiaans H. H. C. M. (2006). *Globalization and cross-cultural product*. The International Design Conference.
[25] Hassenzahl M. and Tractinsky N. (2006). *User experience - A research agenda.*
[26] Hancock P., Pepe A. and Murphy L. (2005). *Hedonomics: The Power of Positive and Pleasurable Ergonomics.* Ergonomics in Design. 13. 8-14.
[27] Norman D. (2004). *Emotional Design: Why We Love (or Hate) Everyday Things.*
[28] Forlizzi J. and Battarbee K. (2004). *Understanding experience in interactive systems.* Designing Interactive Systems: Across the Spectrum.
[29] Schifferstein H. N. J., Mugge R. and Hekkert P. (2004) *Designing consumer–product attachment*. London: Taylor & Francis, 327–331.
[30] Murphy L. L., Stanney K. and Hancock P. A. (2003). *The effect of affect: The Hedonomic evaluation of human-computer interaction*. Human Factors and Ergonomics Society, pp. 764-767.

THE VALUE OF UNINTENDED HUMAN BEHAVIOUR IN EVERYDAY PRODUCT DESIGN

Zulkarnian HASSAN, **Shahriman ZAINAL ABIDIN**, **Rusmadiah ANWAR and Verly Veto VERMOL**
Formgiving Design Research Group, Universiti Teknologi MARA, Malaysia

ABSTRACT
Everyday product design strives to identify a fit between people and technology towards higher usability and more human-centric design approaches regarding product concept ideation. Notwithstanding, limited discussions on unintended human behaviour in interaction design studies and ambiguous methods to interpret the daily phenomena in design activities deter a sound understanding of human-product interaction and communication: a vital criterion for designer's education purpose. This study aims to disclose a pattern of unintended behaviour design (UBD), emphasize its values from various multidisciplinary design expert viewpoints, offer novel design thought parameters concerning everyday design, and expand the current body of literature on design education to develop innovative everyday product designs.

Keywords: Unintended human behaviour, everyday product, user experience, interaction design

1 INTRODUCTION
Individuals interact and communicate with multiple product types for various purposes daily. For example, empty bottles are innovatively utilized to separate egg yolks from their whites, Coca-Cola is employed as a substitute for household cleaning detergents and wire hangers are transformed into disposable towel holders. Such inadvertent discoveries render human life as meaningful and convenient rather than the creations derived from empirical trial-and-error studies. Specifically, a washbasin could be used beyond its intended purpose of washing hands and faces to clean clothes, bathe babies and take ablutions (for Muslims). However, non-designers unintentionally engage in the creation of novel functions with innovative product usage (see Figure 1) [1].

Figure 1. Example of unintended use of product in everyday contexts

Everyday design is not a novel phenomenon in design-oriented studies with a fair acknowledgment of diverse design concept connotations. Regarding the term 'everyday design' under unselfconscious design, users inadvertently employ present product functions in novel ways for goodness of fit [2]. Suri [3] coined the term 'everyday thoughtless acts', which implies perceptions of intuitive designs and individual behaviours and experiences for optimal ideas and alternatives. The notion was then empirically explained as unexpected behaviour [4], designing for appropriation [5], unorthodox use [6], non-international design, design by use [7], and unselfconscious interaction [8].
The design process is perpetuated through projects, re-usage, customization, appropriation, do-it-yourself, and everyday designs without undermining designers' intentions [9]. Design activities that strive to attain a specific objective in specified circumstances extend beyond designers to other relevant and professional design and non-design areas. Users are acknowledged as 'actors' in everyday product development following the interest and enthusiasm in designing user experience, which leads designers to holistically comprehend and interpret human behaviours and interactions by examining unforeseen

elements with the potential to inform the product development team. The widely-utilised everyday design notion by scholars relates to human behaviour where users consciously (or unconsciously) and intentionally (or unintentionally) engage with everyday objects. This study employs the term ‘unintended behaviour design’ or UBD to emphasize its attributes. Unintended behaviour denotes (i) inadvertence as a purpose or goal without deliberate intention (ii) or an impromptu behaviour demonstrated without planning. In Leon Seltzer, “the state of mind that gives rise to creativity does not occur consciously and critically but occurs when the mind is unconscious, not evaluating, unintentional or spontaneous” [10]. Notably, research on unintended human behaviour towards product usage remains lacking compared to the intended counterpart. The ‘unintended behaviour’ underpinning human activities could potentially be factored into product design strategies. Based on past research, the UBD impact on user-designer proves to be ambiguous following a lack of strategy in comprehending user interpretation and behaviour from designer viewpoints. Given that the paucity of such discussions cause designers to disregard its potential and value, this study attempts to justify UBD values together with the key determinants of everyday product design. The proposed study would elaborate on implicit user interpretations of individual behaviours from designer perceptions to recommend how designers could examine the other side of human values and expand their design thoughts to another level.

2 AIMS AND OBJECTIVES OF STUDY

This study strived to present (i) a novel design thought parameter, (ii) guidelines for new product development, (iii) the expansion of design education, (iv) a sound comprehension of user response, and (v) the exploration of design-based activities towards unintended human behaviour-mainstream product interactions within an impromptu setting. The current study also aims to determine the (i) key determinants and characteristics of unintended use interactions in daily life and (ii) explore designers’ interpretations and responses towards unintended use behaviour interactions. The reasons underpinning unintended use reasoning in design activities would be further assessed to facilitate designers’ interpretation in product design conceptualization. The researchers would also identify the viability of establishing a UBD guideline encompassing approaches, methods, and skills for designers’ guidelines.

3 RESEARCH BACKGROUND

3.1 ‘Unintended behaviour’ from psychology perspectives

Gibson’s [11] book, ‘The Ecological Approach to Visual Perception’, presented the term ‘affordance’ in psychology to justify people’s environmental perspectives based on the possibilities for action through object and space affordance, which are reliant on users’ physical capacity. Affordance implies user competence with an object. For example, a pair of pliers enables users to perform specific actions: tightening and opening, knocking, and throwing. In the design community, Norman [12] coined the term in his book, ‘Psychology of Everyday Things’, where object ‘affordance’ denotes users’ perceivable action possibilities as a novel potential. Nevertheless, Gaver [13] rectified the misconceptions entailing the Gibson-Norman affordance connotation through his framework: false affordance exists when action is palpably depicted despite its impossibility. Figure 2 illustrates the affordance theory and how an object facilitates user actions that differ from its intended function.

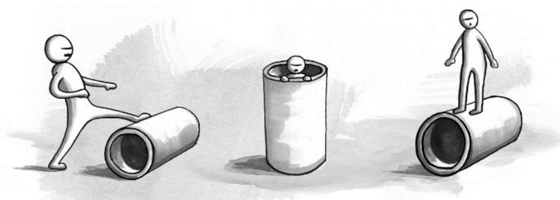


Figure 2. The concept of affordance

Unintended behaviour demonstrates similarities in the given context where object-oriented capacities cause inadvertent usage. Nevertheless, both connotations require due consideration in the design process as the action could only be performed if the object permits it and the user is cognizant of its competence. Based on human creativity-oriented studies, human (locus of control and metaphoric thinking capacity) and situational (time restrictions and situational engagement) elements impact daily interactions: intended behaviour, creative consumption, self-expression, and experience [14]. Individuals would plot object performance possibilities based on their model concept of object performance. The affordance concept denotes object attributes and human interactions to implicitly create the potential actions associated with perception and ability. People create novel object competence to complement their requirements across other settings in the wake of affordance under UBD. Such capacities could catalyse novel design possibilities and insightful ways for designers to develop a specified purpose.

3.2 Research on human interaction and behaviour factor of everyday product

The term ‘interaction design’ was derived from a user interface design-software integration in the early 1980s. Nevertheless, recent research contended the aforementioned connotation to be a common misinterpretation where interaction-oriented designs solely concern software interface and its subsequent intricacies [15]. The interaction process occurring in daily routines motivates people to engage with, adapt to, and internalize their immediate environment. Essentially, interaction design aims to foresee individuals’ product usage, experience modification, and self-designing. Norman’s book, ‘The Design of Everyday Things,’ presents three design levels: visceral, behavioural, and reflective. Specifically, “the interaction at behavioural level is the home of learned skills, triggered by situations that match the appropriate patterns. Actions and analyses at this level are largely subconscious. Even though we are usually aware of our actions, we are often unaware of the details” [12]. The behavioural level denotes the controlled element of unconscious human actions that perform situational assessments to develop a goal-based approach that could be effective in the short run with minimal actions. Behaviour design entails usability, usage effectiveness and pleasure, performance, and object workability. Notwithstanding, designers themselves struggle to outline their association with relevant experiences and predict product functionality. The process of transforming and appropriating objects from design has expanded the current body of knowledge across multiple disciplines in interaction design for the past years [9]. Although design-based studies serve to explore how individuals interact with designed objects using observation and analysis, new functions, and innovative and creative re-use, the interaction did not occur parallel to designer intentions following insufficient resources, human factors, daily experiences, and specified contexts. Although most scholars are positively conscious of creative product behaviour for novel functions [16][17], the designed artifact is utilized as opposed to designers’ initial plans or expectations following an inadequate comprehension of everyday design towards unintended behaviours. Design engineers opine that the design principle for creative unintended use could be significantly developed and applied to complement future design works. The experience of emergent behaviours during product interaction would project future potential values for designers.

3.3 Significance of unintended human behaviour in design research

Human behaviour denotes human-environment connections with the potential to express mental, physical, and social capacities and address internal and external stimuli throughout their lifespan. Unintended behaviour is a psychologically-controlled physical activity encompassing potential human creativity and innovation in daily interactions. Suri’s book implies that “things like unintended way usually indicate something about people’s need that designer should take for granted to translate into design opportunities” [3]. Furthermore, users create novel and multi-uses that imply the extent to which people accept novel notions and make innovative and autonomous decisions following their experience and that of others through unintended behaviour. Creative use (unintended behaviour) denotes problems integrations to resolve novel notions [18] and experience new sensations based on use innovativeness-oriented studies [19]. Hirschman [20] proposed the use innovativeness model constituting three primary elements and two behavioural types while creatively employing a current product: (i) various product usage in its context (multiple use) and (ii) product usage outside its context in unintended ways (creative re-use) (see Figure 3).

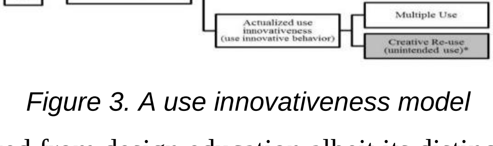


Figure 3. A use innovativeness model

The UBD could not be separated from design education albeit its distinction from professional designs given its part in education. From professional designers’ assumptions, UBD allocates artifacts for alternative usage, which only depicts designers’ misconception of multiple contexts or the designer-user intention gap. Although UBD merely offers design prerequisites for designers, relevant research is deemed pivotal as designers could not foresee dynamic design usage and contexts. Thus, people are entitled to customize an artifact following their needs. As UBD is a more valuable design resource to be employed with other counterparts (personal experience) compared to novel creations, the proposed study would examine the UBD value in design activities within a broader setting.

3.4 Design for behaviour change

Individual wrong behaviour leads to larger-picture social issues, which all too often struggle with taking actions that are not the result of a lack of motivation or information. The intention-action gap refers to the large gap that exists between people when one's values, attitudes, or intentions don't match their actions. In behavioural change research, people always struggle to turn their motivation into action or to make good decisions. Behavioural science studies in product design help designers understand how users think and how their minds work. To intentionally change behaviour in the best interests of the users, a thorough understanding of how their minds work should be developed. They perform optimally in the wrong context, which can lead to cognitive biases and unintended behaviour or unexpected decision making because of limited attention, memory, and willpower of the user. It demonstrates that the intention-action gap occurs as a result of user minds and environmental influences. There is no such thing as a neutral design. The contextual environment heavily influences user decisions and behaviours. Environments and objects with which users interact should be thoughtfully and carefully designed in order to make the process intentional and beneficial to the people in lines with current design education.

3.5 Interpreted human experience through designer hermeneutic perspective

Martin Heidegger’s hermeneutic circle concept (1927), envisions the whole in terms of the reality underpinning an individual’s enriched experience on a daily basis. Gadamer further denoted hermeneutic as “the anticipation of meaning or an iterative process based on the horizon of understanding, prejudice, and conversation as a model of understanding [21]. The hermeneutic circle approach in the design process, which constitutes any form or product, denotes the past circumstances of both designer and artifact that constituting the meaning of human experience, mitigation of prejudice, and expansion of the designer’s horizon. Designers are aware of the potentially misleading past experiences following human experience despite multiple predictions on product functionality strategies. As such, designers are required to integrate hermeneutic skills and attain congruence between (i) creativity, technologies, and human behavioural interactions and (ii) user’s perceptions of daily experiences rather than interpreting personal intentions. Overall, utilizing a product as a medium for user response provides a broad viewpoint for designers parallel to Cross [22]. Interpreted user behave our might include functional quality, performance, efficiency, and ergonomics following Crilly’s [23] elaboration on Mono’s semantic functions (product factor: form and material) - description, expression, exhortation, and identification. Mono’s communication process model outlines product-user communication strategies through transmitted meaning (an optimal conversation) for designers to learn the origins of a personal memory system and ascertain the presence of inspiring, challenging, and expansive ideas with the hermeneutic circle [21]. In this vein, a design functions to translate user needs through hermeneutic circle and interactions with the designer under Shannon and Weaver’s model.

4 PROBLEM STATEMENT

Products are regularly employed in multiple ways as opposed to their original functions intended by the designer [1]. Unintended product use implies a daily conversion from normal to abnormal phenomena regardless of person and place [4]. Following Wongkitrungrueng [24], unintended behaviour is regularly disregarded by multiple designers. Product usage satisfaction and dissatisfaction might be portrayed in implicit product functions through unintended behaviour, which is unaddressed by scholars, designers, and organizations, rather than explicit counterparts. Based on Dix [5], an intended use (by designer)-actual use (by users) gap was determined following creative misuse owing to various aspects. The ignorance of intended functions instigates two implications that are deemed disrespectful to designers: i) positive values and ii) negative and risky impacts for users. The situation suggests there is a huge communication gap between users-designers. The question of why designers ignore unintended behaviours in the design process will unravelled from their perspectives. Hence, the UBD context needs to be duly expanded in the design process stages to benefit designers, users, and product sustainability and address the paucity of relevant scholarly discussions: an inevitable gap that must be addressed.

5 UNDERSTANDING SIGNIFICANCE FACTORS BASED ON LITERATURE

The substantial aspects entailing UBD value with potential contributions in designing everyday product design are duly revealed. The discoveries here are presented under the study background (i) integrating and interpreting designs and users in every design activity remain ambiguous despite multiple relevant studies, (ii) the human-centred design concept with individual experience is a broad phenomenon that complements people's requirements through a holistic comprehension of behaviour, interaction, psychology, and environmental aspects, (iii) the UBD value should be included as a design requirement in the design process to successfully envision the user-based design concept, (iv) user-oriented and user experience design concepts for design interaction ideas prove to be more valuable than designers' hermeneutic skills, and (v) a critical study should be performed to assess how designers interpret a user's idea by integrating the UBD value in mainstream products through designers' sketching activities.

6 PROPOSED RESEARCH METHOD

A qualitative study would be conducted using a descriptive research design to (i) address pertinent questions and (ii) assess the elements frequently incorporated by product designers in the industry and academicians with emphasis on designers' interpretations of unintended human behaviour values in idea creation through summaries in the literature review. The first approach implies a semi-structured interview session involving local respondents through verbal protocol analysis to examine the key determinants of unintended behaviour in everyday activity. Local product design experts would be interviewed to denote the UBD value and answer why most designer disregards it. The next approach involves naturalistic video observations for data gathering on inherent gesture patterns in unintended human behaviours towards a particular product. Empirical research would parallel users' psychological activities during product interaction. Respondents would be arbitrarily involved in the simulation session of how and why their unintended behaviour occurs towards a specified product based on the designer-controlled environment. This study primarily aimed to aid designers' interpretation of inadvertent behaviours and gesture patterns. The final approach entails video observation and verbal protocol assessment that would be conducted with a sketching activity. The product design experts are required to comprehend the reasons underpinning unintended behaviour and how users could experience the product during this experiment. This technique strived to observe the degree to which product designers interact and communicate with visual language by sketching [25] in the design following the UBD value. Data validation would be conducted with the perceptual product experience (PPE) framework [26] entailing two dimensions (presentation and representation), which involves a presentation on the direct stimuli ability related to experience, interpretation, comprehension, and recognition. Interactive elements, behavioural response, and experience are significantly associated with the presentation dimensions in the proposed study setting.

7 CONCLUSIONS

Designers function as actors who are explicitly engaged in the design process and accountable for their parameter development in design thought by perceiving all the significant opportunities and potentials by exploring and evaluating unintentional human behaviour. The examination of such a phenomenon and its intricacies would induce positive outcomes in product design and other disciplines following past study statements. An in-depth exploration would motivate designers to focus on user experience designs encompassing daily behaviour and interaction. Specifically, a critical descriptive study is necessary to support the argument and affirm the potential in designers' design process. Unintended behaviour remains significant in generating novel ideas and comprehending potential human needs despite inconsistent opinions owing to the complexities in determining unintended behaviour responses within human cognition. Behavioural research under the design process would leverage design education in resolving the issues pertaining to daily behaviour and interaction towards built intuitive designs, user experiences, and understanding user unintentional behaviour with mental, physical, and thought-based interpretations. Unintended behaviour has reflected its distinct value, which has been constantly disregarded by designers who should perceive implicit user requirements by observing their behaviours for innovative design education concepts. Notably, empirical contributions from multiple disciplines, including behavioural science result in multiple methods entailing the multidimensionality of product experience given the shift in design research trends from intended design to human experience.

ACKNOWLEDGMENTS
This research is gratefully supported by Universiti Teknologi MARA [Grant number: 600-IRMI/FRGS 5/3 (463/2019)] and Ministry of Education Malaysia under the FRGS Scheme [Sponsorship File no: FRGS / 1 / 2019 / SS107 / UiTM / 02 / 8].

REFERENCES
[1] Kim S., Christiaans H., and Kim C. Understanding Everyday Design Behaviour: An exploratory Experiment. *International Journal of Design*, 2021, Vol. 15(1).
[2] Alexander C. Notes on the synthesis of form. *Cambridge, MA: Harvard University Press.* 1964.
[3] Suri J. F. Thoughtless acts? Observations on intuitive design. San Francisco, 2005.
[4] Brandes U. and Erlhoff M. Non-intentional design. *Daab.* 2006.
[5] Alan D. Designing for appropriation. *In Proc. BCS-HCI,* 2007, pp. 27–30.
[6] Hentschel C. Unorthodox Use: TRIZ for Non-intended Product Use, *The TRIZ Journal.* 2008.
[7] Brandes U., Stich S. and Wender M. Design by use. *Basel, Switzerland: Birkhäuser.* 2009.
[8] Wakkary R., Desjardins A. and Hauser S. Unselfconscious interaction: A conceptual construct. *Interacting with Computers*, 2016, 28(4), 501-520.
[9] Desjardins A. and Wakkary R. Manifestations of everyday design: Guiding goals and motivations. *In Proceedings of the 9th ACM Conf. on Creativity & Cognition* New York, 2013, pp. 253-262.
[10] Dan S. The Psychology of Spontaneity: Why Some People Drop Everything and Go By. July 22, 2015. https://www.elitedaily.com/life/culture/spontaneity-drop-and-go/1130284
[11] Gibson J. J. The theory of affordances. In Shaw, R., Bransford, J. (Eds.), Perceiving, acting, and knowing: Toward an ecological psychology. Hillsdale, NJ: Erlbaum. 1977, pp. 67-82.
[12] Norman D. A. The design of everyday things. New York, NY: Basic Books. 1988.
[13] Gaver W. W. Technology affordances. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, NY: ACM. 1991, pp. 79-84.
[14] James E. B. and David G. M. Exploring Antecedents and Consequences of Consumer Creativity in a Problem-Solving Context, *Journal of Consumer Research*, 2004, 31(2), pp. 402-411.
[15] Kamil M. M. J. and Abidin S. Z. Unconscious Human Behaviour at Visceral Level of Emotional Design, Procedia-Social and Behavioural Sciences, 2013.
[16] Selvefors A., Rexfelt O., Renström S. and Strömberg H. Use to use: A user perspective on product circularity. *Journal of Cleaner Production*, 2019, 223(20), pp. 1014-1028.
[17] Haug A. Defining 'resilient design' in the context of consumer products. *The Design Journal,* 2018, 21(1), pp. 15-36.
[18] Ridgway N. M. and Price L. L. Exploration in Product Usage: A Model of Use Innovativeness: Psychology & Marketing, Vol. 11 No. 1, 1994, pp. 69-84.
[19] Abidin S. Z., Bahari S. A., Ibrahim A., Ghazali A. E. M., Ahmad M. A., Mujir M. S., Delgado M. V. B., Zbiec M., Garrido J., Ortega J. J., Gómez M. V. G., Ratnasingam J., Hashim R., Zakaria S. and Amin M. N. Z. M. (2021). Analysing the Malaysian Higher Education training offer for furniture design and woodworking industry 4.0 as an input towards joint curriculum validation protocol. Asia Pacific Journal of Educators and Education, 36(1), 1–24.
[20] Hirschman E. C. Innovativeness novelty seeking, and consumer creativity, *Journal of Consumer Research,* 1980, vol. 7, pp. 283-295.
[21] Timmer S. (2015). Hermeneutic for Designer. https://www.uxbooth.com/articles/hermeneutics-for-designers By July 22, 2015.
[22] Cross N. Designerly ways of knowing. London: Springer. 2006.
[23] Crilly N. Product aesthetics: representing designer intent and consumer response. Thesis, 2005.
[24] Wongkitrungrueng A. Exploring how and why consumers create unintended uses of products. *International Journal of Business Innovation and Research.* 2018, 16(4) pp. 453.
[25] Toyong N., Abidin S. Z. and Mokhtar,S. (2021). A Case for Intuition-Driven Design Expertise. In A. Chakrabarti (Ed.), Design for Tomorrow - Proceedings of ICoRD 2021 Volume 3 (pp. 117-131). (Smart Innovation, Systems and Technologies; Vol. 223). Springer Science and Business Media Deutschland GmbH.
[26] Abidin S. Z., Warell A. and Liem A. The significance of form elements: A study of representational content of design sketches. *In Proceedings of Conference on Creativity and Innovation in Design.* 2011, pp. 21-30.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

ANTICIPATIVE CO-CREATION METHOD

Nina BJØRNSTAD[1] **and Cheryl Akner KOLER**[2]
[1]The Oslo School of Architecture and Design, Norway
[2]Konstfack University of Arts, Craft and Design, Sweden

ABSTRACT

We experience an urgent climate crisis that shakes our whole existence and calls for change. The field of industrial design education has expanded over the past decades towards a new language of speculative design projects, aiming to influence industry and address unsustainable manufacturing. How designers typically use their capacities for change, is shown in the discursive qualities of proposed solutions. Within the current educational context, not given a commercial brief, new methods arise. This international design master's course aims to find better future product concepts that nudge sustainable ways of living. How they initiate and prototype these product ideas, is through design fiction and co-creation, conceptualizing and proposing solutions to essential problems and needs. By the use of prototypes, designers can bring essential future solutions into the present.

This paper outlines how the new ‘Anticipative Co-creation Method’ emerged. As the foresighted concepts intend to address the negative trends in overconsumption and unsustainable lifestyle, the designs for the far future function as inspirational future versions of the relevant suggestions for today. Through interpersonal anticipatory engagement, concepts grow out of the design fiction. In a dialog with each other students verbalize scenarios and through co-creation concepts become ‘real’ as different videos were created. We have observed that the students build empathy for each other through co-creative activities within the method of anticipation. If we want a thriving future, we need to act now. The design profession has never been more essential in building and critically assessing design futures literacies.

Keywords: Anticipative, design method, co-creation, haptic, future studies, design fiction, prototypes, scenarios, industrial design

1 INTRODUCTION

This case study describes the unfolding of the new ‘Anticipative Co-creation Method.’ The systematic exercise emerged in the ongoing international industrial design master's course on anticipatory design practice, which blends design fiction with two- and three-dimensional prototyping.

We live in an intermediate period that asks for considerable life changes, where new occupational opportunities are emerging in the field of design. The mandate of this international design master's course now brings the tools of design inquiry [1] into the core of complex and dystopic ‘glocal’ problems. Using prototypes, designers can bring forward suggestions to help out on essential far-future needs. The main objectives are to get students to articulate during prototyping and to methodically co-create and play it out through video. The aim is further to make the scenarios by finding essential needs in United Nations’ 17 Sustainable Development Goals (SDGs).

The course deals with new tools for developing, prototyping, and conveying design solutions for the ‘far future.’ Primacy is given to new contexts and themes that require radical rather than incremental solutions. The course is organized around two extensive main iterations and phases. The first phase is based on foresight 3-4 decades in the ‘far future’ and the second phase is backcasted in time based on the results from the first phase and transformed by design to a ‘near future’ contemporary context. The outcome of both phases is physical products conveyed by both digital media and physical models [2].

This course introduces a number of approaches to radical change and anticipatory practice. What characterizes the course is lectures and tutorials on video-based sketching techniques, integrated with early-phase prototyping exercises led by Nina Bjørnstad. By jumping between writing fictional scenarios and making two-dimensional (2D) and three-dimensional (3D) collages, the students find forms of interest they later develop into future products answering to essential needs.

2 THE ORIGIN OF THE AESTHETICAL APPROACH

'Aesthetic driven Co-creative Writing method for short Videos'(ACoWV) [3] is a related method that was developed by the authors and two other professionals during an intra-disciplinary aesthetic seminar supported by the research project 'Haptica'. The seminar engaged project members with diverse backgrounds in sculpture, design education, culinary arts, and hospitality. In the following quote by James Dewey 'Whenever an idea loses its immediate felt quality, it ceases to be an idea and becomes, like an algebraic symbol, a mere stimulus to execute an operation without the need of thinking' [4].

The introductory ACoWV method involved the following five stages. Preparing a short key video showing haptic interaction (brought to the seminar. Viewing of the video (2-3 min each). Reciprocal interviewing (5-7min each). Reflection & expressive writing (10-12 min). Oral performance of the expressive text followed by re-showing the short video (5 min each). The entire process was completed within one hour (for a group of 4-6 participants).

2.1 Objective

The aim of the ACoWV method was to bring together key videos in a workshop designed to engage all of the participants in each other's work and to inspire an expressive writing process concerning each video. It was meant to help both the individual researcher and the collaborative group to explore and develop the artistic- and research potential in the 'Haptica' project on haptic perception. The reciprocal viewing, interviewing, writing and performative stages were done to build empathic ties to each other's work by exploring one's immediate felt subjective and qualitative emotional response while watching the short videos. By daring to put something of ourselves into the work of another and to take a creative and free interpretive role as interviewer, we can offer a more personal account of how the video moved us. Later ACoWV method was presented in a workshop and published in the proceedings of the interdisciplinary micro-conference at Kolding School of Design [3]. Here we learned the importance of nudging the viewers' emotional response as they viewed the videos and carried out the interview before retiring for a mindful writing session.

The following chapters describe the unfolding of a new method in the 'Transform' course by merging a co-creative reciprocal interview- and writing method ACoWV, from 'Haptica' [3] with a fictional explorative short video exercise of making and conveying a 'far future' product scenario. This *research-driven mindful co-creative method* complements the established *prototype- and video-based sketching techniques* that have been part of the course from the beginning.

3 THE NEW METHOD WITHIN THE 'TRANSFORM' COURSE

When looking at the course as a whole, it is recognizable as 'design fiction' (the 'cousin of science fiction') since it creates links between science facts and science fiction and provides the opportunity to speculate within the fictional reality [5]. These fictional design artefacts exist here in the real world and, at the same time, are part of a function in the 'unreal world' [6]. Through the ten years the course has existed it has changed its focus from travelling physically to other cultures to travelling through imagination. All the years we have kept the focus on prototyping. The name of the course changed in 2020 from 'Protohype' to 'Transform', to mark the emphasis on form, aesthetical explorations, co-creation and a transformative change.

3.1 Course context of the 'Anticipative Co-creation Method'

The 'Anticipative Co-creation Method' is embedded in the course 'Transform,' between the initial research phase called 'Refuturing workshop,' and 'far future' concepts. In 3.2 you find more about the learning activities; how they imagine futures and the three types of videos that are created: A- Concept video, B- Process video, and C- Product videos. You can find the learning activities chronologically in the diagram below (Figure 1). From left to right in the diagram, we find the chronological listing of learning activities. After the 'Refuturing workshop,' we perform the anticipative co-creative exercises. Two longer phases follow first 'far future' speculations, and then the 'near future' designs.

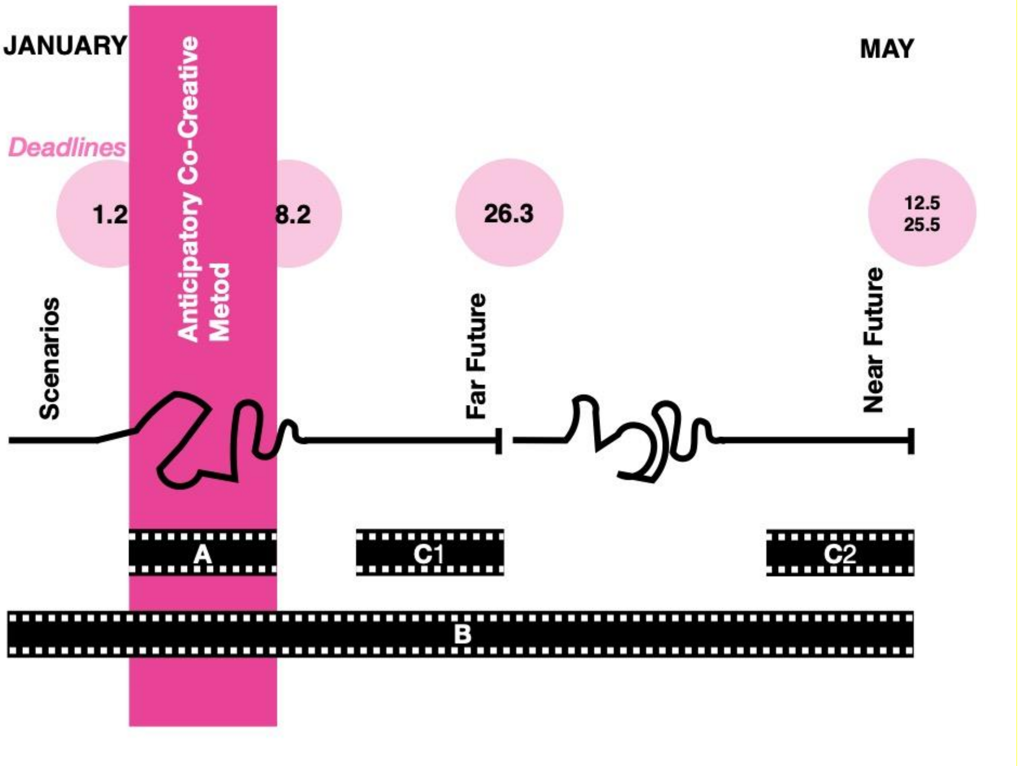


Figure 1. The illustration shows where the method is performed, within the timeline for the 'Transform' course between Scenarios and Far Future

3.2 Learning activities

The initial activity by Håkan Edeholt and Jomy Joseph in the 'Refuturing' workshop is a discussion of the climate and nature crisis, which generates consciousness and backdrop for their future scenarios. Continuously since the course was established, the course programme takes a stance against 'business as usual.' To quickly build up prototypes activate the core industrial design skills, and simultaneously render them into their future scenarios. Jomy Joseph has stated: 'Design fiction is explored here as a focused- and creative way to think about possible future scenarios that broaden the solution space through designed artefacts. These fictional accounts create 'what-if' scenarios' [7].

'Refuturing' and preparing scenarios, happen before the 'Anticipative Co-creation Method' and the creation of the explorative videos are introduced. The first is a *Concept* video, where they might film a material exploration or a roleplay, which plays a significant role in the second *Process* video as it explains the mood and shows the fuzzy beginning of a creative process followed by the third *Product* video communicating the situated result for an audience. The imaginative co-creative process during the making of this first concept video and the unpredictable outcome of explorations show a mindset and actions from which a 'far future' scenario could materialize.

3.3 Early phase anticipative prototyping

The core of anticipation studies lies in 'making futures' through direct participation and co-creation in the ongoing materialization of prototypes [1]. Even though the student's scenarios reveal big-scale problems, objects can bring in positive solutions for basic needs such as lack of food, energy, or safety. Quick 2D drawings and simple paper/clay models represent products on several levels of idea development. The 2D and 3D collages integrated with writing suggested environmental conditions of the surroundings and landscapes for a future scenario to take place.

The rough models are treated as any other intermediate model, with simple cut-outs, found objects, and glued-on parts. Paint is used to blend them into early scenarios. A major inspiration for early prototypes is to explore haptic- and tactile properties in materials themselves and in re-purposing of waste materials from industrial products.

Learning to work with a myriad of rough explorative 3D prototypes and gradually articulate the shapes and details, pivots around the use of 'aesthetic abstractions' of three-dimensional form and space [8].

Cheryl Akner Koler defines the mode of aesthetic abstractions as contextualized reasoning where four categories of abstraction, i.e. I) elements and properties, II) movements and forces, III) relationships and VI) organizational framework, are directly related to the authentic situation and the sensuous cognition of the individual [8]. Aesthetic abstractions complement other modes of abstraction, numeric and linguistic, which are highly coded. All modes of abstractions are used to give the possibility to 'step out' of the situation and treat it in an explorative way. In the aesthetic abstraction mode, one can reconfigure the particular sequence of the images that make up the narrative and even ignore the storyline altogether to freely test other possible combinations. By working with aesthetic abstractions new spatial relationships can also be tested, for example turning things upside down, rearranging things so they create different local relationships, or by testing proportions and shapes that also determine the movements and forces within the composition [8].

The design reasoning applied when working with aesthetic abstractions in this course was built on decades of teaching done by professors Rowena Reed Kostellow and Alexander Kostellow at Pratt Institute in New York City, as they established the first university-level industrial design programme in the US starting in 1934 and is still evolving to this day [9]. Rowena Reed Kostellow applied her sculptural insights from figure studies and sculptural armatures that act as the skeleton of a composition. This inner sense of form and its interdependent relation to space is where creativity may lay [10].

In the 'Transform' course the students are working in the physical world with all its sensory stimuli to explore solutions to products for essential needs that include food, energy, and water. They are also working in a digital world that is mediated through visual and audio signals. How these analogue and digital worlds go together depends a great deal on the time given to explore the physical world, because this is where the students nurture their anticipatory drive. It is our present behaviour in real life that helps us stay in touch as we design for the future, and this is a core aspect of the anticipatory approach.

4 RESULTS

During the 'Transform' course, the 'Anticipative Co-creation Method' was developed by Bjørnstad by adapting and transforming the related ACoWV method, by redesigning a techno-optimistic educational process. To begin with, the students pair up for a reciprocal interview session within a fixed time frame. The interviewer was instructed to ask empathetical questions that reflect their own immediate aesthetic response to the written scenario formulated by the other student. Notes are taken by the interviewer that documents the interviewee's verbal expressions formulated in response to the interviewer's curious questions. At the end of the session, the pair of students sit together and reads through their notes and take turns re-articulating each scenario in a more expressive text using the words from the interviewee in a co-creative fashion. This expressive text is sent to the course leaders. From this point, the students begin to gather and create 2D and 3D prototypes to be used as design probes in the first version of their concept video.

To support co-creativity, the students are encouraged to consider how the re-articulated scenario may affect the production of their concept video. They might also tap into any deep connections they may have felt during interviewing their partner that may bring value and meaning to their own scenario. Finally, the students should assess each other with support from the whole class and the teacher.

The hands-on making of the 2D and 3D prototypes gives rise to associations, which in an empathetical way feeds the imagination. The direct haptic signals received from the tangible stimuli of the materials and tools, feed-forward to spark the creative process. How the haptic imagery is used to shape an imaginative scenario depends on the students' ability to apply aesthetic abstractions that resonate with their emotional connection and intentional motivation.

With time the project starts to make sense. Now the fictional narrative, that holds the scenario together, can begin to unfold. Reflecting on their experience from the co-creative method, the students understand that their emotional responses are significant for imagining the future.

4.1 Step by step 'Anticipative Co-creation Method'

In a design studio lot of interactions are happening, student to student or student to the material, or student to teacher. As we saw the outcome we saw the exercise was liberating, and we found the need for structuring the way we worked.

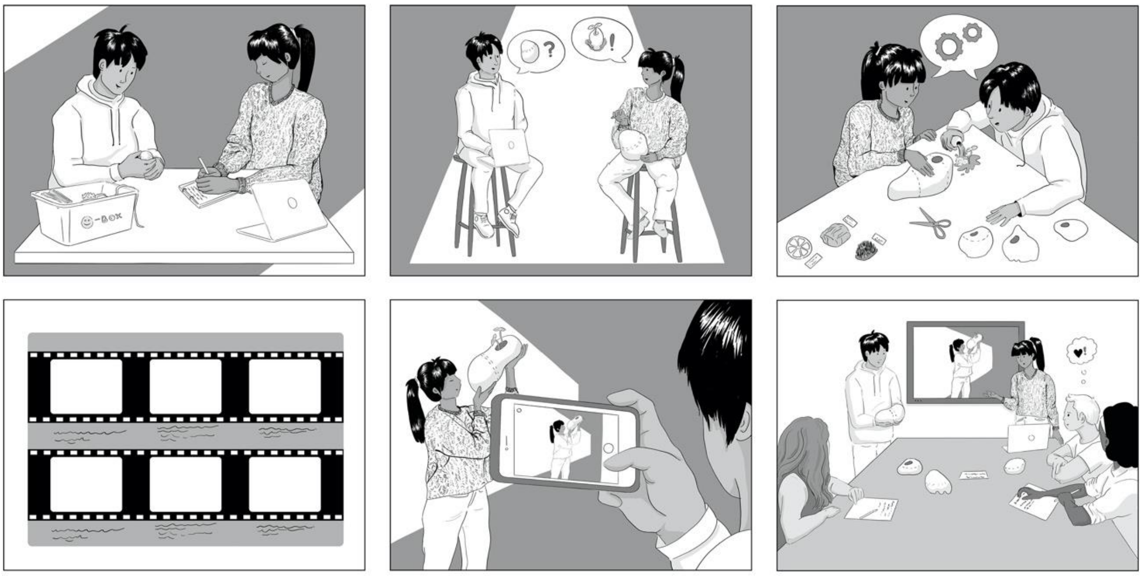


Figure 2. Illustrated model of the 6-stage 'Anticipative Co-creation Method'. From left to right. 1. Writing and illustrating their scenarios, 2. Reciprocal interviewing and re-writing, 3. Embodied scenario building, 4. Storyboard for the concept video, 5. Concept video, 6. Students/teachers assessment

Illustration: Alice Ekelöv

Description of the 6 stages:

1. Writing/ illustrating: This stage intertwines writing a creative text and consequently adjusting the scenarios. With inspiration from e.g., science fiction imagery or biomimicry, students do illustrations including a landscape or cityscape. They are then asked to imagine humans living in this scenario and write in the first person, speaking through their voices. Intentionally, these stories give us a glance into fictional futures.
2. Reciprocal interviewing and re-writing: The students work in pairs and take turns to be interviewer and interviewee, respectively. They interview and listen actively from a subjectively felt curiosity and take notes trying to capture the spoken language of the interviewee. Students continue the co-creative exchange and help each other write a more expressive text, that re-articulates the first version of the scenario into a second version. The interviewee better understands the narrative of one's own scenario and clarifies their intentional drive in the making process.
3. Embodied scenario: The students continue to work together in pairs. The early physical prototypes used in this embodied scenario are often of abstract character and may show some early form concepts spanning from simple paper shapes to 3D printed models. By also using ready-mades, they sometimes mimic categories of objects with solid form, cables, and buttons, without thinking of how it functions in detail. Metaphorical associations occur as the teacher provides the students with a mix of materials.
4. Storyboard for the concept video: An introduction to dramaturgy is given before students draw their own storyboard. They got general advice such as explaining product features and environments through natural sound.
5. Concept video: The students were instructed to act out the storyboard using rough prototypes to create a concept video. The video should capture and give focus to the 'fuzzy phase' in the ideation process. The student voices came through in both product, dramaturgy, and editing. Essentially the video communicates the concept by setting the scene, showing cause (product) and consequence (product function). It is about exploring some embodied aspects of the storyboard by making mock-ups that execute some functions. Each concept video can be seen as an anticipatory action since it highlights behaviour within a tangible life situation in the present [11]. Often the concept videos

show making aspects, which are typical for designers' way of focusing on ‘close to body’ actions.

6. Students/teachers assessment: The paired students take a strong role in assessing each other’s concept videos. The other students in the class are encouraged to give constructive feedback and the teachers assess the narratives.

5 CONCLUSIONS

This paper outlines how the new ‘Anticipative Co-creation Method’ emerged. By a reciprocal way of working together, that creates an atmosphere of support, we nurture cooperation and try to keep it through the entire course. We have observed that the students build empathy for each other, and generosity through co-creative activities. The emerging new ‘Anticipative Co-creation Method’ with its co-creative reciprocal interview and writing method unfolds into making physical prototypes, created to emotionally engage the designers in making the fictional scenarios. The products they describe in the scenarios accentuate the basic needs of our future. Foresight is possible through students that co-create and verbalize concepts, based on the SDGs and explore them through short videos. By inviting one student to respond to another student's short video, they can cultivate a felt experience for the video and support the emotional and narrative qualities of the scenario as it unfolds.

REFERENCES

[1] Celi M. and Morrison A. Anticipation and design inquiry. In: Poli, R. (Ed.). *Handbook of Anticipation. Theoretical and applied aspects of the use of future in decision making*, 2017. Springer. (pp. 1–25).

[2] Master of Design. Available: *https://aho.no/en/courses/70-600/2022-spring* [Accessed 2022, March 6th].

[3] Akner-Koler C., Kosmack V. E., Göran R. A. and Bjørnstad N. Aesthetic driven co-creative writing method for short videos. In: Proceedings of Design Micro conference In Proceedings of Design Micro Conference. Addressing designed form - demarcating design. Herriot. R. (Ed.). 2018. Available: *https://www.designskolenkolding.dk/sites/default/files/publication/download/4_aesthetic_drivenco-creative.akner_koler.pdf* [Accessed on 2018, 6 March].

[4] Dewey J. Art as experience, 1980. Perigee Book. (Original work published 1934).

[5] Dunne A. and Raby F. Speculative everything: design, fiction, and social dreaming, 2013. MIT Press.

[6] Dunne A. and Raby F. Design for the unreal world. *Design for the unreal world in studio time, future thinking in art and design*, 2018. https://www.designedrealities.org/texts/design-for-the-unreal-world.

[7] Joseph J. Critical futures today: Back-casting speculative product design towards long term sustainability, 2019. In: M. Ambrosio & C. Vezzoli (Ed.), 3rd *LeNS world distributed conference* VOL. 1(pp. 904–909). Edizioni POLI.design. http://www.lensconference3.org/images/program/VOLUME3.pdf.

[8] Akner Koler C. Form & Formlessness, questioning aesthetic abstractions through art projects, cross-disciplinary studies and product design education, 2007. Printed by PrintFinder Stockholm Sweden: Axel Books.

[9] Greet-Hannah G. Elements of Design; Rowena Reed Kostellow and the structure of visual relationships, 2002. Princeton Architectural Press.

[10] Akner Koler C. Expanding the boundaries of form theory, Developing the model Evolution of form. In Proceedings: *2006 Design Research Society*. International Conference in Lisbon. IADE 2006.

[11] Poli R. Introduction to anticipation studies. 2017. (Vol. 1). Springer.

PRODUCTS WITH PROVENANCE: DEVELOPING A SENSE OF PLACE IN PRODUCT DESIGN EDUCATION

Lyndon BUCK
Aston University, United Kingdom

ABSTRACT

What role does locale play in shaping design identity? How do designers see their own sense of place made manifest in their work? How can we encourage a sense of localism in young designers? Product design is particularly susceptible to globalisation; its relationship with technology links it to greater homogenisation. The nature of trends and notions of "*good design*" engenders a sense of place and localised design identities, but by definition design is a solution, and solutions cannot be divorced from the problems they address, from their context. This is where sense of place comes in and why it is important; it roots design in its most fundamental reason for existing. Without a sense of place, design can look great, work well, be interesting and engaging, but it can't truly be effective. This paper considers student projects over a 15-year period that trace the development of a methodology where place of design, manufacture and use become key drivers for design outputs. By focusing on immediate surroundings, a series of design projects question the nature of local materials, people and society, through local industry, football teams (from *Potters*, *Glovers* and *Hatters* to *Chairboys*) and social history. The outcomes help to inform students of their surroundings and encourages them to explore and engage with the localities. A defined sense of localism helps to place them, to settle them into new homes and workspaces, and to understand the nature, history and context of their new areas.

Keywords: Localism, spimes, blockchain, product narratives, provenance, placemaking

1 INTRODUCTION

Developing a sense of localism in students through involvement with local industry, materials and society is not new or radical, but the use of spimes and blockchain technology to explore product data and use to consider new product narratives and scenarios of use is growing. Using product provenance to develop new ideas of product lifecycle and inform lifecycle analysis and circular design models, a range of student design and make projects were undertaken with local industries, exploring roles, use of local materials and expertise, and with international partners, considering how designers work with materials and techniques from distinct areas and societies. Students began to consider design miles as analogous to food miles, a form of product terroir, highlighting the role of localised production and distributed manufacturing such as maker spaces and micro factories. Project outcomes show particular emphasis on how this approach allows students to consider product attachment, longevity, personality, narrative, and group affiliation to increase product longevity and alter user behaviours. How might a fuller understanding of material, user and product life stories change the way that we design products?

1.1 Background – football taxonomy

Importance of place is embedded in university DNA, not just traditional "*red brick*" institutions but also those formed to serve local industries. Many UK HEIs (Higher Education Institutions) evolved to train and upskill workers needed in and around the local area, with the workers in turn shaping the towns and cities that built up around them. This importance of trade is reflected in the names of many of the 736 football clubs that compete in the FA Cup [1]. *Potters* (Stoke City), *Hatters* (Luton Town) and *Chairboys* (Wycombe Wanderers, High Wycombe) all reflect more about local industrial heritage than the name of the local university. Some HEI crests or logos may still reference from where they evolved, in particular those that developed to train local industrial apprentices, but this is increasingly rare, with for example Buckinghamshire New University (High Wycombe) (BNU) removing in 2022 any reference in their crest to the local beech woods and furniture trades that made them famous [2].

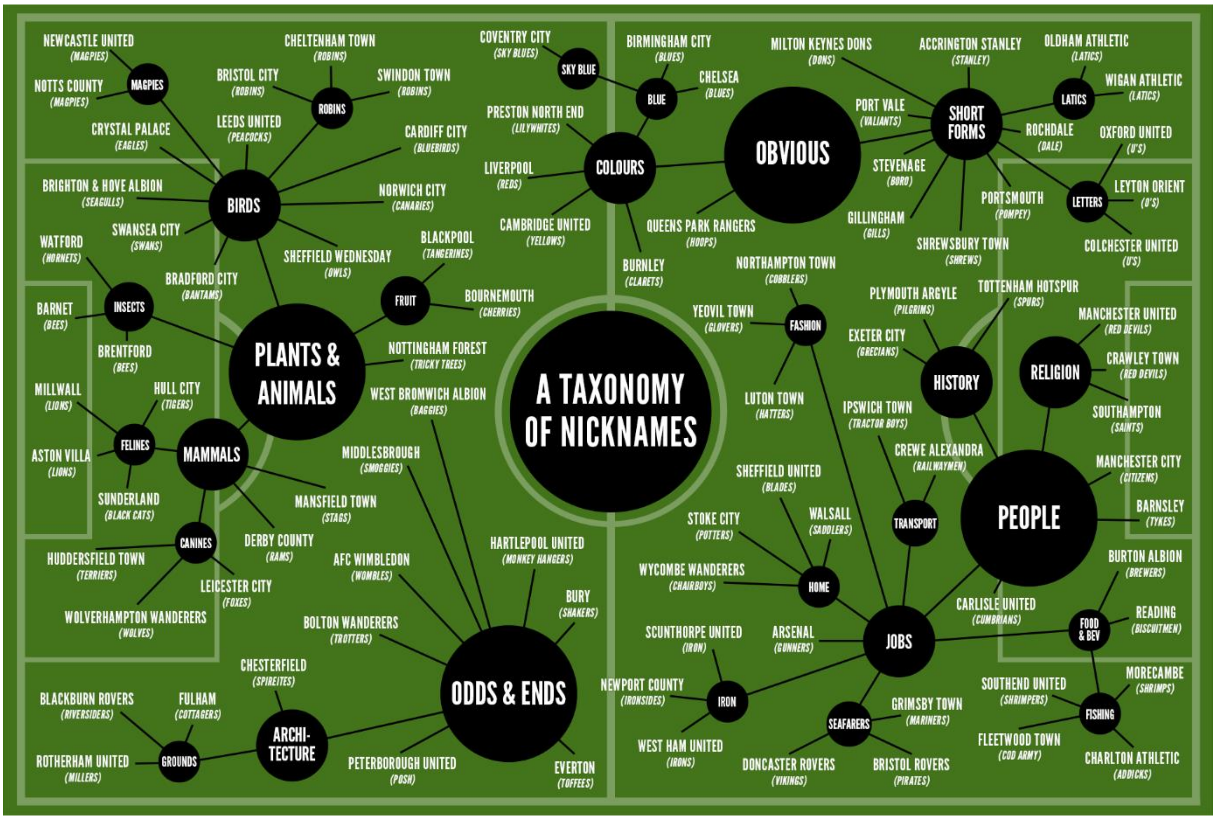


Figure 1. A Taxonomy of Nicknames – the informal fan names of English FA football clubs [1]

1.2 Spimes

Spimes [3] (a contraction of *"space"* and "*time*") are objects that can be tracked throughout their life, emerging through the convergence of technologies related to manufacturing processes, identification and location technologies. They are small, inexpensive means of remotely and uniquely identifying objects over short ranges such as RFID or long ranges such as GPS. Spimes allow us to track objects from concept to manufacture, ownership history, physical location, until eventual obsolescence and return to raw materials. If recorded, the lifetime of the object can be archived, audited and queried, raising awareness of materials, context and narrative of use. Spimes date back to 2004, when the US military demanded all of its suppliers attach Radio Frequency ID tags (RFID or "*arphids*") to military goods to aid with inventory and logistics. How will spimes allow designers to produce products with provenance, and how will this affect engineering and product design, and the way that we teach them?

1.3 Blockchain technology

London-based, Czech designer Martina Spetlova integrates *Provenance* blockchain technology into her clothes, insisting "*it's more about stories*," cutting through the technical jargon and focusing on the benefit to consumers. Blockchains are a trusted system to make supply chains more transparent, and gain consumer trust by allowing them to see where their purchase comes from. Spetlova packages the information into a wash-proof chip stored inside the clothing which can be scanned with a phone to unlock a link detailing the clothing's journey. The link can also be shared online as a way to provide this information for consumers who are curious. "*Unless you really want to know, you don't need to know that this zip has been delivered from YKK to Martina's studio on that day, but it's more about working with communities where you can read about where they're based, you can read their story, see pictures, it's a little bit more of an emotional attachment to the pieces*," explains Spetlova [4]. Having so much brand information so easily available on the shop floor without the need for sales assistants to remember it all will appeal to both sellers and buyers, it's a far more advanced, detailed and trustworthy alternative to a "*made in*" label. The consumer can be connected with the designer directly for repairs and they can add themselves into the chain to show the next stages of the product's life. This part becomes even more interesting if the product is passed on to multiple users and it makes the future of authenticating vintage products potentially a lot easier. Blockchains are largely focused on problem solving, of verifying goods and certifying sustainable supply chains but they also allow users to engage directly with the story behind the product, and to become part of the product narrative.

Figure 2. Martina Spetlova: M-Woven fabric; Selfridges display, London; blockchain fashion label [4]

1.4 Low fidelity methods

Spimes and blockchain allow designers new ways to integrate technology into their products and allow users to trace the provenance of their purchases. Spetlova's scannable chips give a digital life story of materials, sourcing and processing, allowing storytelling and embedded narrative which helps to build consumer, producer and supplier trust. But there are many other ways that designers can draw influence from their locality, from the materials that surround them, and from local history, people and industry. Over a 15-year period a range of design and make projects were conducted with Product and Furniture Design students at BNU which has a long history of engagement with local High Wycombe materials and industry. These projects were devised to allow students to understand more about the local area, but also to think more deeply around the issues of provenance, narrative and sense of place.

2 CASE STUDY 1: GEOFFREY FISHER

Geoffrey Fisher's products first sold in an East London concept store and are now found throughout Europe and America, but they are firmly rooted in his hometown of High Wycombe, UK. By working with unseasoned wood straight from local trees, using foraged and gathered or sustainably coppiced wood, Fisher uses traditional materials and methods to produce contemporary, commercial product designs with strong links to where they were grown and made. Fisher facilitated design and make projects with second year students, beginning with sourcing of timber and seeking inspiration in the natural forms of the wood. He believes the process of making can stimulate on sensory, intellectual and physical levels, and also makes us think about sustainability and ethical sales and production. By using greenwood, the level of practical skills of the makers are less important, and the wood is more forgiving, thereby encouraging greater levels of experimentation and engagement from students. As well as increasing students' appreciation of local area and a sustainable local material, these projects introduced the variety and properties of local timber species, "*it's always at the back of my mind that I'm making something that could end up in the hands of another person on the other side of the world, which will connect them with the maker and place*" [5]. There are often unforeseen benefits from such industrial collaborations – a local brush maker sourced wood for their handles from the local furniture industry, but since it's decline they imported their timber from abroad. They now produce a range of contemporary brushes using Fisher's local foraged timber. Students showed high levels of engagement with the projects, leading to collaborations with Fisher for internships, projects and post-graduation.

Figure 3. Geoffrey Fisher - product labels with sense of terroir; local material sources; production [5]

2.1 Furniture Magpies

An example of a successful collaboration with Fisher is *Furniture Magpies*, a furniture design and make workshop specialising in upcycling, started by two MA Furniture Design graduates from BNU, Nessa Doran O'Reilly from Ireland and Sua Lee from Korea. Starting with local found materials rather than grown timber they realised that furniture is often discarded so there is plenty of objects, parts and materials to reuse. Nessa and Sua's diverse backgrounds helped them appreciate the need for a sense of place and belonging in their work, they offer alternatives to mass-produced products, specialising in regenerating old furniture to meet customer requirements. They create one-off and limited-edition pieces, breathing new life into discarded items. "*We don't believe in good furniture going to landfill when it can be redesigned into a piece that people can love all over again. Our work strives to retain the character and story of the furniture we use, allowing the user an insight into their item's original identity*" explains O'Reilly [6]. Being based in a town renowned for furniture making they have many customers who own locally made furniture, and many with strong family ties to the furniture industry, thus reinforcing the sense of attachment to the pieces. Due to the nature of reusing existing furniture and reclaimed materials, consumers can be confident that pieces are unique and individual. Magpies work has been exhibited at TENT, London Design Festival, Milan Furniture Fair, Anthropology New York and Singapore. Lee went on to study for her PhD in 2019 looking at the reuse of waste furniture materials [7] and runs a furniture business, and O'Reilly balances running her craft furniture business in Ireland with teaching craft skills and television presenting on BBC and Channel 4 in the UK.

Figure 4. Furniture Magpies: Lovely legs; Hang on to your Drawers; DesignHouse journal editorial [6]

3 CASE STUDY 2: HIGH WYCOMBE CHAIR ARCH

Futurecity, a leading London cultural placemaking consultancy, were appointed by Berkeley Homes to develop, curate and manage public realm art commissions for a new development in High Wycombe [8]. *Futurecity*'s motto "*People. Culture. Place*" and their experience of creating a creative narrative for places across the world made them ideal partners. *Masterclasses in Sitting* was a 3-part project lead by Andreas Lang from art and architecture practice *publicworks*. For the first part, *Take a Seat with Us*, design students from BNU built ten unique seats for residents of Wycombe celebrating special places for sitting in the local area. The second, *A Chair for Arching* was a triptych of talks on chair history, chair bodging and celebratory arches in Wycombe. The project culminated in a specially designed, community built temporary chair arch for the development in Wycombe Marsh. Three different chairs were designed, CNC cut and assembled through public construction workshops held on site. Once assembled these chairs interlocked using simple timber dowel and bolt fixings to be configured into a celebratory Chair Arch (the motif of High Wycombe), it remained for two weeks before being disassembled and the chairs distributed amongst the students and volunteers who built them. '*The Last Chair Arch'* was Inspired by High Wycombe's rich history as a centre for furniture production and was a temporary public art piece which stood between furniture, architecture and art. Being developed in collaboration with residents, furniture makers and design students from BNU, pupils from local schools and public participants, it was seen as a way of unlocking the power and potential of space and pride in a location. *Futurecity*'s cultural partnerships aim to make great places that bring brand association through authentic, world leading, sustainable culture and knit them into a place's DNA [8], and these provide an excellent model for producing great *products with provenance*.

Figure 5. Scale study for High Wycombe chair arch; A Chair for Arching; The Last Chair Arch [7]

4 CASE STUDY 3: TAIWANIA

In Taiwan, the ancient *Taiwania Cryptomerioides* is an endangered cypress tree that grows up to 50m [9]. The wood is highly prized, being soft yet durable and heavily scented, and is used extensively for sacred temples and coffins. Its rarity and slow growth make it scarce, giving it legal protection in Taiwan and China. In an effort to increase its sustainable use in small household products the Forestry Research Institute Taiwan and Taiwan Ministry of Education approached National Taipei University of Technology (NTUT) and BNU for a joint UK/Taiwan Design Camp. The project was intended to show how the sustainable use of Taiwania could be encouraged through the design of responsibly designed products made using traditional, local skills in Taipei that highlight the particular properties of the wood, show respect for the tree and for the local customs and regard for this sacred wood. Students from both institutions were lectured on the tree, local customs and beliefs, the properties of the wood, and its significance within local communities, and the two groups then designed and produced their prototypes in their respective universities before bringing them together for a joint exhibition in Taipei. There were noticeable differences in the outputs of the two student groups, with the NTUT students displaying a greater sense of respect for material, and a distinct appreciation of pride and place that the UK students did not demonstrate. In the final lecture to prepare the students for the project, a definition of good design was suggested, a manifesto for the project. *Good design: narrative; place; humour; thought; materiality; care; responsibility; love; pride; judgement; magic.*

Figure 6. Project outcomes of the UK/Taiwan Design Camp exhibited in Taipei; Taiwania tree [9]

This outcome, whereby local students demonstrate a deeper sense of understanding of place, narrative and locale than the remote students, was discussed by Harlow et al [10] where designers responded to challenges from the EU H2020 *WATERSPOUTT* project by designing ceramic water containers for communities in developing countries. The design outcomes, while technically feasible, demonstrated simplistic and naïve matches to the specific requirements of the local users. Designers embedded within the communities unsurprisingly had a much clearer sense of the narrative of use, user and place.

5 FUTURE WORK

Ongoing and future work in this area includes a KTP on blockchains technology, a future Taiwan/UK design collaboration, and a British Council funded project on wheelchair design in UK/Mozambique.

6 DISCUSSION AND CONCLUSION

Jonathan Chapman and Peter Lloyd suggest [11] that design for attachment and trust is key to product longevity - that we as consumers develop product attachment through (amongst others): *memories and longevity (nostalgia), pleasure and enjoyment, self-expression or support of self-identity, product personality and group affiliation*. By making products that remind us of place, of belonging to a group or attaching us to a narrative behind an object, we are making things that we will keep for longer and use more sustainably. Spimes are information melded with sustainability, giving users comprehensive information about energy flows and materials that is documented, trackable, searchable and editable. They have the capacity to change our relationship to time, user, material and provenance of making and use. Designers with a sense of the role of narrative and place may hold the key to a sophisticated relationship with the products around us that we generally take for granted. In *Spimes not Things* Stead [12] identifies 7 key classifying design criteria for spime objects: *context; sustainability; technology; temporality; synchronicity; wrangling; metahistory.* Spimes and the related internet of things can open up a new raft of possibilities for designers, yet the technology can be cold, remote and dehumanising.

By teaching these ideas through low fidelity methods such as in the case studies presented, it is hoped that others will become interested in this area and develop their understanding through further work. One third of UK consumers are "*very concerned*" regarding product origin (Sustainability, July 2018) and there is a growing interest in terroir - 80% of UK food consumers check origin before purchase. It doesn't take too big a leap of imagination to link food miles to product miles - if a typical meal in the USA travels 1500-2500 miles from farm to table and a typical Nike product travels 1200 miles from Ningbo via Shanghai to London then an inevitable move towards distributed manufacturing or cloud production will enable local social enterprise and personal manufacturing, and a greater sense of product place. Gordon Murray's *iStream* automotive production technology (*istreamtechnology.co.uk*) and Arrival (*arrival.com*) are lauded for their micro factories and distributed production while Morgan cars have been living this for over 110 years in their Malvern, UK works. Geoffrey Fisher's work demonstrates that minimal product miles and a sense of terroir can produce sustainable, commercial products which capture the consumer's imagination. By introducing the idea of *product provenance*, it is hoped that the designers of the near future can produce products with a clear and traceable reference to place, use and material, and in doing so can encourage a more sustainable model of manufacture, distribution and use. We can begin to move towards a manifesto of "*good design*" which is sustainable in every sense, where every product demonstrates a balanced narrative of place, humour, thought, materiality, care, responsibility, love, pride, judgement, and hopefully just a little dash of magic.

REFERENCES

[1] Lubowitz E. *A taxonomy of English football club nicknames* (2016). https://www.unusualefforts.com/author/elizabeth-lubowitz/ [Accessed 2022, 7 March).

[2] BNU Identity https://www.bucks.ac.uk/about-us/corporate-identity [Accessed 2022, 11 March].

[3] Sterling B. *Shaping Things,* 2005 (Mediawork, The MIT Press, London).

[4] Pinnock O. *Meet the First Fashion Designer to Adopt Provenance's Blockchain Service* Forbes July 25, 2018 [Accessed 2022, 7 March].

[5] Fisher G. Catapults & Key Hooks, 2018 (Kyle Books, London).

[6] Lee S. and Buck L. *Sustainable Design Approaches Using Waste Furniture Materials for Design Students.* Engineering & Product Design Education Conference 2020, Herning, Denmark.

[7] Lee S. *Sustainable Design Approaches to Reusing Waste Furniture Materials* (2019) Unpublished PhD thesis, Coventry University, UK.

[8] *Masterclasses in Sitting: The Last Chair Arch* https://futurecity.co.uk/portfolio/masterclasses-in-sitting-the-last-chair-arch/ (2015) [Accessed 2022, 13 March].

[9] Thomas P., Wang C. and Li R. *Taiwania Cryptomerioides* (2019) [Accessed 2022, 7 March] https://threatendedconifers.rbge.org.uk/conifers/taiwania-cryptomerioides.

[10] Harlow R. and Buck L. *Improvements in Water Intervention Projects through Product Design Methods*. Engineering & Product Design Education Conference 2019, University of Strathclyde.

[11] Haines-Gadd M., Chapman J., Lloyd P., Mason J. and Aliakseyeu D. (2018) *Emotional Durability Design Nine – A Tool for Product Longevity*, Sustainability 2018, 10(6), 1948.

[12] Stead M., Coulton P. and Lindley J. *Spimes Not Things. Creating a Design Manifesto for a Sustainable Internet of Things*, The Design Journal 2019, 22:sup 1, 2133-2152.

NEO-CRAFT AS A TREND TO DESIGN A NEW TYPOLOGY OF 3D PRINTED PRODUCTS

Luis Miguel GUTIERREZ[1], Luis Alberto CORDOBA[1] and Alejandro ACUÑA[2]
[1]Architecture, Art and Design School, Tecnologico de Monterrey, Mexico
[2]Architecture, Art and Design School, Institute for the Future of Education, Tecnologico de Monterrey, Mexico

ABSTRACT
The concept of crafts is linked to the manual art of creating utilitarian or ornamental objects with traditional materials and processes guided by a generational knowledge. Adding new technologies and materials is acceptable considering boundaries guided by the presence of human customs and family heritage.
The history has been leaded since the human being exists, as a domain of the material and the development of technologies to transform it being capable to create tools that are useful for their survival.
Neo-Craft is a neologism that gives name a new trend in product design where tradition and technology crossover to bring a new typology of products, linked by folk tradition and the richness of cultural manifestations that people maintain through generations with new ways to manufacture using non-conventional materials and processes.
Over a one-week workshop, undergraduate students of Industrial Design programme, designed neo-craft products blending Mexican folk tradition with digital manufacturing technologies.
This paper describes the process in the implementation of the challenge and presents the discoveries that were found during the workshop.

Keywords: Craft, 3D printing, digital fabrication, folk tradition, educational innovation, professional education

1 INTRODUCTION
Mexico is a country with a great tradition in the creation of handicrafts since it has a vast territory inhabited by a great diversity of cultural manifestations due to its cultural wealth that still exists nowadays.
Crafts and design often are confused by the people due to the thin line that divide both concepts, craft is linked with handicrafts and tradition whereas design is related to certain principles and values centred on the study of the user needs and requirements [1].
Clara Porset is one of the most representative examples that crafts and design can coexist in an object, she pursued to integrate the Mexican folk arts with utilitarian products that are designated to be part of the people’s everyday life [2]. Her approach to bring low-cost design, mixing modern elements with folk values, creates a new vision in which both art and design scaffolds the further Mexican identity.
The boundary between artisan expression and design authorship is very thin but can be linked by the signature which is dynamic and unique and defines an artistic object [3]. The signature usually is linked to handmade products by the aesthetic style, but it also can be given by essential elements embedded in the object, the manufacturing technique is not the only way to give authenticity to a craft product, but the background of the author is an important approach to translate it into design elements.
The need to fit this typology of products into a disruptive definition is necessary to start working with the students in the workshop. Their profile as Industrial Designers needs to expand essential concepts that facilitate understanding and empathy to artisan’s guild and their craft.

2 CRAFTS AND DESIGN

The industrial revolution broke the paradigm that the objects must be created only by human hands, the introduction of the machine as a creation instrument generates a new way to transform raw materials into consumer products allowing iterative manufacturing and expanding to reach to a wider public.

During the 1851 Great Exhibition, Henry Cole curated an interesting catalogue of products that collided the use of the machine as an instrument of creation and the expressive elements that give value to the object, mixing an interesting and encouraging new typology of products that changed the way in which the people lived and their relationship to their everyday activities [4].

2.1 Crafts tradition in Mexico

Prior to the arrival of the Spaniards in Mexico, pre-Columbian cultures dominated the American continent as well as its diversity of cultural manifestations that coexisted with each other.

After the conquest, cultural syncretism gave way to one of the greatest stylistic surges in the history of mankind, since being culturally opposed civilizations they merge into an amalgam in which the different styles and worldviews were mixed.

Mexican crafts contain Indigenous and Spanish elements that together present a diversity of colours, shapes and symbolism that are unique in the world.

Some of the artisan manifestations in Mexico have been considered as an intangible world heritage by UNESCO [5], but despite the recognition and protection that has been granted, it continues to be a precarious economic activity that does not guarantee a secure income for those who practice it. In turn, exposure to gentrification and cultural appropriation has brought the tradition at risk due to bargaining and piracy is a common practice.

According to the initiative for a Mexican government law, a craftsmanship is "any economic activity aimed to create, produce, transform and provide goods and services, through unique manufacturing systems in which personal intervention is mandatory for the control of the production and finishing process. This activity will be based on the domain or knowledge of traditional or special techniques in the selection and treatment of raw materials or in the aesthetic sense of their combination and will have as a result an individualized product, not susceptible to totally mechanized production, for its commercialization as a craft product [6]".

2.2 Crafts + Design in Mexico

Designing is solving user problems, solutions can be given based on products, services, systems, spaces, buildings, visual communication, virtual interfaces, food, emotions, experiences, interactions and all the sensory pathways that the human being can perceive.

The cultural richness in Mexico is one of the strengths that provided a fertile ground to the first persons that decided to do design in the country.

After the World War II several foreign talents arrived with the intention of give the Mexican industries the possibility to create products with design values that ensure production quality, economic royalties and customer loyalty.

In the 60s the first Industrial Design schools were opened with the intention to provide local industry professional creative profiles. Mexico entered a stage of promotion supported by the Mexican government during the 70s, with the aim to impulse international exports [7].

Nowadays Mexico has a globalized view that integrates not only local tradition but internalize the external references to create a universal design language that has its own identity.

It could be very easy to believe that since Mexico is a country with a long tradition of craftsmanship and an incipient career in design both activities could merge naturally, and in a certain way they do.

However, there could be a disadvantage for those engaged in crafts activity to the creative, cultural and intellectual exposure of their work, the colonialist practices could manifest during the design process.

The designer's ethic stipulates that the link with artisans must always take place in a co-design environment, giving authorship credit bilaterally and recognizing that the distinctive symbolic elements of the artisan work are native and belong to their cultural heritage. It must be considered that those who dedicate themselves to craftsmanship deserve recognition and fair remuneration for their work always in a sustainability frame.

3 NEO-CRAFT

Neo-Craft is a composed word that combines both concepts Neo (New) and Craft (Artisanal), it is defined as "the alliance between design and artisan production techniques, focused on the search for authentic and respectful objects towards the person who creates them and towards those who introduce them into their intimate environment [8]."

The Neo-Craft frames the possibility to create design products by designers without limit the production techniques or restrict only the traditional influences in the creative process. It results to be a vehicle to manifest different versions of the particular vision of the designer and how they understand the personal relationship between user and object in order to create an intimate bond that expands the experience of the product by itself.

The elements that a Neo-Craft product must manifest are [9]:

- To be useful
- To be beautiful
- To be created by modern technology
- To frame universal aesthetics
- To highlight individual creativity

Neo-Craft is a term to define a new typology of products that allows anyone to create semi-artisan objects based on the heritage of their own culture without worrying about possible conflicts of interest related to artisan work. All this using modern technological resources and from the perspective of industrial design.

4 WORKSHOP FRAMEWORKS

The one-week workshop is offered as an initiative called Semana i by Tecnologico de Monterrey. These courses are stand-alone elective workshops that are scheduled once a year, the students decide which experience they want to live. Semana i requires immersive work by both students and teachers so they pause regular academic activities to dedicate 5 days to strengthen competencies for their professional life. The main objective of this workshop is to design handcrafted products using advanced conceptualization and manufacturing technologies with the intention of developing utilitarian and ornamental objects with materials and processes based on emerging technologies.

The workshop was scaffolded around the following elements that allow the students to conceptualize and design a Neo-Craft product.

4.1 Autoethnography

Is a method of primary qualitative research in which the researcher conducts a self-observation of their subjective experience and is described as an historical record of self-memories by the same designer [10].

Some authors define autoethnography as autobiography, which is very convenient for the exercise of the workshop since a search is made in one's own family history with a focus on moments of childhood.

4.2 3D Printing

3D printing is one of the most popular rapid prototyping techniques because the cost is low, and the level of detail and complexity obtained in the prototype is very high. The 3D printing technique used for the workshop is FFF (Fused Filament Fabrication) and the students must prepare all their deliverables to 3D print eventually.

The workshop was integrated by students from the last third of the programme, their 3D modelling skills were at an advanced level. Different software were used according to their expertise, looking for the files to be exported as STL and printed using Cura to do the slicing.

5 METHODOLOGIES

The elective workshop was given over five days in which the activities were divided following the traditional design process as a basis and focusing on creating a new typology of products mixing the crafts rhetoric and manufacturing it with digital fabrication techniques.

Students involved: 15

Students profile: Industrial Designers

Teachers involved: 2

Experts invited: 2
Workshop length: 5 days
The schedule of activities was implemented as follows.

Table 1. Workshop Schedule

Activity	Day	Deliverable
Debate: Are designers capable to be artisans?	1	Verbal participation
Conceptual development	2	Conceptual map
Design brief	2	Poetic Prose
Product configuration	3	Sketches
Product development	4	3D modelling
Final presentation	5	Infographic

5.1 Debate: Are designers capable to be artisans?
In this activity experts were invited to classroom in order to bring their knowledge about the topic and to open the question if designers can be capable to create artisanal objects. In this exercise the students receive the Neo-Crafts concept as an open field to explore new creative possibilities.

5.2 Conceptual development
The students had to declare a concept using a conceptual map where they make an autoethnographic exercise recalling their childhood memories linked to the traditions and rituals that define their Mexican identity given by their family heritage.
All those elements help to assemble a design concept, trying to define a product that frames these remembrances and nostalgic recollections.

5.3 Design brief
The writing of the brief had the intention of not adopting the professional format and giving it a more poetic character. The students read a text by Octavio Paz in which he expresses himself about craftsmanship, evoking its emotional aspects and elevating the object as the pinnacle of human expression.
After the reading, they wrote a poetic prose in which they referred to their object in a personal and subjective way, linking them emotionally and generating a value based on their personal history.

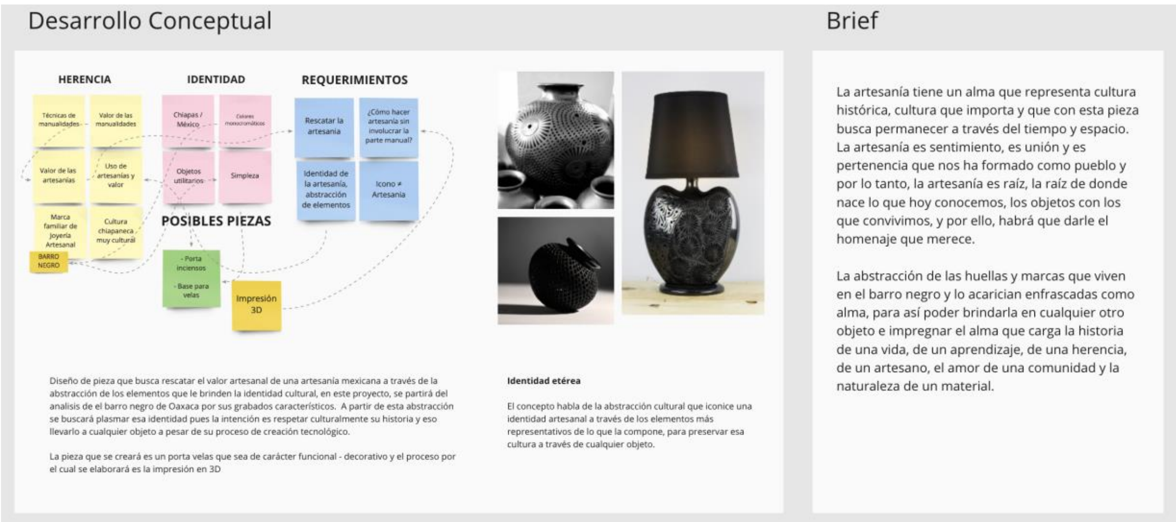


Figure 1. Student's example of auto-ethnography exercise, conceptual development and design brief

5.4 Product configuration
The students start sketching, bringing form and function to the Neo-Craft object and configurating the main concept into a design proposal.

They developed several design proposals aiming to find the most aligned to their design brief and the one that matches the project requirements.

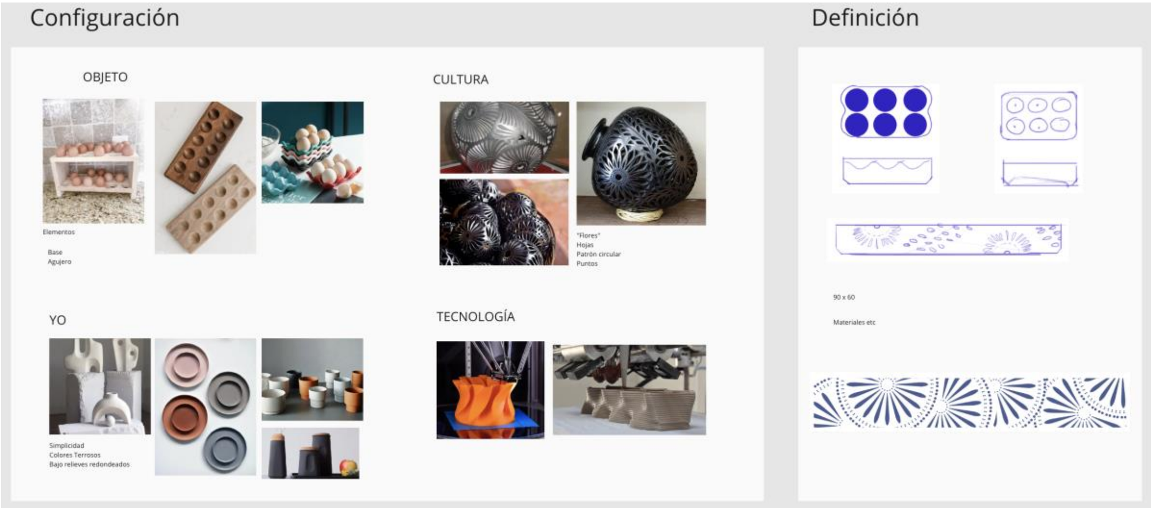


Figure 2. Student's example of product configuration and definition

5.5 Product development

Diverse 3D modelling techniques were used by the students, the aim of this exercise was to generate an input for a successful 3D printing process.
Considering the characteristics of the products, the material selected for the printing of the Neo-Craft objects were CopperFill, SteelFill and BronzeFill filaments giving a handcrafted feel despite having been created by a computer assisted machine.

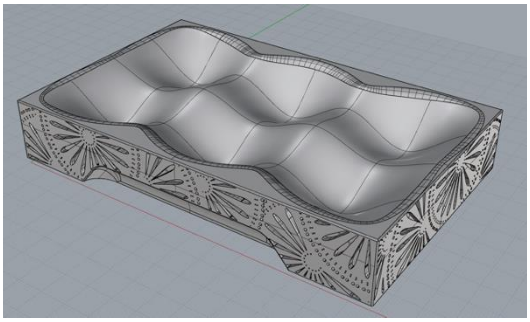
5.6 Final presentation

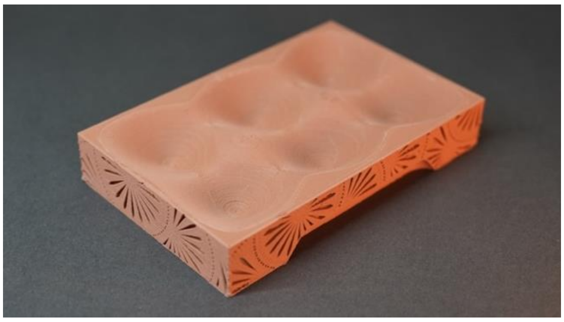
The students prepare an infographic poster where they place a final render of their product, and describe the following elements:

- History
- Meaning
- Ritual
- Use and function
- Technique
- Material

6 RESULTS

Due to the short time to implement the workshop and considering the design process needs a specific amount of time to ensure the concept development is strong enough, the 3D printing of all the design was programmed after the course ended. The results were satisfactory, and the products designed and developed were a successful exercise of autoethnography, conceptualization and digital fabrication.
The students developed a diversity of proposals derived from their personal experiences and family rituals, from objects to continue the home traditions to products linked to the cultural manifestations of the region, all of them demonstrated to have a very strong bond of inheritance not only personal but from the community that has been maintained for generations.
They developed a product with artisan characteristics created by digital manufacturing processes, it does not convert the result into modern handicrafts, since it does not contain the necessary elements to be considered as such. However, the concept of Neo-Crafts fits perfectly into this type of product since they are useful, beautiful, created by modern technology, framed a universal aesthetic and highlight the individual creativity of the author.





Figures 3-4. Student's example of 3D model and printed Neo-Craft product

7 CONCLUSIONS

The students considered this workshop as "an interesting approach to see crafts from another perspective". The link between artisanal and modern technology only can be given by the perspective of the Neo-Craft trend into the product design profession.

They understand that they cannot be considered as artisans because their design activity lacks heritage and tradition but having this perspective into configurate new typologies of products that can have both remembrance and technological implementations and having a responsible agenda of empathy, sustainability and respect for all the cultural manifestations they are free to create new ways to express their artistic curiosity.

Like Clara Porset once said: "A form made by machine is no less beautiful than a form made by hand."

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work. It is appreciated all the collaboration given by the experts and the Industrial Design students that participated in this workshop. Special acknowledgment to Alejandra Zermeño whose project has been used as an example for this paper.

REFERENCES

[1] Zand R. What is the Difference Between Craft and Design? *Sotheby's*, 2018. https://www.sothebys.com/en/articles/ask-roxane-what-is-the-difference-between-craft-and-design (accessed Mar. 03, 2022).

[2] Botello Ibarra L. M. Clara Porset: El arte en la vida diaria, dirección y diseño de exposición, Universidad Autónoma de México, 2017.

[3] Zoran A. R., Dick N. and Glauber N. The choreography of the creative process drawing in time and space. *Leonardo*, vol. 54, no. 6, pp. 643–648, 2021, doi: 10.1162/leon_a_02014.

[4] Johnson B. The Great Exhibition 1851. *The History and Heritage Accomodation Guide*, 2022. https://www.historic-uk.com/HistoryUK/HistoryofEngland/Great-Exhibition-of-1851/ (accessed Mar. 03, 2022).

[5] Secretaría de Relaciones Exteriores, UNESCO Presents Intangible Cultural Heritage Certificate to Mexico's Talavera Pottery. *Gobierno de México*, 2020. https://www.gob.mx/sre/prensa/unesco-presents-intangible-cultural-heritage-certificate-to-mexico-s-talavera-pottery (accessed Mar. 03, 2022).

[6] Gobierno de la Ciudad de México, *Ley de Maestras Y Maestros Artesanos De La Ciudad De México*.Mexico.https://www.congresocdmx.gob.mx/media/documentos/0feeb49365c1105ccf0e9619283faf526809c0d6.pdf, 2021, p. 300.

[7] Salinas Flores O. *Historia del Diseño Industrial*. México, D.F., 1992 (Editorial Trillas).

[8] Gobierno del Estado de Querétaro, Autentica Artesania de Querétaro. Querétaro, México, 2018, Accessed: Mar. 03, 2022. [Online]. Available: https://www.sector11.mx/proyectos/etniko-queretaro/.

[9] Bialogorski M. and Fritz P. Neoartesanías: reconfiguraciones en el campo artisanal. *Cuad. del Cent. Estud. Diseño y Comun.*, no. 141, pp. 31–44, 2021, doi: 10.18682/cdc.vi141.5109.

[10] Maréchal G. *Autoethnography*, 2nd ed. Thousand Oaks, CA: Sage Publications, 2010.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

A USER STUDY FOR FACILITATING EFFECTIVE REMOTE EDUCATION IN DESIGN STUDIOS: TOWARDS INTEGRATION OF CYBER-PHYSICAL TECHNOLOGIES INTO DESIGN EDUCATION

Yuval KAHLON[1], Momoko NAKATANI[1], Haruyuki FUJII[1], Takuya OKI[1], Jiang ZHU[1] and Santosh MAURYA[2]
[1]Tokyo Institute of Technology, Japan
[2]Hitachi Ltd, Japan

ABSTRACT
As remote learning in design studios becomes ubiquitous, it is important to reflect on this shift and structure our path towards effective online learning. Taking an architectural studio as a case study, we held several interviews with students and instructors, and extracted essential user needs which we would do well to address in an online setting. Existing learning environments were then compared in their abilities to fulfil such needs, and thus facilitate effective teaching and learning. The contribution of this study is a new perspective on studio-education which exposes gaps between user-needs and the current online setting, which may be bridged by emerging cyber-physical technologies (CPTs), such as augmented reality (AR) etc. Our findings can inform the future development of CPTs for studio education, and thus aid to maintain the positive aspects of traditional practices, when shifting to a remote setting.

Keywords: Remote learning, future of design education, project-based learning, cyber-physical technologies

1 INTRODUCTION
One important lesson from COVID-19 is that, as design educators, we ought to take distance learning very seriously. The difficulty of co-inhabiting physical spaces has imposed a challenging situation, which demands adapting our traditional practices to the available remote communication tools. As design education relies on discursive methods, effective communication is essential for training future generations of designers. Evidently, design studios (which serve as the core of design curriculums worldwide, regardless of a specific discipline) commonly take a project-based learning approach - students are presented with a design problem, attempt to tackle it by generating various design solutions and continuously improve them based on instructor feedback. In face-to-face instruction, this activity takes the form of a multifaceted real-time interaction between students, instructors, and design representations (i.e., models, sketches etc.). Such rich interaction is difficult to facilitate with existing remote communication tools. A clear example for this would be their inability to fully capture the richness involved in human gestures, which are an essential form of non-verbal communication.
A major technological candidate for facilitating high-quality remote education is the class of cyber-physical technologies (CPTs, e.g., augmented reality). Considering the expected increase in the usage of collaborative computing, CPTs can potentially revolutionize the way we teach and learn to design. Since both instructors and students may be viewed as the end users of these technologies, an important task is to identify their user-needs, which may be served via the future development of CPTs.

1.1 Aim and objectives
Considering the current ubiquity of remote learning (brought upon us by recent world events), we believe that it is essential to build effective remote learning environments for design education. Thus, we aim to support their development, by clarifying the needs of their users.
This study focuses on an architectural design studio (ADS), as a case study. Our main objective is to identify key user needs which characterize traditional studio education (i.e., in a physical setting), which

current remote learning environments (e.g., Zoom, Skype etc.) fail to cater to. To do so, we conduct in depth interviews with expert studio instructors and their students, in the context of an ADS. In this work, we conducted a total of six interviews with instructors and students at a major technological university in Japan.

1.2 Significance

The study proposes concrete insights into the needs of instructors and students of design studios, as the end users of emerging technologies which increasingly facilitate our educational practices. These insights are valuable both for technologist (as they can inform the future development of remote-learning platforms for design education) and for educators (as a way to reflect on the core aspects of traditional practices which should be considered when adapting to the new technological reality).

2 BACKGROUNDS

The recent pandemic had laid a harsh blow on architectural design learners and educators. Educating students in a spatial discipline by relying on flat displays is clearly a challenge. Yet, ADSs are more than physical spaces for spatial model-making. It is a place in which unique learning cultures develop. Acknowledging that we cannot hold on to the studio of the past [1], where do we go from here?

While the shift to online learning in ADSs seems rather sudden, researchers have identified the potential of enhancing the traditional studio via remote-communication tools more than a decade ago. Morkel, for example, has conducted a participatory study in which a physical ADS was augmented by remote communication using Facebook [2]. More recently, yet still prior to the pandemic, it has been further suggested that the traditional ADS is lagging behind advances in the professional world of architectural design, and that remote learning should be considered as one potential solution for this [3].

More specifically with respect to CPTs, Recent years show an increase in studies of CPTs and their potential to support design from the perspective of concept generation [4], product visualization [5], thought externalization [6] and more. Brown and Cowling, for instance, have examined mixed reality systems in the context of design education, and have concluded that such tools can be of value in supporting critical thinking and problem solving [7]. These signal a light at the end of the tunnel, thus motivating the development of CPTs for educational practices.

Thus, while the transition to online learning has been inevitable, imposed and rushed, we would do well to carefully consider and thoughtfully design our path for establishing effective long-term remote-learning environments. This study furthers these efforts, by focusing on the needs of users, as reflected in the traditional ADS, which we may need to leave behind.

3 METHOD

To identify key user needs in ADSs, a series of interviews was held with studio instructors and learners. Considering that the work with physical models (PMs) is a distinctive feature of the physical studio, the interviews focused on the contribution of such models for teaching and learning in ADSs. In this, we follow Alexander's basic distinction of form vs. context [8], such that models which embody the students' original thoughts or architectural creations are considered as "form", and those which display the physical environment in which the former will be positioned are considered as "context" (see 4).

All interviews were conducted at a major technological university in Japan via a remote communication platform (Zoom). Instructors were assistant professors at minimum, who regularly teach ADSs. Learners were graduate-level students majoring in architecture (Table 1). All interviews were conducted by an expert in human-centred design, who possesses extensive experience in conducting user interviews (over 15 years in the field of service design).

Table 1. List of interviewees

Role	Rank	ADS Teaching Experience		Role	Rank
Instructor	Associate Professor	8 years		Student	Masters' 3rd year
	Assistant Professor	5 years			Masters' 2nd year
	Assistant Professor	3 years			Masters' 1st year

The line of questioning focused on the identification of issues related with the usage of PMs, which may demand attention when shifting to remote learning. Interviews were transcribed live and then revised from audio recordings. The resulting protocols were then used to extract specific user-needs that could potentially be served by future CPTs. The minimal duration of each interview was two hours.

4 RESULTS

4.1 Physical models as multipurpose tools for simulation and communication

The making of PMs is a traditional practice in (architectural) design studios. The fact that such models are regularly made, despite the time and effort which this demands, implies on their importance for this practice. How do such models contribute to studio education?

First, in ADSs, two basic types of models exist – building models and environment models, and students are often requested to make both. As explained by one interviewee: “We make a model of the surrounding houses and a simple volume model, and then set one’s own building on the model to see how big or small it is compared to the surrounding buildings, or to see how the road compresses the building.” This comment also reflects a fundamental need which such models serve – being able to visually examine the relationships between the design (form) and its environment (context).

By extension, a second reason for using PMs is the desire to identify strong/weak points of the current design alternative: “When we had a site model made and there was a station of a Yurikamome (train) line, I (the instructor) advised like this: If you put the building you are planning in there, how would it look from the station’s side? How does it look when you get closer to a person's line of sight? If you get off at the station and see this building, it looks like a building you wouldn't want to enter”. Notice that here the model is used both as a means for visualization of the form and as a means for assuming a specific (and perhaps important) perspective, based on the context.

Another advantage of PMs is that they encourage or even “force” students to develop a concrete understanding of how various parts of the design are related in space. As explained by one of our experts: “…many students think in terms of planes and…It's not clear how the first floor is connected to the second floor. With a physical model, they are forced to think three-dimensionally.”

Additionally, instructors have expressed an explicit desire to use the model for exploring various ideas in real-time, for example: “In fact, I would like to crack the model open and say, ‘why don't you just split this into two pieces?’ But, since they are physically glued together, I am not doing that for the sake of humanity…I feel like tearing up people's drawings....Breaking things would be a little bit is easier if it's not physical. I want to operate it while saying, ‘like this’…It would be nice to be able to edit together on the spot, just like when you add a (piece of) code when teaching programming.” In other cases, directly manipulating the model is used for instruction regarding specific aspects of the design which demand attention or revision: “Sometimes wildly, I remove parts from the model. When he had a very open atrium space, but had 3-4 stories above it, I asked ‘what is the use of this?’. And he had no reason to do so, I took it off…I think it is easier to understand because it is visible. I sometimes add to a sketch of a floor plan. When I want students to change their mind, it's easy to understand visually, isn't it? I do it in a performative way, aiming for impact.” Indeed, students utilize such possibilities of real-time simulation by themselves as well: “When I think about the placement of the walls, I think about whether it will be dark here or not, and I shine light on it…it is easy to understand the feeling of openness and so on.”

Finally, PMs are important for collaborative reference, and for coordinating our perceptions and perspectives. As a student explained: “If the teacher remarks which view he/she is looking at it from, I would immediately try to look at it from that perspective, and by doing so, I think I can come up with other issues.”

4.2 Looking beyond physical models

The previous sub-section provided a brief account of the richness of PMs as learning aids in ADSs. However, such models are not without faults. This sub-section introduces some issues which arise when using PMs in an ADS and touches on the possibility of replacing them with digital ones, as attempted in current remote learning environments.

One fundamental issue with using PMs is the fact that they demand space and storage. Consequently, one instructor suggested to replace them with digital representations of the relevant information: “…we cannot use one (environment model) for each person. It is too large...If possible, it would be better if we could superimpose open data such as Google Maps, etc., so that they can be placed in 3D and discussions can have a more realistic feel.”

Another limitation of PMs is their capacity for simulation, which is restricted to a basic visualization of light conditions: "Indeed, when a student designs rooms without windows, I can say that this is no good at the stage of building if we have a simulation function (interviewer: What if they could feel how dark it would be?) Yes, that's useful. I often tell students that, in a building, sunlight comes from the south and the north side becomes darker and shadier. It is good to be able to include such things digitally, and to say that the building will be in shadow due to the surrounding environment."

While the above issues may be addressed by individually using digital models on a personal computer (e.g., using a CAD system), other issues arise when incorporating these into remote learning. One such issue is the inability of instructors to control their point of view – a matter which is trivial in a physical setting: "…face to face, when a student is explaining, I listen to the explanation and crouch down to look at what I am interested in on my own. Sometimes, when a student is explaining, I look at the place with them; other times, I want to look at it on my own." To resolve this, instructors must verbally instruct students to set the display on a specific point of view, which often does not yield the desired result, and is time costly as well: "When they start up a 3D model, I often say, 'Try to rotate it and show it from this side,' and the student says, 'Like this? Like this?' It takes time to get them to move it around."

Such miscommunication relates with the need to engage in collaborative reference freely and effectively: "It is difficult to communicate only verbally (in an online setting). I want to point the specific part and say, 'here.' If I can trace a specific image in my mind with my finger... Just telling them 'here' orally is too rough, so I want to write directly on the model." Another expert phrased this differently, emphasizing the aspect of coordinating attention: "If we can tell students where the faculty members focus their attention and how we look at it (the model), it could be an important point…the current situation is (that we) just tell them in words."

Finally, unlike digital models, PMs are commonly situated in the physical environment of the studio, which is of importance to the instructional process: "In addition to what the students themselves describe, there are also scattered traces of other models they have made, photos of buildings they refer to and sketches in the face-to-face environment. That is frustrating because we can see only those (sketches etc.) they have prepared." Such important clues for tracing the students' thought process and their individual perspective are lost in the transition to an online setting.

4.3 An activity-based characterization of working with models in ADS

Table 2. Activities in ADS and their facilitation in physical/virtual settings

Activity	Needs		Facilitation by Learning Environment	
	Student	Instructor	Physical	Online (current)
Collaborative reference	Signify specific things Help the other party keep track of the conversation		Facilitated (scale-dependent; often ambiguous)	To an even more limited extent than the physical setting
Manipulate the model	Explore various ideas visually in real-time		Facilitated (but some teachers hesitate to do so)	One-sided (only one party can manipulate)
	-	suggest changes to the design		
Visually examine the model	Visually evaluate the current design from multiple perspectives (bird's eye views/eye-level views)		To a limited extent (hard to see interior)	One-sided (only one party controls the view)
Point out potential issues	Share concerns and get advice	Raise points that were not considered	Facilitated	Facilitated (depends on collaborative reference)
Simulate various aspects of the design	Learn about performance of the design; observe consequences		To a limited extent (mainly natural light)	Not facilitated
Introduce relevant references	Share own's sources of insp.	Inspire student and expand their view	Partially (printed material nearby)	Facilitated (share webpages etc.)
Examine student's work environment	Trace student's thought process and understand his/her perspective		Facilitated (hints scattered on desk)	To a limited extent (if stud. have notes)

User needs derived from interviews with respect to using spatial models in ADSs were organized in Table 2. We listed the various activities of student-instructor-model interaction and matched them with underlying needs, from the perspective of both parties. Physical/online settings were then evaluated in their ability to facilitate these activities and fulfil the corresponding needs.

5 DISCUSSIONS

5.1 Reimagining spatial models as design aids

We have seen that the current practices of using either physical or purely digital models in ADSs entail both advantages and disadvantages for learners and instructors. A third alternative may be to use digital models, yet display them using a CPT, thus resulting in what we term a "cyber-physical model" (CPM). Since CPMs are both spatial and non-spatial in some sense, they may enable to reap the benefits of both. Consider the building-mass model presented in Figure 1 below, which was used for real-time light simulation via a CPT, by calculating light conditions at three different hours of the day in Barcelona.

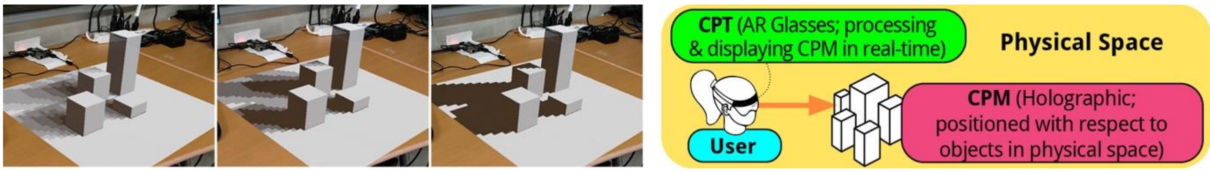


Figure 1. Real-time light simulation in a CPT viewed via a Microsoft HoloLens 2 headset

First, note that the model is spatial in the sense that it is viewed as a 3D object in the context of the physical space in which the viewer is found. Yet, it is non-spatial in the sense that it does not consume any physical space. As such, it maintains the spatiality of the physical setting (we can walk around similarly to a PM) and the cost-effectiveness of the digital model in terms of storage space.

Second, given that the model is stored digitally, it is expected that instructors would not fear "touching" students' creations, as they do with PMs. Using CPMs in an ADS may thus result in increased interaction and richer feedback from instructors, enabling students to witness them in-action. Considering the emphasis placed by Schön on the ability to reflect in-action for performing professionally [9], it seems essential that students witness this practice in real-time.

Third, owing to its digital nature, the above CPM shows the possibility of easily simulating light conditions at various times of the day. Should a PM be used for the same task with a lamp, for instance (as done by one our interviewees), the user would be required to calculate the light source's angle according to the building's location etc. This would be both time consuming and imprecise, thus leading to inferior results compared with the CPM. Further, other types of simulation (e.g., usage of escape routes during emergency) are strictly impossible using a PM.

Fourth, recall one instructor's proposal to replace the environment model with a digital representation. Notice that this suggestion not only expresses a desire to save space, but also to increase the level of realism of the discussion, which seemed of importance to the instructor. While making a realistic environment in a PM is extremely costly, both in terms of time and materials (and practically impossible at certain scales), doing so with a CPM would only require drawing on existing data sources and selectively visualizing them. This is not only feasible, but also entails extremely low costs (mostly in terms of electric power) once the CPT-based learning environment is established.

Fifth, one of our students remarked that they find it important to be attentive to the instructor's point of view when he/she examines the model. This is another type of activity which is trivial in a physical space yet is not facilitated by existing remote learning environments. Using a CPM in combination with a live model of the instructor's body posture (potentially in the form of an avatar) could enable the student to replicate it, and thus assume the instructor's current perspective. Furthermore, while in a PM is it impossible for two people to view a single object from the exact same position simultaneously, placing a digital representation of the instructor in the form of a hologram in the student's view would not preclude the student from assuming that specific view.

5.2 Towards a cyber-physical design studio

We have identified essential user need in ADSs and examined the ability of current learning environment to facilitate them. Following this, we have pointed out the potential benefits of embracing CPTs in studio education. Such a shift, however, poses significant challenges for learners, instructors, and institutions.

On a basic level, current CPTs are not affordable from the perspective of individuals, and costly from the perspective of institutions. For example, the price of a single augmented reality headset currently ranges between 2000-4000$ USD, depending on the brand and specification. This means that students cannot be expected to purchase these and use them for remote learning from the comfort of their homes. Beyond such practical difficulties, however, lies an even greater challenge – the traditional practice of design studios is strongly tied with the physical space in many ways, which would require a major reconsideration of the educational activity as a whole. In other words, it is essential to look beyond the (important) practice of interacting with models and uncover the deeper values of teaching and learning in physical studios, so that these are not lost when shifting to the cyber-physical setting. An obvious example would be the famous "studio culture" which develops when working in the same space for prolonged periods of time. Such aspects of ADSs are highly valuable for teachers and learners, but extremely difficult to develop and nurture in a remote setting. We conclude the discussion with Brown's hopeful image of ADSs' future: "The question…is how we can liberate our discipline from the assumption that an ill-defined space, time, pedagogy and culture is the only way to teach design. It is an opportunity to reconstruct architecture education in a more critical, inclusive and democratic way" [1]. We hope that, despite the challenges ahead of us, we can capitalize on emerging CPTs to realize this vision.

6 CONCLUSIONS

Essential user needs in ADSs were identified and discussed. Current learning environments (physical/virtual) were compared in terms of their ability to facilitate these. Following this, a potential shift to a cyber-physical studio setting and its expected outcomes were considered. Such a shift would demand a significant re-evaluation of the core values of the traditional setting which we wish to maintain and integrate with the new possibilities offered by CPTs, towards the development of a new educational practices. The authors believe that it is essential for both educators and technologists to resist the tendency for replicating existing physical practices in digital settings. Instead, efforts should be made to both broaden and deepen our inquiry of user needs, towards establishing a coherent framework for translating them to CPT-based environments. As education focuses on learners, a first step would be to collect larger amounts of data from students in varying levels of education. Such an investigation may provide a strong basis for identifying the positive aspects of past practices from learner's perspective, while reaping the benefits that future technologies have to offer for education in our design studios.

ACKNOWLEDGEMENTS

This research is supported by the Laboratory for Design of Social Innovation in Global Networks (DLab), Tokyo Institute of Technology, Japan.

REFERENCES

[1] Brown J. B. From denial to acceptance: A turning point for design studio in architecture education. *Distance Des. Educ.*, 2020, 1–9.
[2] Morkel J. Facebook-Enhanced Face to Face Learning: The Architecture Studio. In *5th Inter. Comp. & Instruc. Tech. Symp.*, ICITS2011, Elâzığ, May 2011, pp.22–24.
[3] Masdéu M. and Fuses J. Reconceptualising the Design Studio in Architectural Education: Distance Learning and Blended Learning as Transformation Factors. *International J. Arch. Res.*, 2017, 11(2), 6–23.
[4] Maurya S., Mougenot C. and Takeda Y. Impact of mixed reality implementation on early-stage interactive product design process. *J. Eng. Des.*, 2021, 32(1), 1–27.
[5] Tang Y. M., Au K. M. and Leung Y. Comprehending products with mixed reality: Geometric relationships and creativity. *Int. J. Eng. Bus. Manag.*, 2018, 10, 1–12.
[6] Milovanovic J. and Gero J. S. Exploring the Use of Digital Tools to Support Design Studio Pedagogy Through Studying Collaboration and Cognition. In *Des. Computing and Cognition'20, Gero J. S., Ed.*, January 2022, pp.21–39 (Springer International Publishing, Cham).
[7] Birt J. and Cowling M. Toward Future 'Mixed Reality' Learning Spaces for STEAM Education. *Int. J. Innov. Sci. Math. Educ.*, 2017, 25(4), 1–16.
[8] Alexander C. *Notes on the synthesis of form*, 1964 (Harvard University Press, Cambridge).
[9] Schön D. *The Reflective Practitioner: How Professionals Think in Action*, 1984 (Basic Books, New York).

EXPERIENCES FROM TEACHING CIRCULAR ECONOMY CONCEPTS TO ENGINEERING STUDENTS

Reyn O'BORN and Anette HEIMDAL
University of Agder, Norway

ABSTRACT
For several years, a mandatory bachelor-level course at the University of Agder (UIA) has been educating engineering students on a range of topics and ideas related to system thinking, ethics, and sustainability including circular economy. This paper investigates the learning outcomes of engineering students in this course by evaluating their knowledge of circular economy before and after attending this course to determine if current methods for teaching circular economy are effective for educating future engineers. Active learning and problem-based learning are the two primary learning techniques used in this course and students are evaluated based on their overall application of circular economy principles in group projects. The learning outcomes of the course have been evaluated based on a set of surveys given to students before and after the course to determine to what extent they have had prior knowledge of circular economy principles and how these students believe that knowledge gained in the course can be used to support regenerative and sustainable transformations in their future working life. The survey results show that engineering students have weak prior knowledge of circular economy concepts but that engineers are both enthusiastic towards sustainability issues and understand their importance. The results of this paper show that there is a need to improve circular economy education for engineers.

Keywords: Circular economy, systems thinking, sustainable engineering

1 INTRODUCTION
The need for circular economy teaching in education follows in line with the increased societal focus on circular economy as an international response to environmental damage. Circular economy has three main overarching goals: slowing resource loops (by extending product lifetime and introducing comprehensive systems for managing materials), eliminating waste and pollution in production, and regenerating nature [1]. Achieving a circular economy has thus far involved setting out strategies for change and developing policies that push society towards a consensus on a circular economy framework [2]. The European Green Deal and the series of the European Circular Economy Action plans [3, 4] have shown that the push for circular economy is well rooted in European policy. The challenge for educators is to translate important circular economy concepts and policies into the classroom so that future generations can contribute toward a circular society.
Circular economy concepts have been implemented in education using games in the classroom [5, 6, 7], through eco-design and sustainable product design [8, 9, 10], through project-based learning [9, 11, 12], and through active learning approaches [13,14]. Large emphasis has been placed on life cycle thinking and systems thinking [5, 12] and multidisciplinary approaches towards circular economy are emphasized in existing course structures [15]. However, the teaching of circular economy concepts is neither extensive nor informative enough to create transformational societal change [6] and that previous knowledge on circular economy topics is not widespread among engineering students [16, 17].
For the past several years, the mandatory third-year bachelor-level course ING200 at the University of Agder has been educating engineering students on a range of topics and ideas related to system thinking, sustainability and ethics. The curriculum has been updated in 2021 to teach about the important yet sometimes diffuse concept of circular economy as part of a broader approach towards teaching sustainability to our engineering students. Circular economy is a term that is increasingly used in a sustainability context but is often misunderstood as there are few concrete definitions or guidelines for engineers. The ING200 course has approximately 400 students per year from all engineering

disciplines1 at the University of Agder who learn about basic sustainability and circular economy principles as part of the general course curriculum. It is important to understand to what extent these engineering students have prior knowledge of circular economy concepts to understand better what needs to be taught and how these concepts can be practically applied for future engineers. This paper thus investigates the learning outcomes of students by evaluating their knowledge of circular economy before and after attending ING200 and to determine if current methods for teaching circular economy are effective at educating future engineers towards a circular future.

2 METHODS

2.1 ING200 course content

The course ING200 presents circular economy to engineers with three main principles: system thinking, material loops, and circular design principles. The course covers sustainability and circular economy topics over four separate two-hour lectures by addressing the "why, what and how" of sustainability. The first two-hour lecture covers global environmental trends and foundational knowledge on sustainability (Topic: "*Why sustainability is important*"). Trends such as climate change, biodiversity loss, plastic pollution, and environmental impacts on human life. Foundational knowledge such as the history of the sustainability movement, definitions on sustainability, and frameworks for sustainable development are presented to the students (Topic: "*What it means to be sustainable*"). The second two-hour lecture introduces students to the concept of complex systems thinking, life cycle thinking, and general industrial ecology approaches to sustainability such as eco-efficiency, industrial symbiosis, material flow analysis, and green product design (Topic: "*Technical solutions for sustainability*"). The third two-hour lecture covers life cycle assessment and how to evaluate the environmental impact of systems (Topic: "*Environmental foot printing*"). Finally, the fourth two-hour lecture focuses on circular economy and the green shift. The circular economy topics covered include the basic principles of circular economy from the Ellen Macarthur Foundation [1], the 9Rs of circular economy and material loops [18], and basic circular design principles for engineers [19] before finishing with a critique on circular economy. The overall emphasis is on practical examples of circular economy in action (Topic: "*Circular economy for engineers*").

The students then apply what they have learned through problem-based learning methods to evaluate circular economy, sustainability, and ethics issues on a technology of their choice, preferably a technology that they work with regularly, in a semester project. The semester project challenges students to think about technology in terms of systems, ethics, sustainability, and circular economy. The students are also given access to advisors once per week to discuss their work through active learning methods. The overall learning outcome of the ING200 course is that students learn how to evaluate the sustainability and ethical aspects of technologies as future engineers.

2.2 Survey design

Two surveys were carried out to test the effectiveness and importance of circular economy topics for ING200 students. The first survey was intended to determine their opinions and prior knowledge of circular economy and sustainability topics while the second survey was intended to understand how the students evaluated the importance and application of circular economy topics within their disciplines. The first survey had questions focusing on students' prior knowledge of basic aspects of circular economy (such as material loops and circular design principles) while also evaluating the importance of sustainability for them personally and how they felt that their study programme prioritized sustainability issues. The second survey built on the findings of the first survey and integrated some of the topics covered in the lectures on circular economy to evaluate their importance for the students within each study programme. The questions focused on how the students felt that circular economy and circular design principles were applicable to their respective disciplines and to try to determine their opinions on how society can transition to a circular economy.

2.3 Data collection and analysis

The two surveys were made with the survey tool SurveyXact and were distributed on two different occasions on the Canvas learning platform used in the course. The first survey was distributed to the

[1] Mechatronics, renewable energy, civil constructions, electronics, and ICT/IT

students after the first three two-hour lectures on sustainability but before their lecture on circular economy started. The students had one day to complete the survey, but the lecturer also gave the students time in the classroom before lecture to finish the survey. The first survey had 16 questions in total, with two additional questions given if the students answered "yes" on two qualifying questions. The second survey was distributed two weeks after circular economy topics were covered in lecture. The second survey had 11 questions. Most of the questions were multiple choice questions, while some questions required answers to be given as a free text. The two surveys were compared to see the change between the students' knowledge, opinions and attitudes before and after the lecture on circular economy.

3 RESULTS AND DISCUSSION

Table 1 gives an overview of when the surveys were distributed and closed, and the response rate for each survey.

Table 1. Survey response rates

	Distributed	Closed	Response rate
Survey 1	10-Feb-22	11-Feb-22	25%
Survey 2	25-Feb-22	27-Feb-22	23%

The distribution in gender on the surveys was 73% male and 27% female on Survey 1 and 68% male and 30% female on Survey 2 (2% did not want to answer). The distribution on the students' field of study is shown in Figure 1. This shows that engineering students from all disciplines replied to the surveys.

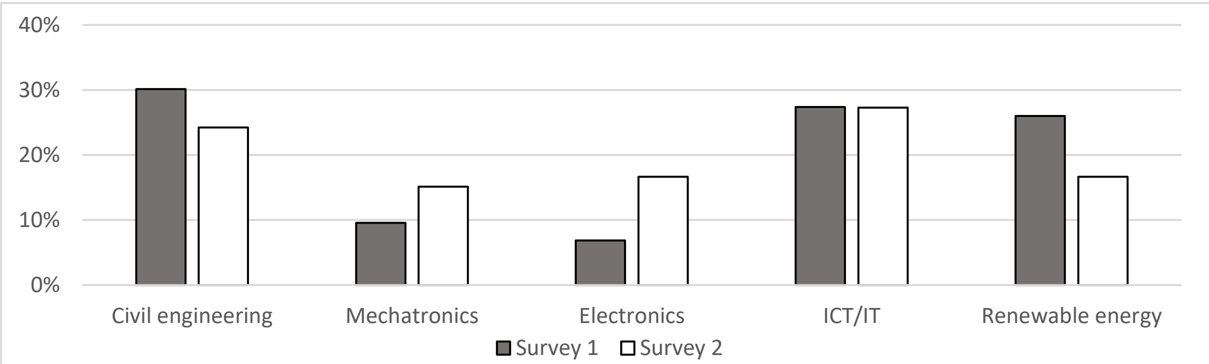


Figure 1. Response rates according to field of study

One of the first questions in the first survey was "*Have you heard of the terms 'linear economy' and 'circular economy' before?*", where 52% answered that they had heard the terms previously. This indicates that only half of third-year engineering students have heard of the terms linear and circular economy. This was also made clear when asked "*What do you think the term 'circular economy' means?*" as shown in Figure 2. This question required a free-text answer and many of the engineering students answered that circular economy is associated with "money". This changed when students were asked the same question in the survey 2 after receiving lectures on the subject where "reuse" and "waste" were the most common associations. This indicates that many students were not familiar with the term before the circular economy lecture was given but more familiar afterwards.

Figure 2. (Left): Word cloud from Survey 1 and (Right) Word cloud from Survey 2 "What do you think the term "circular economy" means?"

When students where asked the question "*How important is sustainability for engineers in your discipline?*" in the first survey, 83% rated it as very important or somewhat important. On the second survey this had a slight increase to 88%. When asked "*How do you feel that sustainability topics are considered in your study programme?*" 70% responded it was somewhat or very much considered on the first survey. On the second survey they were asked how important circular economy topics are in their discipline, where 94% rated it as very important or somewhat important.
The question "*Which of the following sustainable product design principles do you think can be applied in your discipline (mark all that apply)?*" was asked in both surveys with several options for the students to mark. The results from this question are shown in Figure 3 and indicate a consistent decline in all the options from survey 1 to survey 2. This means that the students had a different view on the possibilities within circular economy in their discipline after receiving lectures on this subject. The students have likely learned more about the limitations and challenges regarding circular economy and could have a more cautious view on circular economy based on their answers from the second survey. This could indicate that the understanding of the subject also informed the students about the difficulties or limitations of implementing circular economy in their disciplines.

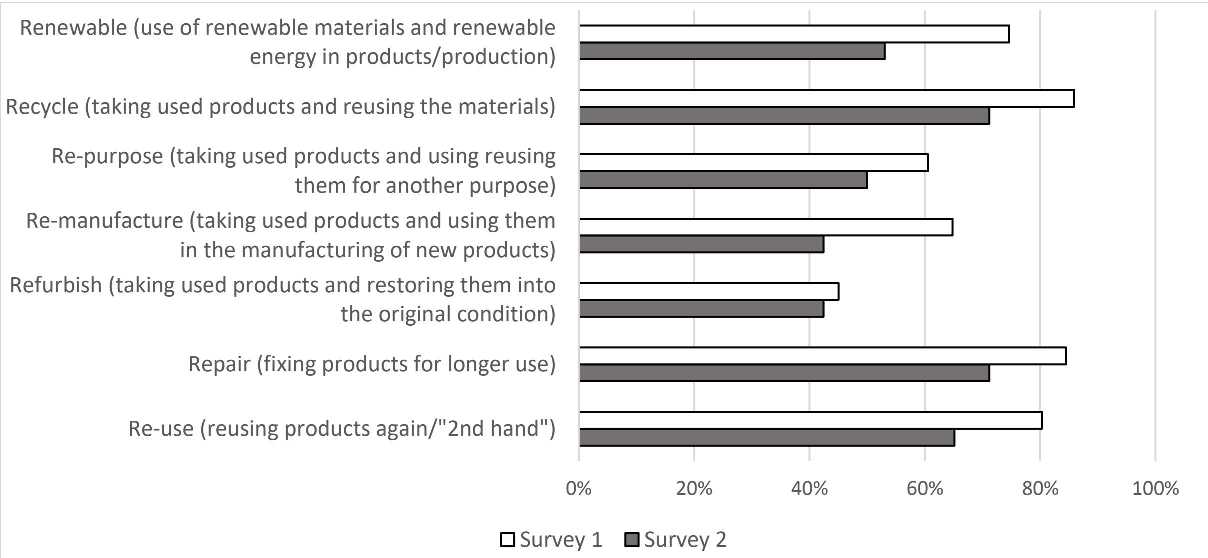


Figure 3. "Which of the following sustainable product design principles do you think can be applied in your discipline (mark all that apply)?"

To get an overview of the students' knowledge on circular economy survey 1 contained questions regarding different circular economy terms. Figure 4 shows the result from these questions, where 73% had never heard of the concepts "*products as services*" and "*dematerialization*", and only 40% had heard of the concept "*regeneration*". On survey 2 these concepts were included, as possible options on the question "*Which of the following sustainable design principles do you think are most relevant in your discipline (mark all that apply)?*". As Figure 5 indicates, many students saw these concepts as sustainable design principles that could be relevant in their discipline. Hence, the students had a better understanding of circular economy and its relevance to their field of study after receiving lectures on this topic. Since 48% had never heard of the terms "linear economy" and "circular economy" before, there is a clear need for teaching these topics in the curriculum for engineers.

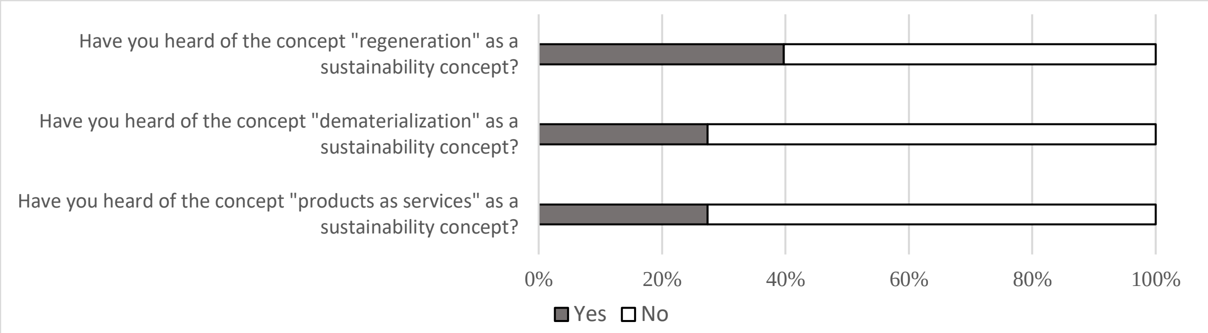


Figure 4. Questions from Survey 1 regarding background knowledge of different terms

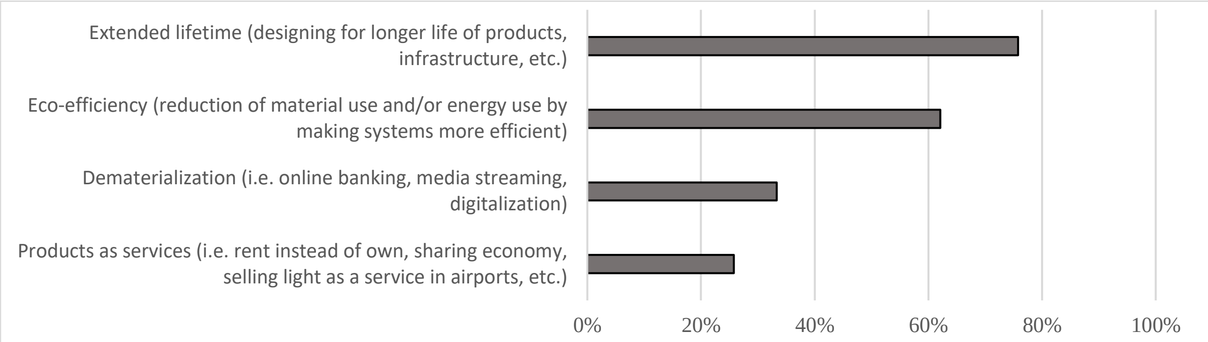


Figure 5. Results from "Which of the following sustainable design principles do you think are most relevant in your discipline (mark all that apply)?" in Survey 2

The results of this study indicate a need for more circular economy teaching in engineering programmes and is consistent with other findings in literature where engineering students are shown to have a low understanding of circular economy topics [6, 17]. This is especially important as results from this survey and previous literature shows that engineering students feel that sustainability is very important to them [5, 13]. Hence it recommended that circular economy topics are taught to engineers in other courses throughout their education. This may be difficult to achieve without training educators and support from educational institutions [16]. It is also important to note that the approach in ING200 is to present foundational knowledge in sustainability before presenting circular economy topics. This is because we consider circular economy and sustainability to be complementary topics to each other as supported by other educators [10]. We also feel that is important to present the transformational nature of circular economy to our engineering students, but that critique of the circular economy concept is necessary in order to not apply the same ideas on existing systems where circular economy will not work [9, 11]. In general, we recommend that engineers are given a discipline focused, practical education in sustainability and circular design topics so that they can use their skills to find transformative circular solutions in the future.

4 CONCLUSIONS

The results of this study show that engineering students do not receive enough training on circular economy topics despite the growing interest in sustainability among engineering students. The results of this paper should be used to show the need for more circular economy curriculum throughout an engineering education if circular economy strategies are to be implemented in wider society. The results of this survey indicate that this need is consistent across different engineering disciplines and that transformational change towards a circular economy will be difficult without greater knowledge of circular economy topics among engineers.

REFERENCES

[1] Ellen MacArthur Foundation, Growth within: a circular economy vision for a competitive Europe, McKinsey Center for Business and Environment, 2015.

[2] Prieto-Sandoval V., Jaca C. and Ormazabal M. Towards a consensus on the circular economy, *Journal of Cleaner Production*, vol. 179, pp. 605-615, 2018.

[3] The European Green Deal - 11.12.2019 COM (2019) 640 final. Brussels: European Commission, 2019.
[4] Circular economy action plan, European Union Directorate-General for Environment, 2019. [Online]. Available: *https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en*. [Accessed: 01- Feb- 2022].
[5] Whalen K., Berlin C., Ekberg J., Barletta I. and Hammersberg P. All they do is win: Lessons learned from use of a serious game for Circular Economy education", *Resources, Conservation and Recycling*, vol. 135, pp. 335-345, 2018.
[6] Kirchherr J. and Piscicelli L. Towards an Education for the Circular Economy (ECE): Five Teaching Principles and a Case Study, *Resources, Conservation and Recycling*, vol. 150, p. 104406, 2019.
[7] de la Torre R., Onggo B., Corlu C., Nogal M. and Juan A. The Role of Simulation and Serious Games in Teaching Concepts on Circular Economy and Sustainable Energy, *Energies*, vol. 14, no. 4, p. 1138, 2021.
[8] Lanz M., Nylund H., Lehtonen T., Juuti T. and Rättyä K. Circular Economy in Integrated Product and Production Development Education, *Procedia Manufacturing*, vol. 33, pp. 470-476, 2019.
[9] Maruyama Ú., Sanchez P., Trigo A. and Motta W. Circular Economy in higher education institutions: lessons learned from Brazıl-Colombıa network, *Brazilian Journal of Operations & Production Management*, vol. 16, no. 1, pp. 88-95, 2019.
[10] Andrews D. The circular economy, design thinking and education for sustainability, *Local Economy: The Journal of the Local Economy Policy Unit*, vol. 30, no. 3, pp. 305-315, 2015.
[11] Kopnina H. Circular economy and Cradle to Cradle in educational practice, *Journal of Integrative Environmental Sciences*, vol. 15, no. 1, pp. 119-134, 2018.
[12] Cappuyns V. and Stough T. Dealing with societal Challenges of a circular economy in engineering education, in *Proceedings of the 8th International conference on Engineering Education for Sustainable Development*, Bruges, 2016, pp. 212-218.
[13] Sanchez-Romaguera V., Dobson H. and Tomkinson C. Educating engineers for the Circular Economy, in *Proceedings of the 9th International Conference in Engineering Education for Sustainable Development*, 2016.
[14] Sandström N., Nevgi A.and Betten T. Excellence in education requires excellence in collaboration: learning modules in circular economy as platforms for transdisciplinary learning, in EESD2021: *Proceedings of the 10th Engineering Education for Sustainable Development Conference*, Cork, 2021, pp. 1-11.
[15] de la Torre R., Onggo B., Corlu C., Nogal M. and Juan A. The Role of Simulation and Serious Games in Teaching Concepts on Circular Economy and Sustainable Energy, *Energies*, vol. 14, no. 4, p. 1138, 2021.
[16] González-Domínguez J., Sánchez-Barroso G., Zamora-Polo F. and García-Sanz-Calcedo J. Application of Circular Economy Techniques for Design and Development of Products through Collaborative Project-Based Learning for Industrial Engineer Teaching, *Sustainability*, vol. 12, no. 11, p. 4368, 2020.
[17] Venugopal P. and Kour H. Integrating the circular economy into engineering programmes in India: A study of students’ familiarity with the concept, *Industry and Higher Education*, vol. 35, no. 3, pp. 264-269, 2020.
[18] Potting J., Hekkert M., Worrell E. and Hanemaaijer A. Circular Economy: Measuring innovation in the product chain, PBL Netherlands Environmental Assessment Agency, The Hague, 2017.
[19] Moreno M., De los Rios C., Rowe Z. and Charnley F. A Conceptual Framework for Circular Design, *Sustainability*, vol. 8, no. 9, p. 937, 2016.

EVALUATING LEARNING EXPERIENCE AND EMOTIONAL TRIGGERS OF VIRTUAL LEARNING ENVIRONMENTS (VLES) USING PSYCHOGALVANIC REFLEXES AND BEHAVIOURAL ANALYSIS

Abhijeet KUJUR, Sadaf H KHAN and Jyoti KUMAR
Department of Design, Indian Institute of Technology, Delhi, India

ABSTRACT
Virtual Environments (VEs) are on the rise as an instrument in various sectors involving emotional states and educational research. Studies till date have tried to explore the effectiveness of VR in a variety of emotional health interventions, treatment of learning phobias, and providing virtual support to students worldwide. Research has demonstrated that VR immersive environments and VR experiences create a significant impact on the users' psyche. A learning experience is related to the emotional state of the person (O'Regan, K. (2003). Therefore, it would be interesting to study the influence of VR experience on the emotional states of the learners. Students around the globe were already struggling with emotional crises even before the pre-covid situation as reported by multiple agencies but now the situation has turned more grievous. Here comes the need for magnified learning experiences in virtual learning environments (VLEs). This study investigates the impact of two different VR-3D learning environments. It draws a comparison between students' emotional states, VR experience, and VR design elements using neurophysiological tools like Galvanic Skin Response (GSR) and self-reporting questionnaires. In the experiment, participants were asked to go through two different VR learning simulations and their physiological responses were recorded for analysis. The two simulations were differentiated based on space and interaction design elements. The study suggests that well-designed Virtual 3D-Environments in an educational setup can help students in reducing stress levels and ways how we can elicit positive emotions and facilitate a better learning experience.

Keywords: VR 3D-environments, emotion, learning experiences, GSR, eye-tracking

1 INTRODUCTION

As we've seen in Covid, the global education system is changing gradually, and our academic environments must be adaptive to meet our dynamic world. It is necessary to redesign educational settings to deliver a modified or enhanced academic experience. Traditional classrooms were built with a factory-style instructional method in mind, which may have fitted the needs of the time. Therefore, they are not equipped to handle today's technological demands or to educate pupils with a variety of working methods and thinking processes [1]. Virtual learning environments (VLEs) or VR classrooms might help bridge this gap. Current research shows that teachers and students value educational learning settings [2]. Educational spaces or academic built environments have a direct influence on students' pleasant or poor experiences, and even little adjustments to their built environment may have a major impact on their day-to-day emotional states and learning results. It is not surprising that there is a visible debate about how to educate our children in the most efficient and appropriate manner [3]. In comparison to the evolutionary history of people and their learning process, the current educational system is exceedingly unnatural and confused [4]. From an academic institution's front entrance to its grounds and classrooms, every aspect of the built environment of a learning space influences brain processing and has a direct impact on how students feel and experience while they are in that area. Neurophysiology has given us a better understanding of how the brain and nervous system work and how to support effective teaching and more importantly, effective learning in an academic setting. [5]. The internal activity of the learner during learning is not limited to cognitive processing; it also involves emotional processing [6]. Neurophysiological tools like Galvanic Skin Response (GSR) provide an understanding of emotional involvement and learning [7]. Affective-cognitive learning models aim to include the learner's emotional state throughout the learning process as part of the causal chain that leads to a learning outcome. Emotion is a strong, short-term reaction to a specific item or event like connecting a new concept to existing knowledge [8]. Understanding and supporting emotional processes in technology-based learning has become a top priority for researchers working on various types of learning environments, such as virtual learning environments (VLEs) [8]. One can employ art in designing learning environments to engage many senses which leads to improved cognition and retention. But the issue remains: what about the physical environments and layouts of our classrooms? Lighting? Sound? How can these and other physical components of the learning environment assist students in learning more effectively? Researchers now encourage everyone to think beyond the preconceived notion of school and what a school or academic space may seem like [5].

2 LITERATURE SURVEY

2.1 Learning spaces and their relationship with emotion

Many scholars have previously worked on generic stress-relieving designs [5]. Because perception, personality, and cultural imprints impact how learning environments affect pupils, it's hard to provide clear metrics or recommendations. Sick, elderly, and youngsters are much more attached to their living environment than others, therefore they're more affected by spatial situations [9]. In the best situation, a well-designed built environment may enhance healing processes (for example, in hospitals), increase fitness and vitality, emotional and cognitive skills, social engagement, and communication [10]. Various studies have demonstrated architecture, urban planning, and design impact humans' behaviour and emotions [11]. If learning spaces or constructed environments aren't created with a student's psychological requirements or mental health in mind, the risk of these disorders increases. These poorly planned and badly designed buildings or built environments magnify the level of negative emotion within an individual. Stress symptoms include palpitations, sweating, dry mouth, shortness of breath, fidgeting, quicker speaking, and heightened negative emotions (if present). Stress causes global adaptation syndrome. Stress contributes directly to psychological and physiological dysfunction and disease by initiating mind-body changes" [12].

2.2 Emotions caused by a virtual learning environment

The virtual learning environment has a significant impact on students' learning results [13]. Open space and noise in schools, as well as the temperature, inadequate light, overcrowded classrooms, misplaced boards, and unsuitable classroom arrangements, might be distracting variables for students [14]. Emotions have a key role in technology-supported academic learning [15]. The three central research concerning emotions during learning are (i) identification of emotions generated during the interaction with the learning environment, (ii) measurement of emotional experience in the learning environment, and (iii) causes and consequences of the learner's emotional state in the learning environment [16]. The first stage is to detect learner emotions throughout a learning session. The next stage is to measure how students feel while using VLEs. Interviews, scale-based questionnaires, and neurophysiological tools like GSR are used in literature to evaluate psychogalvanic reflexes [17]. Final phase: determine causal relationships, causes, and consequences between learning environment elements and emotions. Emotional processing (e.g., emotions felt during e-learning) is linked to cognitive processing (e.g., degree of engagement and strategy use during learning) and learning outcomes. Significant positive and negative relationships were observed between positive and negative emotions and learning performance in a medical learning environment. This study establishes causal relationships between emotion and learning.

2.3 Emotions and their physiological measures

Emotions are affective states that have an impact on behaviour and cognition. Physical and physiological reactions are caused by external or internal stimuli. Facial expressions, behaviour, and physiology may be utilised to distinguish emotions [18]. Emotions' onset and intensity are connected to neurophysiological, mental, and cultural factors. Emotions are produced through physiological reactions to events [19]. Since they're automatic, people don't notice changes in emotional or physiological signals. Physiological signal analysis can identify emotions accurately. Previous research [20] has shown that biosensors can detect emotions by monitoring ANS activity. This research aimed to compare 'Traditional' and 'Nature-Based' VLEs using VR design elements to analyse the psychological and physiological effects of learning environments on individuals. This research uses the HTC Vive pro-eye VR Headset and Empatica-E4 GSR for stimulus exposure and data collection respectively. The goal was to compare participants' positive and negative emotional states and arousal while exposed to two VLEs.

3 METHODS AND MATERIALS

3.1 Stimuli

Two virtual learning environments (VLEs) were designed for different stimuli conditions to evaluate emotional responses of the participants. VLE-1 was designed as a 'Conventional Classroom' setup and VLE-2 as a 'Nature-based Classroom' setup. Both the stimuli vary based on design elements as mentioned in table 1. These stimuli were designed using 'Sketchup-Pro VR' and 'Simlab Composer-10 VR' software. The participants were exposed to the stimuli using 'HTC vive pro-eye VR Headset'.

Table 1. Two different VLEs and variations in their Design Elements

Design Elements	Rear View	Front View	Classification	Suitable Pedagogy	Texture	Layout	Space	Area
VLE 1			Conventional/Classic Classroom Environment	Instructor-based Approach (Formal)	Wood Concrete Steel Tile	Use of linear grid Rows and Columns	Rectangular space Four walled enclosure 4 Edged corners	24 sq.m.
VLE 2			Nature-based Classroom Environment	Suitable for multiple pedagogical approaches	Grass, Stones, Wood, Water, Steel and Concrete	Use of curvilinear forms throughout	Rectangular space Four walled enclosure Curved Corners	20 sq.m.

3.2 Participants

This study was conducted on 11 participants (9 Male, 2 Females; Mean Age = 23.15 years, SD = 2.98 years). All the participants were undergraduate students of design and non-design backgrounds from IIT Delhi. All the participants were residents of urban areas and had a lesser chance of visiting natural areas frequently.

3.3 Procedure

In the study, participants were instructed to wear a VR-headset, a galvanic skin response (GSR) sensor wristwatch and would be exposed to two different VLEs. They were instructed to get acquainted with HMD, observe, and get immersed into the environment. Later, they were teleported to both environments virtually one after the other for 6 minutes each. The tasks included counting chairs and the number of notebooks in VLE-1 while counting the number of trees and rocks in VLE-2. These tasks were given to engage participants completely into the respective VR environment. The experiment was performed for 20 minutes on each participant, 6 minutes for each VLE, and 8 min to prepare the participant. Their psychogalvanic data was recorded simultaneously during the experiment. After the experiment, participants filled a questionnaire and answered a few questions about the experience.

Figure 1. Participant activity during VR-Experiment

4 ANALYSIS AND RESULTS

There were three main ways to collect data for this study. The first way includes in-person semi-structured interviews. In VLEs, the participants stated and characterized their learning emotions and experiences. The second source of information was gathered from the questionnaire sent to participants. The third source of data was psychogalvanic reflexes which were recorded while the participants were interacting with the VLE. Finally, the three types of data were evaluated and analysed as mentioned in this section.

4.1 Interview findings

Participants reported their level of comfortability with the two different VLEs and their elements post experiment. These reports included likes and dislikes in the VLEs and how it is affecting them emotionally. Participants mentioned different VR classroom design elements that made them uncomfortable in the environment. 'Teacher's desk', 'Laminates of furniture', 'Open spaces', 'chairs', 'Sharp edged surfaces', 'Extra chairs' and 'Trees' were a few elements in VR which the participants wanted to add and eliminate. However, the frequency of experiencing these VR classroom design elements varied among participants. The VR elements that were experienced and suggested by the participants are presented in Figure 2 (a) and 2 (b).

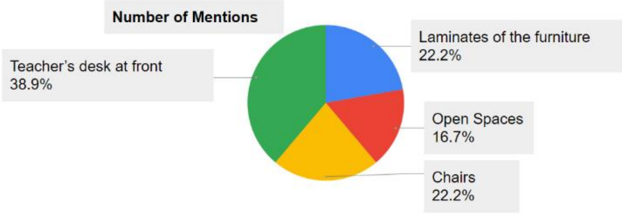


Figure 2(a). VR elements to be added

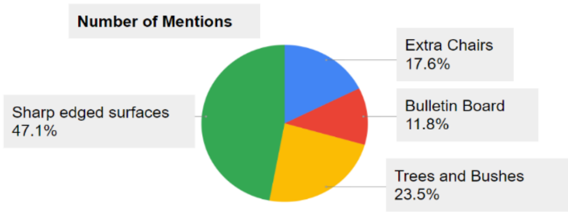


Figure 2(b). VR elements to be eliminated

4.2 Questionnaire findings

From the questionnaire, it can be observed that all the participants experienced both positive and negative emotions during the interaction with the two VLEs. 'Relaxed', 'comfortable', 'calming', 'fresh', 'spacious', 'congested' and 'suffocated' were experienced by almost all the participants. During the activities that included engagement with the VLEs, all participants found that they experienced positive learning emotions such as feeling excited, pleased, and satisfied. It was observed that the pattern of emotions in VLE-1and VLE-2 looks similar. However, despite VLE-1 being systematic and organized, 'satisfaction' was noted to be lesser in VLE-1 during the interaction with elements. The traditional model of the classroom and the congested arrangement of chairs were the two main sources of negative emotions for VLE-1. Four participants felt 'tense' while interacting with VLE-1, whereas eight participants felt 'relaxed' while interacting with VLE-2. 'Greenery', 'close to nature', and 'peaceful' were the reasons for VLE-2 to be more learning-oriented. Although, some participants did mention that VLE-2 is too distracting for being a classroom. The pattern of positive and negative emotions while interacting with VLE-1 and VLE-2 are shown in Figures 3 (a) and 3 (b).

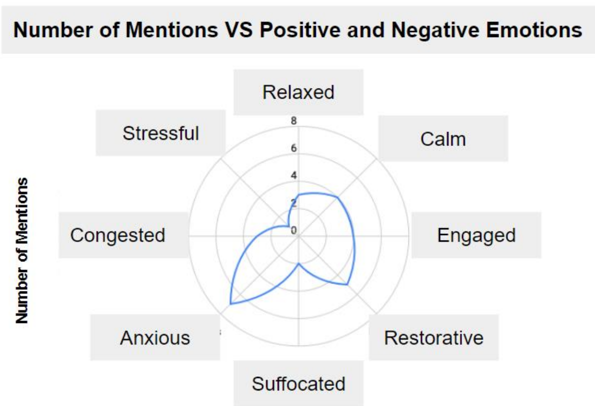


Fig. 3(a). Positive and negative emotions in VLE1

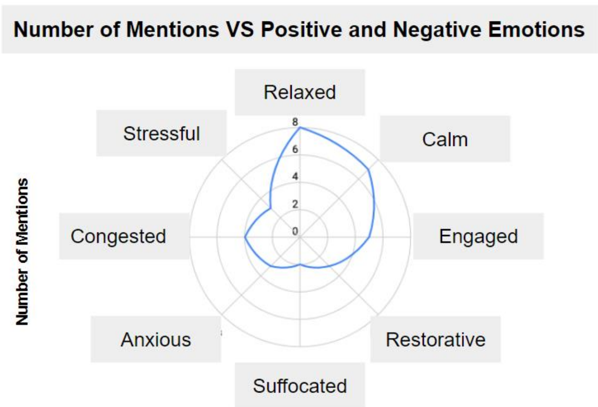


Fig. 3(b). Positive and negative emotions in VLE2

4.3 Psychogalvanic reflex findings

The electrical conductivity of skin is measured via the galvanic skin response. It changes when the activity of sweat glands regulated by the ANS changes [21]. Previous research has found that skin conductivity rises in synchrony with emotional arousal [22]. To measure the GSR signal, we employed a commercial sensor (Empatica E4 wristwatch sensor). The sensor was mounted on the wrist of the individual (Figure 1). To define the variability of the GSR signal, data was studied and analysed in the temporal domain. Data was filtered using the normalizing techniques. Normalized data was obtained using the following equation:

Normalized GSR = Experimental GSR - Baseline GSR

The rate of change of emotional arousal [23]. as measured in GSR sensors for VLE-1 and VLE-2 are as shown in Figure 4.

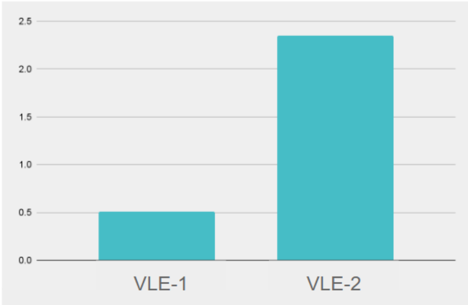


Figure 4. Rate of change of emotional arousal for VLE-1 and VLE-2

5 DISCUSSION AND CONCLUSION

As the two VLEs vary in design (conventional vs. nature-based), the study's data suggests a link between a learning space's built-environment and students' emotional states. These positive and negative emotional states influence learning capabilities and outcomes of the learner. Though the limited sample size is a key limitation of this research, experiment results give great insight into emotional arousal and learning. This experiment shows that interview and questionnaire data may help determine what sort of virtual design required by the learners based on their emotions. GSR helps identifying stimulating VR learning aspects. Even though techniques for identifying emotional states have improved, additional study is required to find effective VR classroom features to trigger emotions that impact learning via cognitive factors like expectancies and perceptions. Basic emotions are universal, but high-intensity VR classroom aspects must be evaluated. As a result, it is recommended that procedures should be implemented in which each participant actively and consciously participates in the selection of what elicits emotion, and is informed of the study's purpose, and hence assists in the process of evoking his or her own feeling.

REFERENCES

[1] Penrod D., Shaw T., Nash J., Dierkes M. and Collins S. Community college students' perspectives on online learning during COVID-19 and factors related to success, *Teaching and Learning in Nursing*. 2022. doi: 10.1016/j.teln.2022.01.012.

[2] Fisher K. and Newton C. Transforming the twenty-first-century campus to enhance the net-generation student learning experience: using evidence-based design to determine what works and why in virtual/physical teaching spaces, *Higher Education Research & Development*, vol. 33, no. 5. pp. 903–920, 2014. doi: 10.1080/07294360.2014.890566.

[3] National Research Council, Division of Behavioural and Social Sciences and Education, Board on Science Education, Board on Testing and Assessment, and Committee on Defining Deeper Learning and 21st Century Skills, *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. National Academies Press, 2013.

[4] Gruskin K. and Geher G. The evolved classroom: Using evolutionary theory to inform elementary pedagogy, *Evolutionary Behavioural Sciences*, vol. 12, no. 4, pp. 336–347, Oct. 2018.

[5] Persaud N. and Eliot M. The Development and Refinement of Student Self-Regulatory Strategies in Online Learning Environments, in *Current Trends in Eye Tracking Research*, M. Horsley, M. Eliot, B. A. Knight, and R. Reilly, Eds. Cham: Springer International Publishing, 2014, pp. 317–336.

[6] Mayer R. E. and Fiorella L. Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signalling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles, *The Cambridge Handbook of Multimedia Learning*. pp. 279–315. doi: 10.1017/cbo9781139547369.015.

[7] Li J., Luo C., Zhang Q. and Shadiev R. Can emotional design really evoke emotion in

multimedia learning?, *International Journal of Educational Technology in Higher Education*, vol. 17, no. 1, pp. 1–18, May 2020.

[8] Smith K. G., Collins C. J. and Clark K. D. Existing knowledge, knowledge creation capability, and the rate of new product introduction in high-technology firms, *Academy of management*, 2005, [Online]. Available: https://journals.aom.org/doi/abs/10.5465/AMJ.2005.16928421

[9] Vollmer T. C., Koppen G. and Kohler K. [The impact of urban architecture on health: the PAKARA model], *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz*, vol. 63, no. 8, pp. 972–978, Aug. 2020.

[10] Bulakh I., Didichenko M., Kozakova O., Chala O. and Kovalska G. Is the hospital-park future of the sustainable hospital architecture?, *E3S Web of Conferences*, vol. 280, p. 04014, 2021.

[11] Higuera-Trujillo J. L., Llinares C. and Macagno E. The Cognitive-Emotional Design and Study of Architectural Space: A Scoping Review of Neuroarchitecture and Its Precursor Approaches, *Sensors* , vol. 21, no. 6, Mar. 2021, doi: 10.3390/s21062193.

[12] Lisinski B. E. Calming chaos in the classroom: The effect of self-regulation professional training on teachers' perceptions of the classroom environment and student behaviour, Trent University (Canada)ProQuest Dissertations Publishing. [Online]. Available: https://search.proquest.com/openview/cd4632e46f014dc54d3f44b22759164a/1?pq-origsite=gscholar&cbl=18750&diss=y

[13] Gilmore S. and Warren S. Themed article: Emotion online: Experiences of teaching in a virtual learning environment, *Hum. Relat.*, vol. 60, no. 4, pp. 581–608, Apr. 2007.

[14] Gilavand A. Investigating the impact of environmental factors on learning and academic achievement of elementary students, *Health Sciences*, vol. 5, no. 7S, pp. 360–369, 2016.

[15] Plass J. L.and Kaplan U. Emotional Design in Digital Media for Learning, *Emotions, Technology, Design, and Learning*. pp. 131–161, 2016. doi: 10.1016/b978-0-12-801856-9.00007-4.

[16] Mayer R. E. Searching for the role of emotions in e-learning, *Learning and Instruction*, vol. 70, p. 101213, 2020.

[17] Miller K. The experience of emotion in the workplace, *Manage. Commun. Q.*, vol. 15, no. 4, pp. 571–600, May 2002.

[18] Ekman P. An argument for basic emotions, *Cognition and Emotion*, vol. 6, no. 3–4, pp. 169–200, May 1992.

[19] Barrett L. F. Feeling Is Perceiving: Core Affect and Conceptualization in the Experience of Emotion, in *Emotion and consciousness , (pp*, vol. 420, L. F. Barrett, Ed. New York, NY, US: The Guilford Press, xii, 2005, pp. 255–284.

[20] Alaoui-Ismaïli O., Robin O., Rada H., Dittmar A. and Vernet-Maury E. Basic emotions evoked by odorants: comparison between autonomic responses and self-evaluation, *Physiol. Behav.*, vol. 62, no. 4, pp. 713–720, Oct. 1997.

[21] Collet C., Vernet-Maury E., Delhomme G. and Dittmar A. Autonomic nervous system response patterns specificity to basic emotions, *J. Auton. Nerv. Syst.*, vol. 62, no. 1–2, pp. 45–57, Jan. 1997.

[22] Lang P. J., Bradley M. M. and Cuthbert B. N. A Motivational Analysis of Emotion: Reflex-Cortex Connections, *Psychol. Sci.*, vol. 3, no. 1, pp. 44–49, Jan. 1992.

[23] Leiner D., Fahr A. and Früh H. EDA Positive Change: A Simple Algorithm for Electrodermal Activity to Measure General Audience Arousal During Media Exposure, *Commun. Methods Meas.*, vol. 6, no. 4, pp. 237–250, Oct. 2012.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

OPTIMISING THE PRODUCT-SERVICE SYSTEM FOR SCOOTER-SHARING IN CITIES

Sam VERVOORT and Ivo DEWIT
Department of Product Development, University of Antwerp, Belgium

ABSTRACT
Over the last few years, electric scooters have become a fundamental part of our cities as they pop up at every street corner people pass by, unfortunately creating more obstacles than possibilities. As part of the so-called micro mobility, they provide a solution for the ‘last-mile,’ the distance you cover between your drop off and destination in the city. Although they seem like an ideal solution, never has a product-service system been so controversial. This paper focuses on the combination and integration of other sharing platforms, new innovations, and insights to improve the overall quality of this product-service system. This paper provides a design tool and first concept to generate a new kind of sharing platform, based on safety, quality, better lifespan, and convenience.
Many attempts have been made to improve the overall ride and use of this concept. However, these small optimalisations will not solve the bigger problem. Companies have not actually changed the general mode of use, rather smaller profit margins inhibit them from resetting the current usability, leaving them with less room for innovation/improvement.
This article focusses on the design of a new platform to optimize user experience and quality. The platform be built up from scratch to have total freedom and control to reimagine the way users acquire, use, and drop off sharing scooters. Using in-depth qualitative research and knowledge of product-service innovation, micro mobility and sharing economy, we will try to solve the most critical problems and controversy on the phenomenon. The goal is to deliver a methodology and product-service system that serves as a benchmark and provides solution for cities and new or existing providers.

Keywords: Electric scooter, micro mobility, last-mile, sharing economy, product-service system

Figure 1. Multiple sharing scooters in the city of Antwerp (Vervoort; 2022)

1 INTRODUCTION
Summer 2017, some students from Singapore manage to create a successful, innovative transport medium for commuters, tourists, and city dwellers [1]. An electric scooter, ground zero for a new

product-service that will be positioned within the sharing economy for micro-mobility (small electric vehicles intended for travelling a short distance by one person).
It doesn't take long before technology companies from Silicon Valley jump take note of this new phenomenon. This is how the companies Bird, Lime and Lyft, among others, arose. After a successful implementation in dozens of American cities, in 2019 the crossing to Europe followed. With active providers and users in multiple countries and cities. Now, a few years have passed, and the electronic shared scooter has become a fundamental part of our major cities and their mobility offerings.
It quickly created a competitive market and extensive offer for the user, even before governments and cities could impose clear rules [2]. In addition, it soon became apparent that the electric scooters used did not meet the expected requirements in terms of ride quality and service life. This requires the exposure of the main problems and appropriate intervention. Both provider and user benefit from an improvement of the system, at product and service level.

2 THE PROBLEM

2.1 Design problem

Although this new platform could perfectly respond to the increasing demand for mobility solutions and the filling in of the 'last mile', both provider and user are experiencing too many problems. This means that a long-term success story might not happen. The quality of the shared, electric scooter does not meet the user's expectations and creates dangers for both them and other road users. The providers are also experiencing problems with the longevity of their product, leading to minimal profit margins and a possible breach of trust. In addition, the host cities are also increasingly questioning whether this new feature contributes to the vision on sustainability and mobility of the future that they want to represent. Before they could determine the impact of this subsystem and the additional necessary rules, the mobility solution was already in place. Clear, communicated legislation and guidelines for the providers are still lacking [3].

2.2 Design opportunity

As a product developer, it is interesting to be able to zoom out and find a coherent solution to the whole of the above design problems. Subsequent research and analysis try to proof how a restructuration of this service in combination with an optimization of the current product can lead to a better product-service for all possible stakeholders. The weaknesses of the subsystem are highly topical. Reports and our own experiences show that interventions can and must be made in several areas.
Firstly, keeping the scooters neatly distributed proves to be very problematic. The strength of shared scooters lies precisely in the 'free float' nature of this mode of transport. The user leaves the scooter where it is most convenient. However, this may create an extra obstacle for other road users [4]. An electric scooter that is insufficiently resistant to incorrect use, vandalism and wear and tear does not fit in with the long-term goal of this system. The lifespan of the shared scooter is significantly lower than hoped for and promised by the providers. This has a negative impact not only on the revenue model but especially on the safety of the user, the point of intervention with the highest priority. The low quality of use and the ignorance of inexperienced and occasional users cause more than two hundred serious accidents every year, including accidents involving children [5].

2.3 Perspective

Product-service system design (PSS-design) is an ongoing discussion and convergence to understand, explore and define the different value perspectives of those who influence the context and others who are affected by it [6]. The knowledge of this matter, creates opportunities to approach and then solve the mentioned, overarching problems. This involves looking at the product offered as well as the service associated with it to offer and use the product. The breadth of PSS design allows for a coherent solution to a multidisciplinary problem.

3 ANALYSES

3.1 Research method

To analyse the problem as thoroughly as possible, extensive research was carried out through various channels and search fields. The current situation was mapped out with an exploratory multidisciplinary analysis, the monitoring of current affairs and accompanying field research to be able to frame the problem as good as possible. Next, an attempt was made to converge on solution-oriented research through discussions with experts and stakeholders. Problems and opportunities were substantiated as much as possible by scientific literature studies.

3.2 Context analysis

The context analysis was carried out to be able to locate the problem of shared scooter systems within the context of (micro) mobility in the city. By ‘zooming out’ and looking at other mobility solutions, one obtains a better overview of the entire situation and the plan of approach that other providers might use. This makes it possible to gather an extensive file of stakeholders, which can be useful in the further course of this research.

The most important stakeholders are the users, the providers, fleet managers, the city council, other road users, competitors and medical staff.

3.3 Field research

To carry out a thorough human analysis, the user journey was mapped out. This makes it possible to locate critical points in the process and to see how this creates opportunities in the design process. The drafted trajectory was tested in practice to determine the points of intervention. It can be concluded that there are several steps within the usage process where intervention is possible. This can be done both in function of the user and the provider. The most important intervention points are raising awareness beforehand, accompanied by extensive legislation and monitoring. In addition, the general ride quality and safety risks during the use of the shared scooter and finally the ending of a ride and the correct disposal of the shared scooter. In the next part of the analysis, it will be shown, among other things, how targeted research can lead to specifications that can bring improvements for these intervention points.

3.4 Technological analysis

The technological analysis is based on a detailed analysis of the shared scooter itself. By defining the strengths and weaknesses of this vehicle, it is possible to create a set of specifications and intervention points. These form a basis for developing 'the shared scooter of the future', which will contribute to the needs of the user and the requirements of the provider. The shared scooter has already evolved greatly over the past few years. A wrong estimation of the life span of a shared scooter, made it necessary for providers to make fundamental adjustments to their product. To be less polluting than other means of transport, the shared scooter should be used for an average of 9.5 months. In practice, this is only 7.5 months [7]. In general, the partial scooters are not sturdy enough. This is because most providers chose to buy the basic product, the electrical scooter, from a specialized manufacturer like *Xiaomi* or *Okai*. However, these scooters were originally designed for private use. Consequently, they are often unable to withstand the extensive use, weather elements and vandalism associated with this sharing platform.

3.5 Human analysis

It is important to find out from the end user why they would use this mobility solution and what their expectations are. In addition, the user journey already showed some critical intervention points.

The most important reason for the use of subsystems within micro-mobility is convenience. In a survey conducted by McKinsey ACES(n=7000), this came with more than 50% for being cheaper than a private car or taxi. Followed by a possible company fee, not having to carry cash, and not having a driving license. The most important requirements that a consumer expects are as follows; safety, followed by a competitive price and in third place the availability and reliability of these sharing systems [8]. This research supports the findings observed after own use and questioning by other users.

The fleet managers were questioned by means of qualitative research (n=26). A survey of the most important tasks on the one hand and most frequent problems on the other led to the following conclusion. The most important tasks they must perform daily are charging the shared scooter or replacing replace replaceable batteries, moving and rearranging the shared scooter outside the user's hours and finally the maintenance of this means of transport.

Figure 2. A fleet manager blocking the passage for pedestrians (Vervoort,2021)

3.6 Economical analysis

Within the problem definition and context analysis, the economic size of this billion-dollar industry was already briefly explained. With an estimated European market size of one hundred billion dollars by 2030, it is no secret that this market is proving to be very attractive to startups and investors [9]. The technical analysis already mentioned that the lifespan of a shared scooter does not meet expectations. This has major economic implications. Companies must continue to innovate and analyse to keep their product alive and remain financially healthy as a provider. Also, the revenue model is currently too limited to be able to speak of a success story. The past pandemic and ongoing war between Russia and Ukraine are still affecting the market. The choice for a private mobility solution because of the infection risks prevails over cost and convenience for the time being [10]. When looking at the cost distribution per sub-step, one can also speak of a story before and after the pandemic. It can be concluded that the largest part of the cost is in moving the sub-step. This is due to the fees that providers owe to the fleet managers. An optimization or adjustment of this component could lead to higher profit margins for the providers.

3.7 Comparative study of product sharing systems

After this analysis, the decision was made to also conduct a comparative study between a provider of shared-steps, *Bird*, and a competitor within shared mobility, *Blue-bike*. The study is based on a comparison between the usage method on the one hand and the business models on the other.

The study makes it possible to look at what elements in both providers determine their success and where the problems and opportunities lie. In this way, it is possible to zoom out and examine whether it might be interesting to combine certain characteristics into a new product-service that could provide a favourable share-step system in the long term. The analysis has shown that the product-service system of Blue-bike better meets the intended lifetime of these mobility solutions. The addition of an access point creates the possibility to better monitor and guarantee the condition of the rental bikes to the next user. The maintenance and management of the shared bicycles will be simplified because of the fixed location of these lending points. For the shared-steps, this could mean that the main problems raised in previous analyses could find a possible solution in the implementation of some elements of the product architecture used by Blue-bike.

4 CONCLUSIONS

4.1 Critical aspects and trade-off parameters

This paper contributes to the improvement of mobility solutions for smart cities by identifying the major concerns for users as well as distributors and providing matching product-service system concepts.

The most important critical aspects were synthesized from the analysis. These aspects are technical, human, ecological and economically related to the product and service provided. They form a base for defining a new product idea or improving existing goods.

The sharing-scooter that is currently on offer is an iteration of a product that was developed for private use and therefore does not meet all the essential requirements. Providers need to commit to adapting their scooter to a suitable model. They could and should focus on modularity, stability, safety, and connectivity. These factors all contribute to a higher quality product-service and should prove their economic added value in the longer term.

The necessary sensitization and prior knowledge of the user is lacking. This can lead to incorrect use and accidents as a result. To this end, providers and local legislators should cooperate more closely. These verifications can increase the overall reliability.

Companies must continue to innovate and analyse to keep their product alive and remain financially healthy as a provider. Optimizing this product service can certainly help. The overall analysis of this promising form of mobility has shown that there is room for improvement in several areas. Providers should dare to zoom out to better locate their offered product within the current mobility offer.

To generate a new product system, the following questions were asked. In this way, possible design routes for the new PSS emerge. A few examples are given:

What can be changed/obtained if one:

- Tries to combine/merge the advantages of different product-service systems?
- Moves away from the existing free floating approach?
- Focusses on the last mile principle? Rather than replacing public transport?

Can we improve quality and durability of this product-service by:

- Exposing the weaknesses of the electric scooter and provide them with appropriate, innovative solutions?
- Designing and producing modules that each tackle a specific problem? After which they can be added onto existing scooters and increase product lifetime.

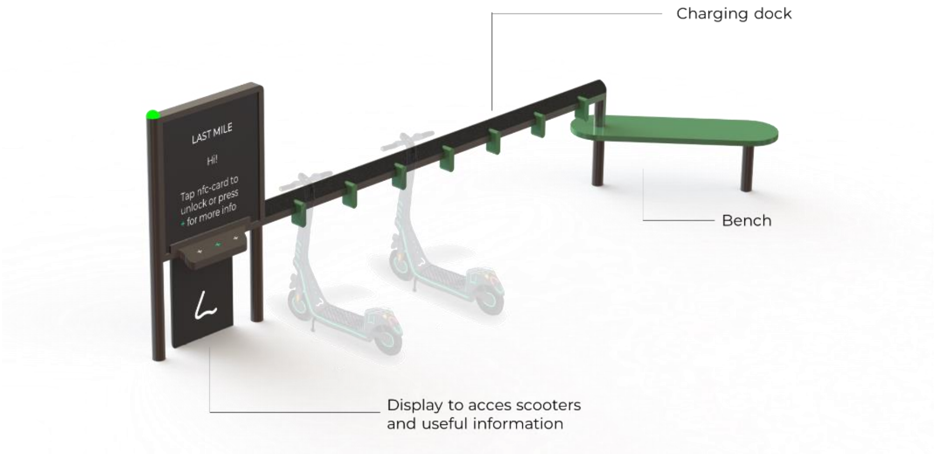


Figure 3. Concept for a new approach to share and charge electric scooters (Vervoort,2022)

In the next phase of this study and design process, the most important problems and opportunities will be converted into real products and services to improve the current situation. Aside from being a useful guide for new and existing providers within this niche, this study also contributes to product development, design and education in general. The approach used in this research may be acquired in other, design related studies.

REFERENCES

[1] Cross D. *Great scoot! A short e-scooter history.* Available: https://zagdaily.com/trends/great-scoot-a-short-e-scooter-history/ [Accessed on 2021, 02 October], (2020).

[2] WE ALL WHEEL. *Stormachtige ontwikkeling van deelsteps.* Available: https://we-all-wheel.com/woon-werkverkeer/deelstep [Accessed on 2021, 7 November], (2020).

[3] Glasco J. *E-SCOOTERS: A PASSING FAD OR SMART MOBILITY?* Available: https://hub.beesmart.city/en/solutions/smart-mobility/electric-scooters-a-passing-fad-or-smart-mobility [Accessed on 2021, 14 October], (2020).

[4] BRUZZ. *Dropzones, snelheidsbegrenzing en strengere handhaving voor deelsteps.* Available: https://www.bruzz.be/mobiliteit/dropzones-snelheidsbegrenzing-en-strengere-handhaving-voor-deelsteps-2021-10-25 [Accessed on 2021, 10 November], (2021).

[5] Willems S. *Vias pleit voor aanpassingen wetgeving elektrische steps.* Available: https://www.vias.be/nl/newsroom/vias-pleit-voor-aanpassingen-wetgeving-elektrische-steps [Accessed on 2021, 21 October], (2021).
[6] Dewit I. *PSS Design and Strategic Rollout Toolkit, edition one*, 2018 (University Press Antwerp).
[7] Belga. *Elektrische deelstep te vervuilend door beperkte levensduur.* Available: https://www.demorgen.be/nieuws/elektrische-deelstep-te-vervuilend-door-beperkte-levensduur~bde8622d/ [Accessed on 2022, 10 March], (2020).
[8] Heineke K., Kloss B., Timo M. and Wiemuth C. *Shared mobility: where it stands, where it's headed.* Available: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/shared-mobility-where-it-stands-where-its-headed [Accessed on 2021, 24 October], (2021).
[9] McKinsey center for future mobility. *Micromobility's 15,000-mile checkup.* Available: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/micromobilitys-15000-mile-checkup [Accessed on 2022, 5 May], (2019).
[10] McKinsey & Company. *From no mobility to future mobility: Where COVID-19 has accelerated change.* Available: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/from-no-mobility-to-future-mobility-where-covid-19-has-accelerated-change [Accessed on 2021, 27 October], (2020).

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

DIGITAL LEARNING ENVIRONMENTS TO SUPPORT DESIGN EDUCATION

Lukas Valentin HOPPE[1], Sebastian KUSCHMITZ[2], Paul Christoph GEMBARSKI[1], Thomas VIETOR[2] and Roland LACHMAYER[1]
[1]Leibniz Universität Hannover, Institute of Product Development, Germany
[2]Technische Universität Braunschweig, Institute of Engineering Design, Germany

ABSTRACT

In times of the pandemic, universities are increasingly dependent on developing high-quality digital teaching materials and making them available to students for learning. For the development of learning environments, several methodological approaches and concepts already exist in the literature, which consider the pedagogical added value and thus describe rather didactical goals. This paper looks specifically at the technical requirements that can be placed on digital learning environments. In order to identify these, the *Elements of Value* are used as a basis to derive added values of digital learning environments and to establish requirements. Subsequently, the requirements developed in this way are compared with 3D learning environments for engineering design and it is examined whether this comparison could possibly be helpful for the development and extension of digital learning environments.

Keywords: Design education, digital learning, Elements of Value, WebGL, 3D environments

1 INTRODUCTION

Digital learning environments are already frequently used in university teaching and also find an application in design education [1]. The advantages are mainly due to the fact that students are provided with non-linear access to information and that learning environments are available from any place and at any time [2]. In addition, it provides the opportunity for students to influence the level and pace of the learning process themselves and to try out additional learning strategies such as collaborative learning. The provision of interactive learning materials or learning objects in corresponding digital learning environments serves this purpose [3]. Many universities use a hybrid model for teaching, so that digital learning environments are used as a supporting tool alongside lectures, e.g., for preparation in the Flipped Classroom [4]. Digital learning environments open up new opportunities in the design of learning processes due to the multimedia and interactive presentation possibilities [5]. However, there is still a considerable need for didactic and technical design in order to efficiently implement and evaluate digital teaching and learning processes [6].
Especially for the didactic approach in the development and design of learning environments, a variety of methods are described in the literature [7]. The didactic evaluation of digital learning environments usually takes place through an evaluation of the users, whereby the usability and the learning experience are in the foreground [8]. But also, the technical requirements for digital learning environments are considered in literature. However, the establishment of these criteria is mostly done via meta-studies [9, 10]. In this paper, the authors would like to approach the requirements from a different perspective and show a value-oriented derivation of such criteria.

2 THEORETICAL BACKGROUNDS

The value of a product or service is very individual and is therefore always in the eye of the beholder. Nevertheless, it is possible to identify essential elements of value which are close to the customer's heart [11]. With the *Elements of Value* approach, companies can determine what constitutes the true value of an offer from the customer's point of view. This enables companies to differentiate themselves more clearly from the competition and helps them to achieve a higher market share and greater price autonomy [12]. The *Elements of Value* were established by Almquist et al. and break down the solution of customer problems as well as the achievement of customer goals to basic customer needs such as "Fun and

Entertainment", " Simplifies" or " Motivation". Analogous to Maslow's pyramid of needs, the elements break down to the four levels of benefits: Functional, Emotional, Life Change, and Societal Impact. The *Elements of Value* can either be used to develop new value propositions or to enhance existing products and services. A comparison of the *Elements of Value* can also be used to compare different value propositions. As an application example, Almquist et al. consider Amazon's market share growth in connection with the *Elements of Value*. According to empirical studies, eight elements are met in 2005, illustrating the strength of a core offering's value proposition. The company's particular focus has been on reducing costs and saving time. The addition of streaming media to Prime met additional needs such as "provides access" and "fun/entertainment," which also attracted new customers and significantly increased annual fees [11].

3 DIGITAL TEACHING REQUIREMENTS

In the following, the authors present an approach that derives the technical requirements for digital learning environments based on the *Elements of Value* (see Table 1). For this purpose, the authors initially thought it would be useful to group the *Elements of Value* in order to avoid duplications and overlaps in content. Discussions with teachers resulted in eight superordinate groups that summarize the statements of the respective *Elements of Value* with regard to digital teaching. Thus, the added value of digital learning environments could be derived from different points of view. The individual added values were then explained in a brief description. In order to concretize the properties and break them down into recommendations for action, the last step involved interviewing experts to develop requirements that can be used to achieve the established added values.

Table 1. Framework for the requirements of digital teaching

Elements of Value	Added value for digital learning environments	Description	Requirements for digital learning environments
Integrates Affiliation/ Belonging Heirloom	***Promotes teamwork***	Digital learning environments can support and promote the learning process in teamwork. Through collaborative task accomplishment, different participants are integrated into a group structure and can develop a solution by combining their individual competencies. Through teamwork, contacts can also be made, and experiences can be passed on to other learners.	• Enable collaborative work
Self-actualization Wellness Self-transcendence	***Strengthens individuality***	Digital learning environments can strengthen the individuality of the learner. This means that learning content can be processed at an individual learning pace and with an individual learning path. In addition, the learner should be able to work independently of time and place in order to allow flexible learning.	• Create freedoms of use
Sensory Appeal Attractiveness Variety Design/Aesthetics	***Allows appealing and diverse design***	Digital learning environments can present a diverse range of learning opportunities in a high-quality design. A combination of different types of information provides variety and takes different learning types into account. In addition, an appealing design of the environment and simple and intuitive operation lead to increased motivation to use it.	• Multimedia knowledge presentation • Aesthetic and activating design
Connects Provides access Therapeutic value	***Simplifies and promotes interaction***	Digital learning environments can create new and diverse types of interaction. On the one hand, this includes communication with fellow students, which can lead to information exchange and mutual support. On the other hand, communication with teachers can also be significantly simplified and accelerated.	• Provide communication opportunities
Fun/Entertainment Badge Value Rewards Me Motivation	***Increases fun and encourages learning***	Digital learning environments can increase fun and thus encourage learning. For example, learners can be shown their progress, which motivates them to reach further milestones. Furthermore, leader boards and competitions can be used to arouse ambition and reward good results.	• Indicate progress and set intermediate goals • Promote competitions

Nostalgia			
Organizes Reduces risks Simplifies Informs	***Supports knowledge access***	Digital learning environments can facilitate knowledge access through a uniform and systematic structure. The provision of high-quality learning content involves ensuring quality and accuracy on the one hand, and appropriate presentation of the content on the other. For a successful learning process, this should be designed in such a way that new content can be linked to already known knowledge. In addition, navigation can ensure that the required knowledge is accessed in a targeted manner.	• Systematic knowledge presentation • Quality assurance of the content
Avoids hassles Quality Reduces anxiety Provides hope	***Supports the learning process***	Digital learning environments can actively support the learning process by determining the learner's level of knowledge and providing him or her with individual feedback. A wide variety of test formats are used for this purpose, in which the user's learning status is ascertained and reflected. Supportive feedback provides assistance in solving tasks and achieving the learning objective.	• Provide examination opportunities • Survey of learning status • Giving feedback
Reduces effort Reduces costs Saves time Makes money	***Simplifies application and accelerates processes***	Digital learning environments offer the advantage that they simplify the creation of learning units and create the possibility of automating processes. Once a learning environment has been created and implemented, it can be used again and again. In addition, it can be easily adapted or transferred to new learning fields thanks to a systematic structure. By automating teaching processes, for example, the correction of assignments and exams can be taken over, thus reducing the teaching workload.	• Extensible and reusable • Automation of corrections

A total of 14 requirements for digital learning environments were detected during the creation of the framework. These are now to be used as criteria to evaluate already existing learning environments with regard to their technical possibilities. These interactive 3D environments from engineering design are presented below and described in terms of content.

4 INTERACTIVE 3D LEARNING ENVIRONMENTS

Digital learning environments, e.g., physical and digital 3D view models, are particularly suitable for design teaching, as they can create a visual impression of design features that goes far beyond purely textual or pictorial descriptions [1]. To promote design teaching for additive manufacturing, three interactive 3D environments were developed. These were created for free display in a web browser as a *WebGL* plugin and embedded in a web page. Thematically, the developed interactive 3D applications deal specifically with the possibilities of function integration in additive manufacturing. In particular, the powder damping of components and the resulting advantages are to be brought closer to the students here. Powder bed-based additive manufacturing processes can be used to produce the component and the integrated particle damper in a single manufacturing step. The process flow offers the potential to leave unfused metal powder in voids (cavities) and to greatly increase component damping globally or locally through targeted particle friction [13]. Since the environments will not be used for additive manufacturing until later in the event design, a basic knowledge of the users is assumed.

The interactive 3D applications are divided into a theory environment, an application environment and an assessment environment. These can be accessed directly on a learning website. In addition, images and descriptions are listed on the website to embed the 3D applications thematically. In the environments, the user can move interactively through the space by changing the view by rotating and zooming or by clicking on buttons or individual features to activate corresponding activities or further windows. It is also possible to navigate through the model with predefined camera views or to change the view and the material.

The tuning fork environment is the introductory environment for the topic of powder attenuation, in which the students can move freely (see Figure 1a). The centre of the environment are two identical looking tuning forks, which reveal their differences only after clicking on them. As expected, one tuning fork produces a long and high-pitched tone, while the second responds to the animated clapper beat with a short-muffled sound. After this experience, two buttons fade in, offering the user additional information. Clicking the cut button (2) changes the display of the tuning forks so that they become visible in the cut. This makes the cavity of the dull tuning fork visible and thus also the reason for the different vibration behavior. The info button (1) opens an additional window in which the situation is briefly explained with the aid of CT images.

The demonstrator environment serves to deepen the acquired knowledge and to show the relevance of the topic through application examples (see Figure 1b). The centre of this environment is a wooden table with three different demonstrator components, which were additively manufactured and provided with powder damping. These are a wheel carrier, a fork bridge and a turning tool which can be viewed from all directions in the environment. When clicking on a demonstrator, it rises from the table, the camera moves towards the centred object and a rotation of the view around the component starts. In addition, the surface texture is switched transparent so that the cavities become visible in red. A short description completes the display.

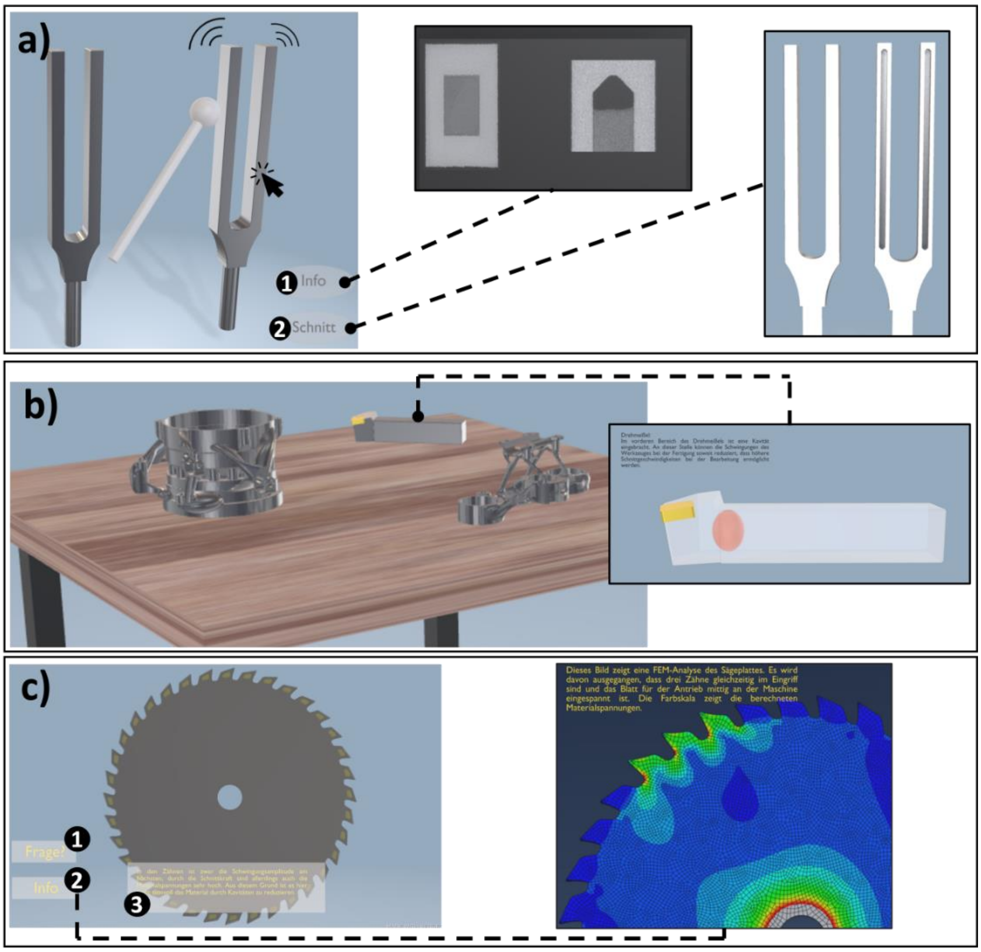


Figure 1. 3D learning environments

The saw blade environment serves as a small assessment environment. Here, the learner can check his knowledge level himself (see Figure 1c). For this purpose, the user is presented with a saw blade model and a task (1), which can be called up again and again via a button. The task is to determine a reasonable position for the cavities in order to reduce the saw blade noise. To edit the task, the texture of the saw blade becomes transparent as a hover effect and three different positions of cavities become visible. These can be selected with a click. Thereupon the system gives textual feedback (3) how good the decision made was and justifies this hint. To make the task easier, additional information on the component stresses in the operation can be obtained via the info button (2).

5 EVALUATIONS

To evaluate the interactive 3D environments, the three environments are compared in a matrix with the elaborated requirements for digital learning environments (see Figure 2). The evaluation was done in a panel of subject matter experts and used the evaluation scheme fulfils the requirements, partially fulfils the requirements, and does not fulfil the requirements.

It can be seen that through the website integration, all three environments are available around the clock and system-independent, creating absolute freedom of use. Through the 3D environments with realistic textures, an activating design could be created. The requirements of quality assurance and extensibility could also be fully met by developing the content with a panel of experts and by developing environment templates. The presentation in the tuning fork environment is even more multimedia-based than in the other environments due to additional audio outputs. The systematics of the knowledge presentation becomes apparent in the tuning fork environment by the fact that certain information must first be unlocked in order to be able to link to what is already known. The Saw Blade Environment, as an assessment environment, does not emphasize the modelling of knowledge. In contrast to the other environments, it is possible to check one's own knowledge, to correct wrong answers and to get short feedback. A survey of the learning status only takes place for the user himself; the system cannot store the answers and attempts and draw conclusions from them. This also means that it is not possible to display the respective progress in the environments. Similarly, the requirements of collaboration, communication and the promotion of competition cannot yet be met in these learning environments.

Requirements / Learning Environments	Enable collaborative work	Create freedoms of use	Multimedia knowledge presentation	Aesthetic and activating design	Provide communication opportunities	Indicate progress and set intermediate goals	Promote competitions	Systematic knowledge presentation	Quality assurance of the content	Provide examination opportunities	Survey of learning status	Giving feedback	Extensible and reusable	Automation of corrections
Tuning fork	○	●	●	●	○	○	○	●	●	○	○	○	●	○
Demonstrators	○	●	◑	●	○	○	○	◑	●	○	○	○	●	○
Saw blade	○	●	◑	●	○	○	○	○	●	●	◑	●	●	●

○ not fulfilled ◑ Partially fulfilled ● fulfilled

Figure 2. Rating matrix

6 DISCUSSIONS

The value-based requirements developed in this paper correspond to a large extent to the existing criteria from the literature. Kurilovas and Dagiene's evaluation criteria for digital learning objects also have a focus on quality standards, design and usability, and reusability. Other functional criteria include user control strategies and appropriate system architecture [9]. Emotional and social aspects such as communication possibilities or freedom of use are not considered in contrast to the framework developed in this paper.

The evaluation of the learning environments clearly shows which technical requirements of the framework are already covered by the connection of the three learning environments and which requirements are not yet met. This means that the teacher can be given a clear picture of the current state of the learning environments. In addition, possible technical enhancements can be shown in order to further develop the environment. However, the question now arises as to whether the goal should be exclusively to fulfil as many requirements as possible with digital learning environments or whether they should not complement the competence transfer of the learning events in the sense of blended learning and thus mainly depend on the learning goals of the event. So, if a lecturer would also want to impart teamwork competences, an accompanying learning environment would make sense, which fulfils the requirements for collaborative learning. The benefit of the framework then also lies in the fact that the teachers can read off the required requirements based on desired added values and implement them for their individual learning environment. If, for example, the environment is to increase fun and encourage learning, progress displays, intermediate goals and competitions can be implemented according to the framework.

7 SUMMARY AND OUTLOOK

In this paper, a framework was established that determines added values for digital learning environments by structuring the *Elements of Value* and derives specific requirements for digital learning environments from their descriptions. Thereupon, 3D learning environments for design teaching were presented and their possibilities were shown. The application of the established requirements to the 3D environments shows that some of the established requirements for digital learning environments can be met. However, it also shows which requirements still need to be met in order to unfold the social added values of digital learning environments in particular. For example, tools such as chats, and forums could be added to the website to provide communication opportunities and promote collaborative work. However, the framework can also be used to define specific requirements based on desired added values for one's own learning environment.

In the future, the framework is to be expanded. On the one hand, the developed requirements will be diversified through in-depth studies with teachers and students. On the other hand, digital learning tools will be identified in addition to the requirements. Through these tools, concrete directions for development could be given for requirements that still need to be met. Furthermore, it should then be found out whether the extended framework can also be a useful tool for the new development of digital learning environments.

REFERENCES

[1] Kumke M., Watschke H., Hartogh P., Bavendiek A. K. and Vietor T. Methods and tools for identifying and leveraging additive manufacturing design potentials. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 12.2, 2018, 481-493. DOI: 10.1007/s12008-017-0399-7.

[2] Violante M. G. and Vezzetti E. Implementing a new approach for the design of an e-learning platform in engineering education. *Computer Applications in Engineering Education*, 22.4, 2014, 708-727. DOI: 10.1002/cae.21564.

[3] Hoppe L. V., Gembarski P. C. and Lachmayer R. Intelligent Tutoring System as a Tool of Formative Assessment in Design Education. In *DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education E&PDE*, Herning, Denmark, September 2021. DOI:10.35199/EPDE.2021.40.

[4] Gembarski P. C. Good idea or bad idea? – Teaching knowledge-based engineering in a flipped classroom. In *DS 104: Proceedings of the 22nd International Conference on Engineering and Product Design Education, E&PDE,* Herning, Denmark, September 2020. DOI:10.35199/EPDE.2020.53.

[5] Hielscher M., Hartmann W. and Rothlauf F. Entwicklung eines Autorenwerkzeuges für digitale, multimediale und interaktive Lernbausteine im Web 2.0. *DeLFI 2013: Die 11 e-Learning Fachtagung Informatik*, 2013, 203-214.

[6] Conole G. and Fill K. A learning design toolkit to create pedagogically effective learning activities. *Journal of Interactive Media in Education* 1, 2005. DOI: 10.5334/2005-8.

[7] Mandinach E. The development of effective evaluation methods for e-learning: A concept paper and action plan. *Teachers College Record* 107.8, 2005, 1814-1836.

[8] Balaban I., Bubas G. and Pipan M. Key elements of an e-learning course evaluation survey: An empirical validation. *2011 14th International Conference on Interactive Collaborative Learning*. IEEE, 2011. DOI: 10.1109/ICL.2011.6059600.

[9] Kurilovas E. and Dagiene V. Learning Objects and Virtual Learning Environments technical evaluation criteria. *Electronic Journal of e-Learning*, 7.2, 2009, 127-136.

[10] Vargo J., Nesbit J. C., Belfer K. and Archambault A. Learning object evaluation: computer-mediated collaboration and inter-rater reliability. *International Journal of Computers and Applications* 25.3, 2003, 198-205. DOI: 10.1080/1206212X.2003.11441703.

[11] Almquist E., Senior J. and Bloch N. The elements of value. *Harvard business review* 94.9, 2016, 47-53.

[12] Almquist E., Cleghorn J. and Sherer L. The B2B elements of value. *Harvard Business Review* 96.3, 2018, 18.

[13] Ehlers T., Tatzko S., Wallaschek J. and Lachmayer R. Design of particle dampers for additive manufacturing. *Additive Manufacturing*, 38, 2021, 101752. DOI: 10.1016/j.addma.2020.101752.

SYSTEMS-ORIENTED DESIGN AND DEMOCRACY

Linda BLAASVÆR[1] **and Birger SEVALDSON**[2]
[1]Norwegian Labour and Welfare Administration, Norway
[2]Oslo School of Architecture and Design, Norway

ABSTRACT
This paper introduces a discussion about systems-oriented design (SOD) as a method to design for democracy. The context for the study is master-level studio-based SOD education. We have analysed student projects produced at three SOD courses, at the Oslo School Architecture- and Design (AHO), one course a year from 2016 -18. The main theme for all three courses was Design for Democracy, with three subcategories: 1. participative democracy within a municipality, 2. workplace democracy, 3. representative democracy and how to engage young people to vote. This analysis led to the description of the application of eight pre-existing tools and techniques in the students' democratic design projects. These are rich design space, giga mapping, ZIP analysis, systemic relations, systemic evaluation, leverage point analysis, expert networks, strategy- or synergy mapping. These techniques are in extension described and discussed up against theory on democracy to converse about design as a praxis to understand, develop, maintain, and design for democracy.

Keywords: Systemic design, systems-oriented design, design method, strategic design, design for democracy, democracy design compass

1 INTRODUCTION
This paper discusses systems-oriented design (SOD) as a democratic design technique. The context for the study is a student course on master-level in design education with an emphasis on SOD. We have explored the student praxes and projects to identify and describe democratic design processes and strategic planning. Our main interest has been the democratic design praxis. SOD can be described as the combination of systems theory and design practice, has provided perspectives and techniques that students can utilize to understand and handle data, structures, systems, relationships, dynamics, complexity, and holistic perspectives as design dimensions. The students used the visualization technique of giga mapping to synthesize, analyse, and design in cooperation with the stakeholders. It is the students' praxes of designing through giga mapping and the subsequent results that the praxes produced that are discussed as democratic design techniques. The SOD course Design for Democracy introduced techniques that designers could use to change society on a systemic level. The students got an introduction on how democracy works as a system with its dependencies and imperfections. Design research has developed various methods that can be considered democratic in that they build on participatory, cooperative, and inclusive processes. However, these methods do not address or contribute to the understanding of complex systems, nor does the theory they are based on recognize the society or democracy as exceedingly complex [1] designers thus, lack techniques that enables them to work with this complexity. It is therefore a paradox that such complex contexts are typically approached with the above-mentioned methods. We have studied design for democracy through the research question of; how to create democratic design processes? Our intention with this exploration was to identify techniques that students used that in different ways facilitate democratic processes. By categorizing these techniques within a matrix with praxes describing various dimensions and types of democracy, we could also identify areas that the techniques used did not cover. Thus, areas have been identified that by description may serve as potential new techniques.

1.1 Course description
The three courses (24 ETCS, on master's level) that make the empirical data for this research was executed between 2016 -18 with the theme of design for democracy, with three subcategories:

1. participative democracy in urban planning with a municipality in Norway, 2. workplace democracy with UDI – the Norwegian Directorate of Immigration and Gjensidige, Norway's biggest insurance company, 3. representative democracy and how to engage young people to vote in collaboration with Norway's business newspaper, Dagens Næringsliv. The students were given an open brief with an intent to create innovations and interventions to improve and redesign democratic processes. The students studied texts on democracy by choosing literature from different sources and particularly from a compilation of literature, The Democracy Files, collected by Nelson and Sevaldson [2]. The students conducted additional steps in the SOD methodology, such as ZIP analyses and the creation of rich design spaces, to grasp more of the complexity of the developed problematiques [4]. The projects included very rapid learning processes to assess the high complexity tasks involved through a full SOD process that includes the design and co-design of numerous giga maps guiding knowledge acquisition and desk research, fieldwork, mapping dialogues together with experts, and the involvement of users eliciting experiences from stakeholders. Despite these rich and intense knowledge processes, it is that, within the timeframe, their ability to reach a state of deep insight was limited. It was not our intention to teach deeply about democracy but to enable designerly action for and within democracy. Therefore, the students were challenged by us, the teachers, and researchers, to design for democracy as a design topic and hence as a situation designer´s can handle based on their limited theoretical and scientific knowledge. The students who chose the course out of interest were naturally aware of the recent decrease in the cultural conception of democracy and in the measured rating of democracy [4]. We discussed the recent fast developments of IT, big data, and the exceeding amount of information channels, targeted information filtering, and the current trend towards more authoritarian leadership in numerous countries. Design for Democracy has a history reaching back to the 1970s, as stated by Victor Margolin in his lecture [4]. The course is meant for the students to discuss their projects considering theory on democracy and thus be more aware of what democracy is and how it can play a role in a design project and subsequently influence users of designed services but most of all to equip students with SOD methodologies to design projects that contribute to a democracy society.

2 SYSTEMS-ORIENTED DESIGN

SOD is a methodology for handling complexity and creating and sharing a holistic picture of a problem or situation. Typically, we understand SOD as systems practice tailored for practicing designers. SOD is a design praxeology within the broader field of Systemic design [5]. Giga mapping is the main tool in SOD, and it is a technique for extensive mapping and visualization method that crosses perceived boundaries and scales. The intention is manifold, but we can mention the following: to build a deep understanding of the systems at hand and their environments and wider landscapes; to initiate a very rapid learning process; to uncover “unknown unknowns"; to serve as a dialogic tool across silos and disciplines; to engage stakeholders and non-stakeholders as well as affected bystanders; to cater for sustainability, life cycles, and circular economy issues; to serve deep creative processes; and to memorize large amounts of information and insights. SOD thus involves not only the Giga mapping and understanding of vast numbers of entities isolated but also the study of the qualities of the relations between them. Visualization may thus function as a major contribution to the understanding of systems. Visualizations make grounds for all stakeholders to see, share, follow, discuss, contribute, and influence the project together. That is, the information is created together simultaneously in a continuous manner by the group [6, 7]. Hence, the shared work produces much more shared and communicated information in comparison with various people reading reports alone before a meeting, SOD is thus interdisciplinary [8].

3 METHOD

The empirical data for this research consists of the student projects conducted in the three SOD courses Design for Democracy from 2016 – 2018 [9], a portfolio of nineteen projects. To perform the analysis, we developed a matrix with two axes, where the x- axis describes four modes of: design for, of, as, and in democracy [5] and the y-axis represents four different kinds of democracies: representative, direct, deliberate, and liquid (Figure 1).

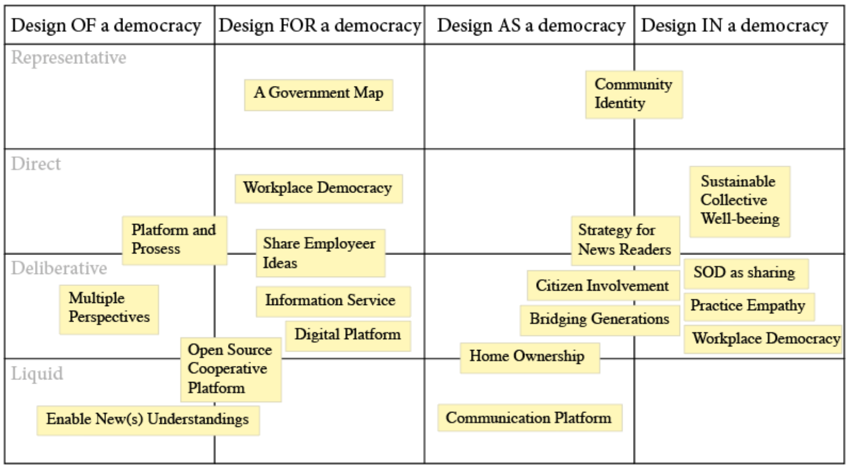


Figure 1. Design projects in relation to mode of design and kinds of democracy

We analysed the projects by positioning them within the matrix and thereby categorized them in relation to the two dimensions of democracy. The matrix provided fruitful information about the students' focus. However, our main emphasis is to explore the work praxis itself considering democratic functioning to identify techniques for democratic design praxis. To learn more about the role of the SOD methodology and process as a democratic process itself in this context, we sought the techniques that the students described that they used. A further look at the students' praxis revealed the following list of research and design methods that they made use of while working with design for democracy. The list is roughly categorized into nineteen categories of techniques, embracing subcategories gathered from the student reports that documented their processes and praxes. These are 1. field- and desktop research, 2. rich design space, 3. giga mapping, 4. ZIP analysis, 5. systemic relations, 6. systemic evaluation, 7. leverage point analysis, 8. user journey, 9. digital platforms, 10. SOD as sharing, 11. participatory design, 12. co-creation, 13. discussion tool, 14. expert networks, 15. prompting tools, 16. strategy, or synergy map, 17. critical thinking, 18. design thinking, 19. communication. Eight of these methods lie in the field of SOD (Table 1).

Table 1. Eight techniques placed in a matrix of four kinds of democracy

	Rich Design Space	Giga-mapping	ZIP analysis	Systemic relations	Systemic evaluation	Leverage point analysis	Expert networks	Strategy-, synergy mapping
Representative	x	x		x			x	
Direct	x	x						
Deliberative	x	x	x	x	x	x	x	x
Liquid				x		x	x	

This analysis led to the description of eight pre-exciting techniques as dimensions to understand and facilitate democratic processes. These techniques are then discussed against theories on democracy to study their effect in relation to SOD as a praxis and SOD as a technique for strategic planning for services, processes, and structures for democracy. These techniques demonstrate what we understand as design praxis [10], that is, specific actions, circuits, and interaction of circuits that the students took in the inclusion of others in the process in any way. By including the dimension of democratic design praxis in our study, we seek to describe the possible systemic influence the student praxis has on the process of involving and including others. That is, we consider the democratic dimensions of the process itself.

4 DEMOCRACY TYPOLOGIES

This chapter introduces the theory used to develop the matrix for analysing the student work praxes (see Figure 1). The activity of developing the matrix and the subsequent analysis served as an enabler for us to describe what design for democracy is, namely through describing the disclosed techniques that elicit democratic thinking, dialogue, and planning as design mechanisms (see Table 1). Margolin [5] recognizes the convergence between democracy and design in four respects: 1. Design of democracy which is about improving democratic processes and the institutions on which democracy is built. It addresses the structural elements that function as frames and regulators of human action in a democratic system. It focuses on institutions, such as branches of government, agencies, bureaus, courts, and offices, and procedures, such as laws, regulations, rules, and protocols. 2. Design for democracy enables more people to participate in the democratic process, especially using technology. It increases the opportunities for citizens to participate in deliberate processes. It focuses on transparency which enables citizens to be aware of on-going processes of governance and deliberative methods, which can be understood as the opportunity to be involved in decision-making processes. 3. Design in democracy builds access, openness, and transparency into institutions in ways that assure equality and justice. It refers to all design initiatives that are particularly responsive to the goals of democracy. It may deal with the provision of human rights and fundamental freedoms (such as access to food, shelter, healthcare, and education) and, more in general, with the transition towards a more resilient, fair, and sustainable society. 4. Design as democracy is the practice of participatory design, which constitutes the possibility for diverse actors to shape our present and future worlds in fair and inclusive ways. It sets a stage on which diverse actors can come together and democratically collaborate in shaping their present and future worlds. It engages diverse people and publics in co-designing and co-producing processes concerning different aspects of their everyday life.

The second axis represents a synthesis of different types of democracy. Most people think of democracy as consisting entirely of the voting process in a representative democracy. Naturally democracy is formed by much more than that. However, for this exercise we found it practical to operate with four basic forms of democracy, indicating principal differences in how democracy might be structured: representative, direct, deliberate, and liquid democracy. 1. Representative democracy is what we normally think of as democracy, voting for representatives to represent us in a dialogue that goes on in a parliament or something similar on levels spanning from municipalities and regions to nations and federations like the European Union. Representative democracy is a form of indirect democracy. 2. Direct democracy describes a system where issues are voted on directly. This is practiced in smaller organisations and in a few cases on municipality and Nation level. Switzerland is an example of a country that to a large degree is based on direct democracy. 3. Deliberative democracy, also called dialogic democracy, describes participatory processes in society, spanning from hearings to involving all parts of the (organized) civic society. This is practiced on municipality levels where participation is regulatory in Norway. However, these processes are rarely working very well and need rethinking. 4. Liquid democracy describes the role of digital media, big data, and how networks allow new forms of democracy to emerge. It combines direct influence with representation [3]. The modern forms of liquid democracy are interesting because it indicates that there is a potential in digital technology to enhance democratic processes and on the other side that democracy is under pressure from the digitalisation of society.

5 DISCUSSIONS

We categorized all the nineteen projects within the matrix (Figure 1). The categorization shows that most of the projects are positioned within the area of deliberate democracy. The finding is interesting and perhaps expected, as it shows that design students who use user-oriented design methods and facilitate participation processes that themselves are highly deliberative. This is also coloured by the fact that participatory design and co-design are central methods in contemporary design discourse. These approaches demonstrate the democratic nature of modern design methodologies and hence partly imply design as democratic. However, this was not necessarily stated very clearly in the projects. The projects helped us to crystallise these insights and build our own knowledge about design for democracy. The orientation on direct and deliberate democracy may also illustrate a lack of systemic thinking in that considering systems theory supposedly would lead to considering information and communication as having an integral function in society, such as within the understanding of liquid democracy. While analysing the students' projects within the matrix, a question emerged. What can designers contribute that political science cannot when taking care of, maintaining, developing, and designing democratic processes? First, design is a practice profession which is about change. While most sciences are predominantly about describing and theorizing *what is*, design is about creating *what ought to be*. Ideally, we would want to establish a transdisciplinary approach including different knowledges like political science, sociology, and others. Designers are proficient facilitators of co-design processes and are experienced in bringing people together to grasp their different perspectives, combined with a designer's skills for visualization in, for example, giga mapping. That led us to categorize the student's work with emphasis on praxis within different types of democracy and look for patterns in their use of methods and techniques.

5.1 Typologies of Democracy

In Table 1 we show eight of the nineteen research- and design methods the students reported using while studying design for democracy. Our scope is to understand SOD in relation to democratic processes, so we extracted these eight methods that lie specifically in the SOD methodology.

5.1.1 Representative democracy

Table 1 shows that we have placed the following SOD techniques in the column of representative democracy: rich design space, giga mapping, systemic relations, and expert networks. The rich design space represents all your data, research, and insight and can include the perspectives of others that are present in this space while the person does not have to be. The rich design space also holds space for the three next techniques included in representative democracy: giga mapping, systemic relations, and expert network. A way to start using these four techniques combined could be to start with stakeholder mapping to build an expert network for the project and to invite those experts in to have a common giga mapping session. Further, the group could build on the initial giga map and try to identify relationships in it, and in the next step search for new understandings of those relationships. This process will usually lead to several maps. All those maps belong in the rich design space and will represent the current state of knowledge within the group investigating a problem. A well-curated rich design space could express and communicate the current state of knowledge on its own. However, they rarely do, and one of the experts within the group would have to be present, and present and represent the project content to an outsider.

5.1.2 Direct democracy

Table 1 shows that we have placed the following SOD techniques in the column of direct democracy: rich design space, and giga mapping. Both techniques include the perspectives of a variety of actors in this visual space, and their voices are present in the giga map as well as in the rich design space. As a facilitator of a design process, one can invite people in to have a direct influence on the mapping process and the creation of knowledge and to make sure their voices are recognized to have an impact on different issues described in a giga map and the rich design space. The visual representation in the giga map and the rich design space provides immediate communication about the different issues at hand, and the observer can have direct influence and give feedback to the information at hand.

5.1.3 Deliberate democracy, participation and dialogue

Table 1 shows that we have placed the following SOD techniques in the column of deliberative democracy: rich design space, giga mapping, ZIP analysis, systemic relations, systemic evaluation, leverage point analysis, expert networks, strategy- or synergy mapping. Considering deliberative democracy, the students made use of all the SOD approaches. Just to mention some interesting techniques that the students came up with, a hugging festival, designing for conversations between youth and elderly, creating a rich design space at the collaborating partner's office, a Future Fest: where architects, and urban planners and the public are invited to have debates and conversations during a festival week.

5.1.4 Liquid democracy, a combination of direct and representative

Table 1 shows that we have placed the following SOD techniques within the landscape of liquid democracy: systemic relations, leverage point analysis and expert networks. To design for liquid democracy understanding relationships and actors, - building expert networks are relevant, as networks allow new forms of democracy to emerge and further self-organize. When performing a leverage point analysis considering liquid democracy, one can acquire a holistic overview of the dynamics of the system at hand, and when intervening the effects can change whole systems. An interesting example of a student technique was the use of open source: how citizens can add and edit the information into the objects and spaces to redefine the meaning of their own space and combine direct influence with representation. Hence, it served as collective decision-making.

6 CONCLUSION AND FURTHER RESEARCH

This research has described SOD as a democratic design technique, which in turn inspired us to consider democratic design praxis as equally important to the design projects or that an emphasis on democratic design praxis may lead to projects that function in accordance with the democratic goals for the project. This analysis led to the description of several techniques as dimensions to understand and facilitate processes for and to design for democracy. These are rich design space, giga mapping, ZIP analysis, systemic relations, systemic evaluation, leverage point analysis, expert networks, strategy- or synergy mapping. These techniques are further discussed against theories on democracy to study their effect in relation to SOD as praxis and SOD as a developing process or strategic tool for democratic service design. We find these groups that are in detail described in the appendix to be of particular interest for the planning of design projects for democracy and further research. In this instance, we would like to focus on the democratic praxes of giga mapping when it comes to the planning of education and design projects as well as future research. These praxes are collaborative giga mapping, observing rich data in giga maps individually and collectively, SOD as a technique for managing complexity. Others are sharing by giga mapping, giga mapping as a tool for discussion and generating consensus, collective sense-making, conversation overview, information access, constant and immediate feedback, scenario thinking, and collection of research, systems, and information. The matrix developed in this research may serve as a strategic compass as well as a pedagogical approach and a design tool. The research so far shows the functioning of the matrix in analysing student projects and their positioning within different types of democracy landscapes, and which mode of design for democracy to activate. The matrix may help to reveal which stakeholders to activate, which networks to work with, what mechanisms of democracy to emphasize, and according to Meadows' 12 leverage points, places to intervene in a system [11]. The intervention may represent change of governance on several levels within democracy, whether it is activating individuals to take a stance, bringing about structural changes within the government, or changing existing paradigms. The design for democracy matrix or compass demands a thorough thinking process to position a project in the democracy landscape described by the two axes. The compass may also stimulate more reading and facilitate reflective discussions that lead to strategic planning. Several perspectives are yet not covered in this article. For example, we have not discussed how to include outsiders, affected bystanders and non-human actors. For future research, we also suggest including feministic design approaches [12], which involve the study of the suppressed as stakeholders. This may serve as an important factor for democratic design methods. The fields where the students made use of, or created techniques for the designing of democracy, such as the categories of direct and liquid democracy, may point at a need for the development of new techniques. We suggest these as fields for further research.

REFERENCES

[1] Pickering A. The Cybernetic Brain: Sketches of Another Future. CH: University of Chicago Press; 2010.

[2] Nelson H. G. and Sevaldson B. The democracy files 2017 [13.052019]. Available from: *http://systemsorienteddesign.net/index.php/projects/design-for-democracy/the*

[3] Sevaldson B. Rich design research space. *Formakademisk*. 2008;1(1).

[4] Margolin V. J. Latsod, Carnegie Mellon University. *Design and democracy in a troubled world.* 2012; 11.

[5] Nelson H. G and Stolterman E. The Design Way: Intentional Change in an Unpredictable World *- Foundations and Fundamentals of Design Competence.* Cambridge, US: MIT Press; 2012.

[6] Luhmann N. *Introduction to systems theory*. Baecker D, Gilgen P, editors. Cambridge: Polity Press; 2013 cop. 2013. XX, 284 s. p.

[7] Gulden T. Engagement by lamination of autopoietic concentric interaction systems in games: A study of football and Pokémon GO. *Human Technology*. 2018;14(1):96-134.

[8] Bertalanffy Lv. *General system theory: foundations, development, applications*. Revised edition ed. Rousseau D, Hofkirchner W, editors. NY: George Braziller Inc; 2015, 295 p.

[9] Sevaldson B. Students of design for democracy 2015 - 2019 [Available from: *https://systemsorienteddesign.net/index.php/projects/design-for-democracy/democracy-projects.*

[10] Bateson N. *An Ecology of Mind: A Film Portrait of Gregory Bateson*. 2010. p. 1:00:8.

[11] Meadows D. H. *Thinking in systems: A primer*. Wright D. London: Earthscan; 2009, 218 s. p.

[12] Place A. *Designers should all be feminists* 2019.

IDENTIFYING PROTOTYPING COMPETENCIES AND ROLES IN EDUCATION

Vanessa Y Y CHIA[1], Franklin ANARIBA[1], Carlye LAUFF[2] and Lucienne T M BLESSING[1]
[1]Singapore University of Technology and Design, Singapore
[2]University of Minnesota, United States of America

ABSTRACT
There have been recent efforts at the Singapore University of Technology and Design (SUTD) in identifying levels of design competency to support teaching and assessment, which has resulted in the development of the Design Competency Assessment (DesCA) framework. One competency area in this framework is prototyping. To understand the nature of prototyping activities, an extensive literature review was conducted along with an empirical study at SUTD to address the following research questions: *How do individual instructors define prototyping? What roles do prototypes play in the design process in courses at the university? What prototyping frameworks, methods, and tools are introduced in these courses?* Herein we report preliminary results based on 17 interviews with SUTD instructors from different disciplines, who teach, supervise, or are interested in prototyping. Insights from this work include: (1) variations in definitions of what a prototype is across different fields, (2) lack of intentionality in prototyping, and (3) missing associated competencies, including how to select appropriate prototyping methods and tools. Taken together, these insights will allow us to re-examine the way prototyping is taught and how prototyping is represented in the DesCA framework.

Keywords: Role of prototypes, prototyping strategy, competencies, design education, design thinking

1 INTRODUCTION
Prototyping is a key feature of design and a common activity in design education. We define a prototype to be “a physical or digital embodiment of critical elements of the intended design, and an iterative tool to enhance communication, enable learning, and inform decision-making at any point in the design process” [1]. Literature has established the importance of prototyping in design education. Prototyping with a clear purpose allows students to avoid wasting costly resources while maximising the opportunity to obtain valuable insights for improvement [2][3]. Yet, prototyping is “consistently described as a one step process” when taught [3], with the focus on the building of prototypes themselves rather than the whole process, including planning, analysing results from testing and communicating. The authors have been involved in design education for many years and can confirm this first-hand: prototyping is often seen as making without much thought into what, why and how. Our literature review reveals that, apart from competencies required to build prototypes, those required for comprehensive and successful prototyping are not always clearly defined. This may be the reason that these competencies are often not explicitly taught nor assessed. While design literature does provide a wide range of design support for prototyping, i.e., frameworks, methods, and tools [4][5], these are not often incorporated into education or linked to specific prototyping competencies. Our research aims to identify the role of prototyping in education, how it is taught and assessed, what competencies are required, and—in subsequent work—integrate this understanding and suitable methods and tools into a design competency framework to support educators.

1.1 State of the art and research questions
Purposeful prototyping is linked to an understanding of the different roles that prototypes play in design [6]. These roles have been summarised at various levels of detail in ref. [1][7][8]. While students who have taken undergraduate engineering design courses might be familiar with the classification of prototypes along the physical/analytical and comprehensive/focused dimensions [9], they might be unaware of the existence of other prototyping frameworks [8][10][11][12]. In addition, heuristics have been used to describe prototyping strategies in design science [2][3], yet these are not often applied in

design education. Most salient of all tools have been developed, such as the prototyping canvas [13] and the prototyping planner [14], which show promising results, but have yet to be disseminated and integrated with design support currently being used in design education [5].

While some work has compiled and related design support to various phases of the design process [15][16][17], most support, including that for prototyping, does not make explicit the design competencies they foster or require. We follow in our research the prior work on competencies at our university, the Singapore University of Technology and Design (SUTD), defining competency as an overarching term comprising knowledge, skills, attitudes and behaviours [18]. Knowing these competencies will help in the design of courses and programmes.

This prior work includes the Design Competency Assessment (DesCA) framework which maps design competencies to phases in the design process, learning outcomes, and associated design support, to enable instructors to plan and develop the design content of their courses in a manner that facilitates teaching and assessment [19]. DesCA is still a work-in-progress. The research reported here adds value by exploring the nature of prototyping activities carried out at the university to provide preliminary insights to the following research questions:

RQ1: How do individual instructors define prototyping?

RQ2: What roles do prototypes play in the design process in courses at the university?

RQ3: What prototyping frameworks, methods, and tools are introduced in these courses?

This will provide the basis for defining prototyping competencies.

2 METHODOLOGIES

2.1 Participants

The study methodology involved in-depth interviews conducted between June and September 2021 with instructors of undergraduate courses at SUTD that involved prototyping. We approached the course leads of all courses, that, according to the course descriptions available from the different pillar/cluster websites, were requiring a prototype as one of the deliverables, using a preliminary definition of a prototype—anything that is a physical or digital artifact. In total, 79 email invites spanning 68 courses were sent out, with 17 course leads agreeing to participate in the study. Course leads who were also instructors of other shortlisted courses were interviewed about each course they taught, resulting in data of 27 courses, representing each of SUTD's pillars and clusters (Table 1).

Table 1. Participant breakdown by affiliation

Affiliation	Pillar/Cluster	Contacted	Responded
Architecture and Sustainable Design (ASD)	Pillar	14	2
Engineering Product Development (EPD)	Pillar	21	2
Engineering Systems and Design (ESD)	Pillar	13	2
Humanities, Arts and Social Science (HASS)	Cluster	3	2
Information Systems Technology and Design (ISTD)	Pillar	19	4
Science, Mathematics and Technology (SMT)	Cluster	9	5
	Total	79	17

2.2 Data collection

Instructors were given a choice between online or in-person interviews. Prior to the interview, instructors were briefed about the study, asked for permission for an audio recording to be made, and asked to share course materials. Two instructors declined audio recording. In those cases, handwritten notes were taken by the interviewer instead. All interviews were conducted solely by the student researcher (first author), with the co-investigator (second author) observing two of them. Interview questions spanned (1) the instructor's perception of prototyping, (2) the purpose and nature of prototypes done in the course/project, (3) prototyping skills students can expect to learn by the end of the course/project, (4) prototyping tools and methods taught/used in the course/project, and (5) the assessment of prototypes and prototyping competencies. Questions that were not applicable to an instructor, based on their descriptions of what was done in a course/project, were skipped over at the interviewer's discretion. Each interview lasted about an hour.

2.3 Data analysis

Transcription of audio recordings were performed using Microsoft Word's *Transcribe* function. Initial coding was done in Microsoft Excel in the following ways for each research question.

To answer *RQ1: How do individual instructors define prototyping?*, examples of prototypes and non-prototypes provided by instructors were classified, with their reasons as to what differentiates a prototype from a non-prototype noted. Future work will use inductive coding on the responses.

To answer *RQ2: What roles do prototypes play in the design process in courses at the university?*, abductive thematic analysis was first carried out on instructors' responses to relevant questions asked. Coding was subsequently expanded to the entire interview when it was noticed that answers to other questions asked contained implicit purposes of prototyping. An abductive approach provided a foundation for prior literature on the roles of prototypes to be incorporated, while allowing new themes from our study to emerge. In particular, the seminal work by ref. [1] on the role of prototypes in companies was chosen for a priori codebook development over the comprehensive literature review in ref. [8] because the former provided a more fine-grained set of categories of roles than the latter. However, the empirical study conducted by ref. [1] differed from our study as the former took place in an industrial context, whereas our study is based in an educational context.

To address *RQ3: What prototyping frameworks, methods and tools are introduced in these courses?*, a more exploratory analysis strategy was taken, whereby any frameworks, methods, and tools mentioned were listed and grouped into categories.

3 RESULTS AND DISCUSSION

The results presented below are preliminary and only cover the first three research questions of our project. A comprehensive and in-depth analysis of the interviews is still ongoing at the time of writing.

3.1 Variations in definitions of prototypes

While most instructors could agree that prototypes are works-in-progress, we observed wide-ranging definitions, with variations across pillars/cluster. Examples cited by instructors from the ISTD pillar include software, programmes, and applications, while ESD pillar instructors felt that only algorithms or software with a certain degree of functionality can be considered prototypes. Instructors from the EPD pillar tended to regard prototypes as physical objects with certain functions, while ASD pillar instructors referred to scaled physical models and virtual artifacts as prototypes. An interesting observation was the translation of prototyping into instructors' own disciplines, best exemplified through instructor SM02 (mathematics).

SM02: If you think of a prototype being a model, like a mathematical model of how you find the velocity of an object given some acceleration data, at the end what you produce is a model that approximates the acceleration somehow. You could think of that as a 'soft' prototype.

We also noticed that only a few instructors were aware that variations exist in the perception of what a prototype is, but this was not articulated unless prompted. This could mean that instructors might not be actively aware of the possibility that definitions of prototypes can vary between disciplines, and therefore, might not communicate this to students.

3.2 Contention along the boundaries of what makes a prototype

In addition, we found certain areas of contention between what instructors would and would not consider prototypes, such as sketches, drawings, diagrams, and numerical simulations. Apart from being field dependent, we posit that these discrepancies might also be linked to purposes of prototyping perceived by instructors. For example, if the purpose of prototyping is to facilitate communication between designers and end-users, then every sketch, drawing and diagram should be considered a prototype. However, if the purpose of prototyping is solely to aid in learning about the technical feasibility of a functional subsystem, then the abovementioned might not be considered as prototypes. This level of metacognition was not articulated by any of the instructors, and we hypothesise that it is likely not communicated to students either. The implication of the above observations is that as students proceed from a common first-year curriculum into their respective pillars (majors), their perceptions of prototyping might become pillar dependent. However, when students work together in multidisciplinary teams for their mandatory final year capstone design project, these variations in definition might create misunderstanding and miscommunication in the team.

3.3 Lack of intentionality in prototyping

We found that purposes of prototyping varied across pillars and clusters as well (Table 2). While we did not ask instructors if these purposes of prototyping were communicated to students, in our experience they are not. Hence, students might fail to appreciate the roles and importance of prototyping in the design process. Moreover, we discovered in courses that have a stronger industry focus, such as in ESD, the roles of prototypes are similar to those found in industry [1], whereas in EPD, there seems to be a gap between the views of industry and education on the purposes of prototyping, despite design projects done in collaboration with industry, such as the capstone design project. We also note that some instructors did not really explain why they chose to include prototyping in their courses, such as in the case of instructor IS03 (software).

Interviewer: Based on your own definition of prototyping, would you say a prototype is necessary for each of these courses you teach?

IS03: So, the short answer is definitely, yes… I mean, I cannot imagine a software engineering course which does not have [prototyping]. It would be quite necessary. I don't know how I can elaborate.

Interviewer: So, my next question is, why do you include prototyping in your course? I understand that based on what you said for the software engineering side…

IS03: I mean, this is just the nature of the course. You know, like you are teaching a software development course from a problem statement to the prototype, but without effort or time like it's a direct contradiction, right?

This reflects a possible lack of intentionality for prototyping, which exacerbates the problem of incongruity within activities carried out in those and subsequent courses. Students cannot be expected to understand the purpose(s) of prototyping if these are not communicated to them.

Table 2. Purposes of prototyping in various courses as mentioned by the instructors

Purposes of Prototyping	Common courses*	Pillar/cluster specific courses				
		SMT	ASD	EPD	ESD	ISTD
Gathering feedback for iteration	✓					
Gathering feedback on stakeholder preferences					✓	
Testing of certain functions			✓			✓
Hands-on way of applying concepts taught		✓		✓		
Applying skills taught in the course			✓		✓	✓
Gaining confidence in building artifacts	✓					
Encouraging risk-taking behaviour				✓		

** Design courses that are mandatory for all students*

3.4 Missing competencies during introduction of frameworks, methods and tools

We noticed that no frameworks were mentioned. The prototyping tools and methods that were introduced varied from course to course. When tools and methods are not taught, students are asked to rely on training provided by SUTD's fabrication lab (FabLab) or teach themselves. In the case of most EPD and ASD courses, tools used to prototype, such as laser cutters, 3D printers, and CNC mills and lathes are introduced in the lecture, but students are to rely on FabLab training to learn how to use it. In the case of most ISTD and ESD courses, students learn about tools (e.g., programming languages) and methods (e.g., modular code, object-oriented programming). One competency that was largely missing from the interviews, however, was how to select appropriate (fit-for-purpose) prototyping methods and tools. While some instructors were not cognisant of this competency, those who were gave various reasons for not including this in their courses, ranging from the belief that students should pick up this competency on their own, to a lack of time, such as the case of instructor EP02 (engineering design).

Interviewer: Do you also teach students how to select the best prototyping tool, or is it more like telling them that, 'Oh, I think this is the tool you should use'?

EP02: So, I have one lecture, I think, where I [talk] about the fabrication approaches, when I basically go through in broad strokes, I kind of tackle that. Like so this type of fabrication approaches, for example subtractive [manufacturing], are better for these types of scenarios where you want to achieve this type of resolution or when you're working with these types of materials.

This instructor was one of the very few whose response suggests that a prescriptive approach was outlined to students regarding the selection of appropriate methods and tools albeit in broad strokes. Yet, it was only upon further clarification that we realised that instructor EP02 was actually aware of the selection strategy. However, we are unsure if this was explicitly taught to students in the course.

EP02: So, for example if you're building a little car, and you need an axle for the drive train. And that axle is meant to support a lot of weight, or a certain weight and have low friction… I would just buy a stock steel or hard metal and cut it to size, or machine something down to the diameter you want. Because with a metal you will get a higher load capability, and also when you machine it with a lathe, for example, you can get a smooth surface that will give you very low friction. So that's what I mean, that you should keep your objective in mind. What are the functional requirements of the part that you are trying to prototype, and are those aligned with the process that you're choosing?

The implication of not teaching the process of selecting the most suitable prototyping methods and tools is especially salient and threefold: (1) students might waste resources and time by using methods and tools that are not fit for purpose, because they did not consider this, (2) the lessons learnt by students after such trial-and-error processes might contain misconceptions, and (3) students who do not know the fundamental criteria for selection of appropriate methods and tools might find it harder to apply new methods and tools that they pick up in industry. Therefore, there is a need to teach the whole prototyping process based on experiences and expertise in the respective fields to enhance student learning.

4 LIMITATIONS AND CONCLUSION

In summary, based on our sample of 17 instructors, while many agree that prototypes are works-in-progress, variations in what constitutes a prototype exist across disciplines. We found that what individual instructors perceive as the purpose(s) of prototyping in design also influences how they differentiate prototypes from non-prototypes. Unsurprisingly, the roles prototypes play differs between courses. Of the main purposes of prototyping [1]—enable communication, aid in learning, and inform decision making—enabling communicating was not mentioned by our interviewees. We did find additional purposes, though, compared to the detailed categories of [1] (industry perspective) and [7] (education perspective): hands-on way of applying concepts taught (including chemistry, mathematics, and physics concepts), gaining confidence, and encouraging risk-taking behaviour (see Table 2). We hope this finding triggers a review of the purposes of prototyping in education and a comparison with industry. Furthermore, even though no prototyping framework was articulated by any of the instructors, they do introduce a wide variety of discipline-specific methods and tools, they often rely on FabLab staff to train the students. More importantly, we realised that the competency of selecting appropriate prototyping methods and tools is largely missing in all courses.

The following limitations of the study have been identified. Firstly, the study was conducted at SUTD, whose curriculum arguably has a far larger emphasis on design than most technical universities. The findings may thus be specific to SUTD. Secondly, some instructors provided data about up to three courses, i.e., their view may have influenced our findings more than the views of other instructors. Thirdly, for courses with multiple instructors, as is common in design, methods of instruction can be expected to differ within a single course. Due to time constraints, we have chosen to reach out to course leads, accepting that discrepancies and coherence within courses would be hardly accounted for.

Despite its recognised importance, the purposes and process of prototyping seem to lack explicit attention in education, where large differences in understanding about the role of prototyping exist. It is necessary to identify the competencies, methods and tools required for effective prototyping, accounting for differences between disciplines, and to develop a framework to aid instructors and students. This will be the focus of our future work, which centres on DesCA [19] as the integrating framework.

ACKNOWLEDGEMENTS

Financial support from the SUTD Undergraduate Research and Honours Programme (SGPRSSHARP) is acknowledged. The authors thank EPD undergraduate Anshiqa Agrawal for help in transcribing.

REFERENCES

[1] Lauff C.A., Kotys-Schwartz D. and Rentschler M. E. What is a Prototype? What are the Roles of Prototypes in Companies?. *Journal of Mechanical Design*, 2018, 140(6), p.061102.

[2] Camburn B., Dunlap B., Gurjar T., Hamon C., Green M., Jensen D., Crawford R., Otto K. and Wood K. A Systematic Method for Design Prototyping. *Journal of Mechanical Design*, 2015, 137(8), p.081102.

[3] Christie E. J., Jensen D.D., Buckley R. T., Menefee D. A., Ziegler K. K., Wood K. L. and

Crawford R. H. Prototyping Strategies: Literature Review and Identification of Critical Variables. In *2012 ASEE Annual Conference & Exposition*, Texas, USA, June 2012, p.25.1091 (American Society for Engineering Education).
[4] Blessing L. T. M. and Chakrabarti A. *DRM: A Design Research Methodology*, 2009 (Springer, London).
[5] Hansen C. A. and Özkil A. G. How We (Sometimes Do Not) Evaluate Design Support: A Review of How Design Support Is Evaluated in Practice. In *Proceedings of NordDesign 2020*, Lyngby, Denmark, August 2020, pp.1-12 (The Design Society).
[6] Petrakis K., Wodehouse A. and Hird A. Physical Prototyping Rationale in Design Student Projects: An Analysis Based on the Concept of Purposeful Prototyping. *Design Science*, 2021, 7, p.e7.
[7] Petrakis K., Hird A. and Wodehouse A. The Concept of Purposeful Prototyping: Towards a New Kind of Taxonomic Classification. In *Proceedings of the Design Society: International Conference on Engineering Design*, Vol. 1, No. 1, Delft, The Netherlands, July 2019, pp.1643-1652 (Cambridge University Press).
[8] Menold J., Jablokow K. and Simpson T. Prototype for X (PFX): A Holistic Framework for Structuring Prototyping Methods to Support Engineering Design. *Design Studies*, 2017, 50, pp.70-112.
[9] Ulrich K. T. Eppinger, S.D. *Product Design and Development, 6th Edition*, 2016 (McGraw-Hill Education, New York).
[10] Thomke S. H. Managing Experimentation in the Design of New Products. *Management Science*, 1998, 44(6), pp.743-762.
[11] Moe R. E., Jensen D. D. and Wood K. L. Prototype Partitioning Based on Requirement Flexibility. In *ASME 2004 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Vol. 3a, Utah, USA, January 2004, pp.65-77 (American Society of Mechanical Engineering).
[12] Gill C., Sanders E. and Shim S. Prototypes as Inquiry, Visualization and Communication. In *Proceedings of E&PDE 2011, the 13th International Conference on Engineering and Product Design Education*, London, UK, September 2011, pp.672-277 (The Design Society).
[13] Lauff C., Menold J. and Wood K. L. Prototyping Canvas: Design Tool for Planning Purposeful Prototypes. In *Proceedings of the Design Society: International Conference on Engineering Design*, Vol. 1, No. 1, Delft, The Netherlands, July 2019, pp.1563-1572 (Cambridge University Press).
[14] Hansen C. A., Jensen L. S., Özkil A. G. and Pacheco N. M. Fostering Prototyping Mindsets in Novice Designers with the Prototyping Planner. In *Proceedings of the Design Society: DESIGN Conference*, Vol. 1, Cavtat, Croatia, May 2020, pp.1725-1734 (Cambridge University Press).
[15] Sanders E. B. N., Brandt E. and Binder T. 2010, November. A Framework for Organizing the Tools and Techniques of Participatory Design. In *Proceedings of the 11th Biennial Participatory Design Conference*, Sydney, Australia, November 2010, pp.195-198 (Association for Computing Machinery).
[16] Castaños C., Chin A., Jiang J., Kim E., Kramer J., Nitta C., Ryu S., Shkurti J., Agogino A., Beckman S., Poreh D., Roschuni C. and Yang M. *The Design Exchange – BEST Lab at UC Berkeley*. Available: https://best.berkeley.edu/best-research/thedesignexchange [Accessed on 2022, 9 March].
[17] Lauff C., Wee Y. H., Teo K., Png S., Swee A., Collopy A., Vargas B. and Wood K. L. *Design Innovation Methodology Handbook: Embedding Design in Organisations*, 2021 (Singapore University of Technology and Design-Massachusetts Institute of Technology International Design Centre).
[18] Thandlam Sudhindra S., He Y. J., Blessing L. T. M. and Khan S. A. Stories of Design Education: An Analysis of Practices and Competencies. In *Proceedings of the Design Society: DESIGN Conference*, Vol. 1, online, May 2022 (Cambridge University Press).
[19] Thandlam Sudhindra S. and Blessing L. T. M. A Framework for Design Competency Assessment. In *Proceedings of the Design Society: ICED21*, Vol. 1, Gothenburg, Sweden, August 2021, pp.91-100 (Cambridge University Press).

LESSONS LEARNED FROM A DESIGN-DRIVEN ENTREPRENEURSHIP PROCESS THAT BRIDGES ACADEMIC RESEARCH AND DESIGN EDUCATION

Louise KIERNAN[1,2], Eoin WHITE[1,2], Orfhlaith Ni BHRIAIN[1,3], Bernard HARTIGAN[1,2] and Megan O'MAHONY[1,2]
[1]School of Design, University of Limerick
[2]Health Research Institute, University of Limerick
[3]Irish World Academy of Music and Dance, University of Limerick

ABSTRACT
Research and education can be distinctly separate activities in institutions, where academics try to divide their time between the two roles. Many research initiatives necessitate large-scale funding to be completed. In response, this paper presents an alternate strategy in which educational design initiatives can promote academic research activities. The study looks at how a design-led entrepreneurial approach combines research and education to create marketable solutions. A literature review was undertaken to understand the disconnect between academic pedagogy, postgraduate, design-driven research and design entrepreneurship. An undergraduate Product Design degree course was also examined to understand the means through which innovative solutions are incubated. We then applied our findings to progress a final year project through master's level with a commercial focus to determine the viability of our approach. This study presents findings and lessons learned from a paradigm built inside a research cluster, in which viable design proposals are incubated as undergraduate final year projects (FYP) and then selected for postgraduate development with the goal of commercialization. A variety of difficulties and possibilities, as well as lessons learned, were recognized, including choosing the right topic to develop, forming partnerships with different disciplines, intellectual property, money, expertise, and resources. By bringing together the often-separate entities of research and education, this paper shows how research and educational activities are not mutually exclusive but can be combined to provide rich educational experiences along with meaningful research outputs.

Keywords: Innovation, entrepreneurship, design, health and wellbeing, research

1 INTRODUCTION
Universities are now at the front of innovation and entrepreneurship with calls for them to be competitive and sustainable as funding from state departments is reduced [1]. While research, entrepreneurship and innovation are at the forefront of university activity it is often disconnected from the educational role of universities. Education often retains a more inferior position over academic research, to the point of being neglected [2]. While institutions teach both theoretical and practical subjects, there is criticism that some programmes that offer entrepreneurship are, applying outdated curriculum and pedagogical techniques that do not connect students to industry and the workplace [1, 3]. However, design programmes have the potential to be the foundation for entrepreneurship to drive and support design driven entrepreneurial research in academic institutions. This paper describes a model where design education and entrepreneurial research can coexist and become embedded to create mutual benefits for both entities.
It also describes how design programmes can be a catalyst for design and innovation research and potential commercialization, through cross collaboration within academic institutions.

2 LITERATURE REVIEW
The relationship between education and research is a contemporary issue [4]. Education through research is specific to the specific aims of the project, whereby the application of already established design pedagogy seeks to solve specific design issues, as opposed to using those issues as a learning

experience. However, design practice and research have begun to become intertwined, the results of which have produced "practitioner-researchers" [5]. While there has been a limited emergence of "new practitioners", whose skillsets combine practice, education, and research in one compound skillset, it is still a relatively new concept, and potentially underutilised [6]. However, there are also many aspects to the future of design which are uncertain, as design professions evolve and change [7]. Current design education runs the risk of having students specialising in areas that may be irrelevant as these professions evolve [4]. This is further exacerbated by the disconnect between research and education, as research focuses more on contemporary design issues whereas education may lag behind in that regard, potentially favouring outdated concepts of learning and teaching to inform design [8]. Design research is less concerned about producing knowledge as an end in itself, but instead focuses on making new things possible [4].

Design driven innovation in academia has grown due to the central role of design thinking in innovation, and the well-documented increase in technology transfer over the past few decades [9-11]. Many universities have a well-established technology transfer infrastructure to both encourage and promote entrepreneurship as its own subdomain within academia [12, 13]. To that end, design driven innovation is a key contributor to technology transfer due to the broad nature of design research, as well as its involvement in other domains such as engineering, healthcare, and science [14-17]. Design entrepreneurship can enable academic institutions to spinout commercially viable research projects companies to acquire further funding to continue growth and IP development [18-20]. Funding bodies such as the European Commission's "Design for Enterprises" the European Design Innovation Initiative (EDII) support design-driven innovation in Small and Medium Enterprises and academia [21, 22]. Through these initiatives, universities and other academic settings have developed their own commercial outputs through both academic research and industry collaboration [23, 24].

However, there is a disconnect between academic pedagogy and postgraduate, design-driven research, whereby the educational aspects and research aspects are kept separate. In design education, tools, skills, methods, processes are taught to students for them to competently enter the design profession [4]. It can be argued that design educators prefer to teach general, basic design fundamentals which ensures their relevancy in contemporary design education, but does not account for research-specific problem solving and ideation [25]. However, it is also argued that there is no such thing as a general design education [4]. Interdisciplinarity in design education is becoming a critical issue for design schools [26]. Design is not solely a practical skill that someone can be taught, but something one learns how to make [4]. Combining design principles with different disciplines can lead to better education and design outputs. Just as how other skillsets can lend themselves to design, design-thinking is also useful in entrepreneurship education and can also enhance cooperation with industry [27]. At an undergraduate, academic level, design courses may offer entrepreneurship modules to help position their design projects and aspirations accordingly [28]. However, there is a paucity of data in the literature relating to how potentially viable projects can be identified at an undergraduate level, scoped out, and taken forward to post-graduate research with the intention of developing IP and commercialising the design outputs in the form of a spinout company.

3 METHOD

Three case examples are presented from a research cluster which connects academics from Product Design and the Performance Arts in the area of music and dance. The research cluster was established through a funding award with a specific focus and expertise (Scientific and Technology Advisory Board STAB) but was specifically design-led to have the expertise required to realise product-based solutions. The cluster is made up of other disciplines as outlined in Figure 1. The cluster focus is aimed at developing innovative solutions that can address the needs of dancers and singers in the performance arts and health fields as this was an area that has been neglected in terms of product development.

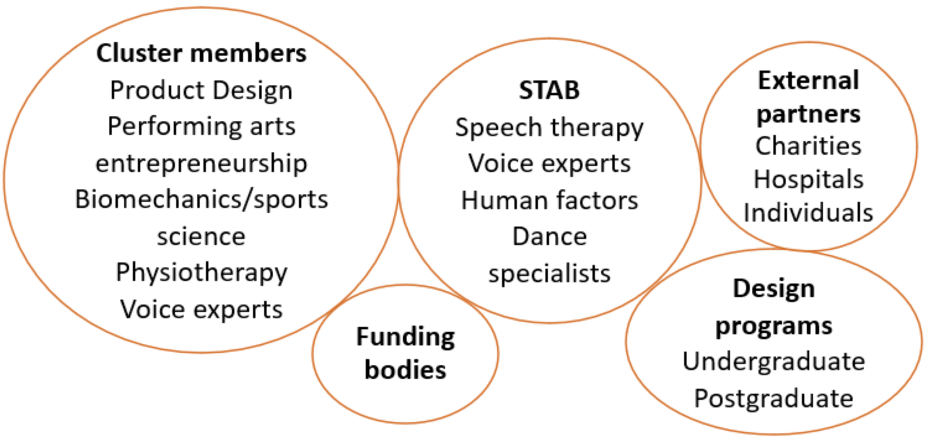


Figure 1. The cluster structure

While the cluster was funded by the institution, these funds were limited and inadequate to incubate more than one project. Therefore, the cluster relied on design programmes at both undergraduate and post graduate level to develop and incubate projects. Table 1 provides the detail of each project path. Figure 2 provides images from the three projects.

Table 1. Project descriptions

Project description	Phase 1 delivery	Phase 2 delivery
A design of a heavy Irish dancing shoe to mitigate against the injuries in Irish dancing. Project originator: Irish World Academy of Music and Dance -interfaculty collaboration.	6-week collaboration with four undergraduate Product Design students. Outputs: Early concepts with drawings and rough prototypes.	PhD project in progress. Studies completed: observations, interviews, and surveys to understand the needs of dancers. Video analysis of 28 dance steps to determine the biomechanics of the foot. Force plate testing.
The application of algometry to measure tissue sensitivity and pain perception. Project originator: Algotronics - external start-up company.	6-week collaboration with four undergraduate Product Design students to develop and test a soft padded garment to accurately house pressure sensors to record bio data. Outputs: developed concept through iterative drawings prototyping and testing.	Project completed at stage 1.
Device to support the health and performance of the vocal tracts of singers and those receiving voice therapy. Project originator: Final year undergraduate product design student.	Final year project at undergraduate level. Output: Qualitative research report with singers and singing teachers and a concept of a device to support singers applying the SOVT with prototype and cad drawings.	Project in 2nd phase with a researcher. Scope expanded to include speech and language therapy needs. The project has received the first stage of a commercialization fund to the value of €15,000.

Figure 2. The Irish dance shoe, Algometry, and Voice Health

4 FINDINGS

Table 2 describes the process undertaken by a small research cluster to incubate projects that can provide opportunities for innovation.

Table 2. The incubation process and selection criteria

1	Research cluster established through funding award with a specific focus and expertise (Scientific and Technology Advisory Board STAB) as per Figure 1.
2	Collaboration sought between external partners or other academic departments – School of Design and Irish world academy of Music and Dance.
	Project starts with undergraduate product design students with emphasis to the research and testing with stakeholders.
3	Project assessed and given red or green light to proceed to the next phase.
4	FYP student brings the project forward to a taught master's programme or is recruited as Research assistant to bring project to the next stage.
5	Collaboration with Technology Transfer Office (TTO) to file invention disclosures and file patents.
6	In conjunction with STAB and TTO apply for feasibility and commercialization funding.
7	Establish a spin out company or license the design to a company.

Several factors were used to rate the three projects to determine if they should proceed to the next stage of the process, see Table 3. All the projects progressed through Phase 1. However, only two of the three projects passed the screening to proceed to the next phase. Project 2 did not progress and failed on several criteria. The next stage of the project involved embedding sensors into the soft product that was designed in phase 1. It required the development of a working rig that included software and a working interface. Therefore, the scope was too great for the cluster, the expertise was not within the cluster, and there was not enough available time to seek external support. The cluster did not have sufficient resources to devote to the project and, as the partner was an external company, the cluster could not use its funding to develop the project further. The company also sought to retain the intellectual property rights.

Table 3. Rating criteria of the projects for stage development

Criteria for screening	**The Irish dance shoe**	**Algometry**	**Voice health**
Correct scope	Yes	No	Yes
Expertise	Yes	No	Yes
Time	Yes	No	Yes
Resources	Yes	No	Yes
Funding	Yes	No	Yes
Requirement for External Partners	No	Yes	No
Commercial Viability	Yes	Yes	Yes
Intellectual property (IP) potential	Yes	Yes	Yes
Intellectual property (IP) ownership	Yes	No	Yes

The success of the projects is contingent on several factors. Cluster oversight, access to experts and expertise across a variety of disciplines, access to research participants, access to key stakeholders for feedback and co-design, access to participants for testing, access to funding and IP ownership. It was also necessary to ensure a rewarding educational experience for the students involved.

5 DISCUSSION & CONCLUSION

Design programmes operate a studio-based learning model which is often time intensive for academics leaving them with limited time for research and practice. Our approach can enable academics to create a balance between teaching activity and research by combining both activities. The findings have shown that the incubation of solutions with commercial potential is possible through this approach while also providing a rich educational experience for students. A grass roots approach rooted in academic rigour, interdepartmental communication, and exposure to entrepreneurship principles at early-stage design projects leads to enhanced project outcomes and the generation of technically and financially feasible products for further development. Engaging with a project at undergraduate level allows for several projects to be explored and their potential developed without any capital investment. Promising projects may then secure funding for further development which can lead to commercialisation through spinout companies or industry partnerships. This approach is highly iterative, and through repeated testing and building, it is possible to meet the needs of the stakeholders. This approach can also allow for the development of refined prototypes that can be used to secure feasibility and commercialisation funding. The support of a STAB group and the TTO ensures that the right expertise is available at each stage of the project. The TTO can also relieve some of the workload for academics by supporting funding applications and intellectual property protection (IP). While working with industry partners is beneficial at many levels there are challenges around ownership of IP which in future collaborations would require upfront agreements put in place through contracts with each partner. As advocated by [1] our process is sustainable in that projects can be incubated to a stage without any significant costs. As not all projects have the potential for the marketplace, this also provides a supply of projects from which to select the most promising ones for commercialisation ensuring that projects that are put forward for funding are more likely to be successful.

This combined research and educational approach can also provide relevant industry linked experience for students as advocated in the literature [29, 30] where industry partners provide expertise and practical feedback as students work on projects with real world constraints. Cross disciplinary learning experiences have also been shown to enhance student's learning experiences [26]. By combining teaching and research agendas this ensures that the educational experience for students is not given a secondary role to research as has been criticized in the literature [2] and that the pedagogical approach is up to date and relevant [1].

REFERENCES

[1] Huq A. and Gilbert D. All the world'sa stage: transforming entrepreneurship education through design thinking. *Education+ Training*, 2017.

[2] Juhl J. and Buch A. Transforming academia: The role of education. *Educational Philosophy and Theory*, 2019. 51(8): p. 803-814.

[3] Jackson D. and Chapman E. Non-technical skill gaps in Australian business graduates. *Education+ Training*, 2012.

[4] Redström J. Certain uncertainties and the design of design education. *She Ji: The Journal of Design, Economics, and Innovation*, 2020. 6(1): p. 83-100.

[5] Biggs M. and Büchler D. Communities, values, conventions and actions, in *The Routledge companion to research in the arts*. 2010, Routledge. p. 112-128.

[6] Dunin-Woyseth H. and Nilsson F. *Design education, practice, and research: on building a field of inquiry*. 2014.

[7] Kiernan L., Correia de Barros A., Cotrim T. and Chamberlain P. The Future of Design for Health and Wellbeing, in *Developments in Design Research and Practice. Senses* 2019. Springer Series in Design and Innovation, R.C. Duarte E., Editor. 2022, Springer.

[8] Nordquist J. and Sundberg K. An educational leadership responsibility in primary care: ensuring the physical space for learning aligns with the educational mission. *Education for Primary Care,* 2013. 24(1): p. 45-49.

[9] Ambos T. C., et al. When does university research get commercialized? Creating ambidexterity in research institutions. *Journal of management Studies*, 2008. 45(8): p. 1424-1447.
[10] Belitski M., Aginskaja A. and Marozau R. Commercializing university research in transition economies: Technology transfer offices or direct industrial funding? *Research Policy*, 2019. 48(3): p. 601-615.
[11] Abbas A., et al. University-government collaboration for the generation and commercialization of new knowledge for use in industry. *Journal of Innovation & Knowledge*, 2019. 4(1): p. 23-31.
[12] Shahidan N. H., Latiffb A. S. A. and Wahabc S. A. University Startup Framework for Intellectual Property Rights (IPR) Commercialisation: A Qualitative Study. in *Proceedings of the 4th UUM International Qualitative Research Conference (QRC 2020)*. 2020.
[13] Muscio A. and Ramaciotti L. How does academia influence Ph. D. entrepreneurship? New insights on the entrepreneurial university. *Technovation,* 2019. 82: p. 16-24.
[14] Letourneur D., et al. Enabling MedTech Translation in Academia: Redefining Value Proposition with Updated Regulations. *Advanced Healthcare Materials*, 2020: p. 2001237.
[15] Borah D., Malik K. and Massini S. Are engineering graduates ready for R&D jobs in emerging countries? Teaching-focused industry-academia collaboration strategies. *Research Policy,* 2019. 48(9): p. 103837.
[16] Palo-oja O.-M., Kivijärvi M. and Aromaa E. Challenges in academic commercialisation: a case study of the scientists' experiences. *International Journal of Knowledge Management Studies*, 2017. 8(1-2): p. 23-37.
[17] Sanami M., et al. Translating healthcare innovation from academia to industry. *Advances in Mechanical Engineering*, 2017. 9(3): p. 1687814017694114.
[18] Holley A. C. and Watson J. Academic entrepreneurial behavior: birds of more than one feather. *Technovation,* 2017. 64: p. 50-57.
[19] Prokop D. The determinants of University spinout formation and survival: The UK context of network, investment, and management team effects. 2017, Cardiff University.
[20] Himpler J.-P. An Investigation of the Importance of Patents in Academic Entrepreneurship. *GAZDASÁG ÉS TÁRSADALOM*, 2018(2): p. 21-44.
[21] Whicher A. and Swiatek P. Design, Innovation & Policy 2020–anticipating trends for design--driven innovation in *Ministry of Design–from Cottage Industry to State Enterprise Colloquium Proceedings*. 2015.
[22] Ferrara M. and Lecce C. Design for Enterprises: Developing European SMEs Capabilities for Design-driven Innovation. *Markets, Globalization & Development Review*, 2020. 4(2).
[23] Walden R. Progressing a university-industry collaboration (UIC) model for open and sustainable innovation. *Cumulus Hong Kong 2016: Open Design for E-very-thing*, 2017.
[24] Jussila J., et al. Rapid Product Development in University-Industry Collaboration: Case Study of a Smart Design Project. *Technology Innovation Management Review*, 2020. 10(3).
[25] Boucharenc C. G. Research on basic design education: An international survey. *International Journal of Technology and Design Education*, 2006. 16(1): p. 1-30.
[26] Self J. A. and Baek J. S. Interdisciplinarity in design education: Understanding the undergraduate student experience. *International Journal of Technology and Design Education*, 2017. 27(3): p. 459-480.
[27] Fiore E., Sansone G. and Paolucci E. Entrepreneurship education in a multidisciplinary environment: evidence from an entrepreneurship programme held in Turin. *Administrative Sciences*, 2019. 9(1): p. 28.
[28] Moroz P. W., Hindle K. and Anderson R. Collaboration with entrepreneurship education programmes: building spinout capacity at universities. *International journal of innovation and learning*, 2010. 7(3): p. 245-273.
[29] McMahon M. and Kiernan L. Beyond the studio: collaboration and learning outside the formal design studio. 2011.
[30] Kiernan L. and Ledwith A. Is design education preparing product designers for the real world? A study of product design graduates in Ireland. *The Design Journal*, 2014. 17(2): p. 218-237.

DESIGN FOR SIBLINGS OF CHILDREN IN NEED OF INTENSIVE CARE

Fien HUYBRECHTS and Ivo DEWIT
Department of Product Development, University of Antwerp, Belgium

ABSTRACT
Having a sibling with an illness or disability can be very stressful. Siblings in this context need sufficient support, otherwise this can have a negative impact on the long-term well-being of the siblings. Today we see all too often that these siblings are a kind of forgotten group. Parents are often very busy caring for their sick or disabled child and siblings often fade into the background. As a result, siblings often push themselves to the side and have difficulty expressing their emotions because they do not want to be a burden to their parents. Therefore, the right support is needed to promote siblings' mental well-being, self-expression, and skills. Despite the various studies already conducted, the current support system is still often inadequate. There is a lack of recognition of organizations that support siblings in this context, even though there is a substantial need for them. Funding and recognition are still often a problem today. In this paper, the needs and problems of siblings are examined through qualitative research. Based on the collected insights, a list of requirements was composed that can help designers to support siblings in expressing their feelings and stimulate communication between parents and child. This paper contributes to the literature on the well-being of siblings of children with illnesses or disabilities, by looking at the problem from a different angle. In this way, an attempt is made to prevent mental problems in the long run and to offer adequate support.

Keywords: Sibling support, well-being of siblings, disability, childhood illness, product service system

1 INTRODUCTION
About 82% of all children grow up with a brother or sister [1]. The sibling relationship is therefore important and has a great influence on the child's development. It is the longest lasting relationship in the life of an individual, as it starts at birth and continues throughout life [2]. The brother-sister relationship in most cases lasts longer than the parent-child relationship, as parents usually die sooner than their children [2]. What does this relationship look like for siblings of children who need intensive care, what are the differences and similarities with an ordinary brother-sister relationship, what difficulties do these siblings experience and what can we do to support them sufficiently? This paper examines the sibling relationship and the different needs and difficulties that siblings of children with a disability or illness face. By means of qualitative research in the form of a literature study, in-depth interviews and short questionnaires, information concerning the theme is mapped out and analysed.

2 PROBLEM DEFINITION
The brother-sister relationship is dynamic. As you grow older, you will experience the relationship differently. So, it changes over the years [3]. Having a brother or sister with a disability or a serious illness can cause a lot of stress and tension that can lead to problems and overburdening later in life. Yet here too, the bond is unique and unbreakable [3]. Siblings of children who need intensive care sometimes experience conflicting and unresolved feelings and it is not always easy to deal with this. On top of this, they are three times more likely to experience mental problems and overburdening [4]. It is therefore important that they receive sufficient support to prevent the negative long-term effects. Today, it still appears all too often that these siblings are a forgotten group. In families where one of the children has a serious illness or disability, all the attention of the parents and caregivers often goes to the sick or disabled child. This is very normal and logical. However, it should be considered that this can also influence the development of the other siblings. It is not easy for parents to find extra time for their other children, so they often fade into the background and teach themselves not to talk about conflicting feelings such as anger, frustration, fear, jealousy, or guilt, because they do not want to burden their

parents with them. Even though they usually have a great deal of understanding for the situation, they may also experience it as unfair because they receive less attention. Siblings of children who need intensive care often feel that they have extra responsibility and take over tasks from their parents or help to take care of the sick child or child with a disability [5]. They worry about their sick brother or sister. Open communication about the illness or disability is therefore important to avoid fear, incomprehension, guilt and wrong thinking or expectations on the part of the siblings [5].
These siblings need the right attention, sufficient support, and the necessary understanding for the various feelings they experience throughout their lives. In this way, mental problems and overburdening later in life can be prevented. Communication between parent and child is essential. Today, there are few or no tools that focus on the communication between parent and child, and therefore few tools available that can be used at home without the help or presence of a caregiver. Here lies a great opportunity for designers.

3 CURRENT STATE OF THE ART

Over the past 40 years, there has been increasing interest in siblings of children who need intensive care. This is logical since inclusion is becoming more and more important in our society [6]. Various studies have been conducted to examine the influence of having a sibling with a disability or illness. These studies have often produced contradictory results. For example, many studies indicate that having a sibling with a disability or illness has a negative impact on the development of the sibling, while other studies indicate that it has a positive impact on development. Moyson's [3] research shows that these contradictions can be explained by the fact that the sibling's relationship is always a unique and dynamic one, but also by the fact that most research is done with adult siblings. Using adult siblings ensures that often the memories that have stayed with them are the ones who are told the most. These will be the most negative and most positive memories, which can lead to contradictions in existing studies. The sibling's relationship is unique and special, and each sibling reacts differently to his or her situation. This is confirmed by the contradictory results of the studies. Moyson [3] noted that no universally valid conclusions can be formulated about this relationship.

3.1 Context

Children with an illness or disability require a lot of attention and care. This care can be provided by the parents and siblings, but sometimes a caregiver is called in when the care becomes too heavy. Also, for the siblings themselves, a counsellor can be called in to find out how they feel about the situation. Siblings can often also turn to certain teachers, friends, or family at school. Having a sibling with a disability influences the lives of these siblings. The impact depends on various factors within the family, in the network surrounding the family and in society [7]. Every sibling is in a different situation and will need support in a different way or in a different place. Some siblings spend a lot of time in the hospital because their brother or sister must go there often, while others hardly ever come into contact with the hospital. The place where these siblings need support depends on their specific situation. Why do they need support? These siblings often must deal with the concept of "living loss". When having a sibling with a disability, it can sometimes feel like a "living loss". It can be difficult for a sibling to cope with important moments in their life such as marriage, childbirth, and graduation. This because they are constantly reminded that their brother or sister may never be able to experience this themselves. In addition, having a brother or sister with a disability or serious illness can sometimes feel unfair since their sibling who needs intensive care is entitled to more attention, care, or support [3]. These siblings may feel that they always must be the ones who 'give' and that they never get anything in return [4]. It is therefore important that not only parents, but also caregivers give them sufficient attention and support so that they know they are also important and that they are also thought of.
Today, there are several organisations dedicated to the well-being of siblings of children who need intensive care. Most of these organisations organise sibling days to put siblings in the spotlight. During such a sibling day, fun activities are organised, such as going to the zoo, or a handicraft workshop... This way, siblings can meet each other. Many organisations also aim to expand the knowledge and skills of these siblings. For example, courses are organised in which siblings learn how to deal with their brother or sister with autism, or days are organised in which siblings can visit an operating theatre because their brother or sister often must be there. There are also organisations, such as Kadodder, who offer home counselling for siblings. This counselling often consists of a simple conversation with the sibling. This way they feel they matter and that they are not alone. Counsellors can then give tips to parents on how to deal with the situation.

4 RESEARCH METHODS

As a research strategy, qualitative research was chosen in the form of literature study and in-depth interviews. Various sources were consulted, such as the 'Brothers and Sisters Book' by van Dijken [4], but also various papers. In addition, in-depth interviews were conducted with the main stakeholders. In this way, the needs, and underlying thoughts of siblings of children who need intensive could be mapped out further.

5 FINDINGS & DISCUSSION

5.1 Literature exploration

The image of siblings of children who need intensive care has evolved a lot over the years. From the literature exploration it is clear that in the past, the focus was very much on the negative effects of being a sibling of someone who needs intensive care. However, the study by Poppe et al [6] shows that in recent years a more nuanced and positive view has emerged about being one of these siblings.

But it is not always easy. Siblings of children who need intensive care often have different experiences from their peers, which can make it difficult for them to connect with their peers. Various studies have repeatedly shown that in families where a chronically ill or disabled child is present, the attention of parents, but also of care providers, is mainly focused on the ill or disabled child [9]. In families where there are other children present, this can cause these children to end up in a difficult position [4]. Various studies also point to the fact that these siblings are more likely to cause mental problems and overburdening. This overburdening may be caused by the excessive expectations set by parents. Often, parents do not realise that they are setting other expectations for the siblings and that these expectations are sometimes too high.

As mentioned earlier, it is important to realise that the sibling's relationship is a unique and complex one and that it is not easy, or even possible, to define this relationship in a one-sided and straightforward way [6]. Siblings describe being a sibling of someone who needs intensive care as a "dynamic continuum with positive effects at one end and negative effects at the other" [6]. How they feel and where they are on this continuum depends on the situation, they are in. It is also important to bear in mind that not every sibling has the same needs, it depends very much on their home situation and the relationship they have with their parents.

According to the research of Moyson [7], there are nine domains that influence the well-being of these siblings, namely: joint activities, mutual understanding, own time, acceptance, tolerance of behaviour, concern for sibling welfare, sharing of experiences, support from the environment, dealing with the outside world. Moyson [7] indicates that siblings who do activities together with their brother or sister with a disability or illness, and experience these activities as something positive, but are also able to do things on their own, usually accept being a sibling of someone who needs intensive care. When joint activities do not go well or there is no balance between the two, being a sibling of someone who needs intensive care is more likely to be perceived as an inconvenience and acceptance will be more difficult or even non-existent. Of course, the acceptance process also depends on other factors [7]. Another striking fact from her research [7] is that almost all the siblings indicated that meeting fellow sufferers has a positive effect on their well-being. This is also reflected in the nine domains. These domains can be used by parents or caregivers to start conversations with the siblings and to find out how they are feeling. Designers could implement these nine domains in products or services that can support siblings in this situation.

In addition to the negative consequences of being a sibling, it is also important to consider the positive consequences. For example, these siblings often have a higher degree of maturity, compassion, and resilience. They are less likely to have prejudices about someone because of their own situation and experiences. This was also mentioned in the in-depth interviews that were done. As a parent or caregiver, it is important to capitalise on these success stories. Ask what activities they enjoy doing together, or what they have learned from their sick or disabled sibling. It is important not to focus only on the negative aspects of being a sibling of someone who needs intensive care. When siblings are actively asked about the positive effects, they are more likely to consider them [7].

5.2 Interviews

A total of ten people were interviewed for the study, including four adult siblings, one parent, one paediatric oncology trainee, three experts and one expert who also is a sibling of someone who needs intensive care. For each interview a structured questionnaire was drawn up which served as a guideline for the discussion. The questionnaire was not strictly followed. From these interviews, several insights emerged that confirmed and complemented the findings from the literature studies.

5.2.1 Siblings

Earlier in this paper it was mentioned that siblings of children who need intensive care are up to three times more likely to have mental problems. This was also evident from the interviews, where three out of five siblings of children who need intensive care indicated that they ever needed psychological help because they were struggling. One of the siblings also said that she did not need it herself, but her brother did. Two of the five siblings even indicated that they themselves fell into a depression and several siblings indicated that their parents had different expectations of them and that they felt this was not fair and sometimes difficult. According to these siblings it is difficult to see their brother or sister being treated differently and being allowed more than them. They also indicated that they sometimes felt held back in their development because they could not always be 100% the brother or sister they wanted to be and sometimes put themselves aside in order not to burden their parents. Talking about it is very personal and makes you vulnerable. "By talking about it I felt relieved but also misunderstood because my dad said: it is not that bad after all" (J. VM, personal communication, 22 November 202).

There is a difference between siblings of children with a congenital disease and siblings of children with a non-congenital disease. The first ones get more used to it because they grow up with it. Most of them accept it as part of their normality (A. B, personal communication, 29 October 2021). However, it is important to realise that it can still be difficult for them. Just because something is normal does not mean it is necessarily easy (A. M, personal communication, 25 October 2021). For siblings of children with a non-congenital illness it is a little different. They often must learn to cope with sudden changes. Many fun activities are suddenly not available to them, and their family situation suddenly changes (A. B, personal communication, 29 October 2021). In addition, there is also a difference in how siblings express their emotions. Some of them internalise their emotions very strongly, some of them externalise them very strongly and some of them do both (A. M, personal communication, 25 November 2021). Siblings who internalise their emotions and thus often hide them are often seen as the ‘perfect sibling’ because parents often do not notice that they are struggling. These siblings will often do well at school, help out at home and try to excel at everything so that their parents don’t have to worry about them. “Yet it is important to realise that these siblings could often crash at any moment” (A. M, personal communication, 25 November 2021).

Siblings who externalise their emotions often become too absorbed in their emotions and express them very strongly. These children are often labelled by parents as the ‘annoying or difficult child’ because they often display behavioural difficulties (A. M, personal communication, 25 November 2021). However, the origin of this behaviour must also be considered with these children; perhaps they find it difficult to accept that their brother or sister is receiving more attention.

In addition to the negative effects, the positive effects were also mentioned during the interviews. All the siblings indicated that they felt they were less likely to be prejudiced against someone because of their own situation, and that they had a higher degree of maturity and independence.

5.2.2 Parents

Parents can also find it difficult to accept that their child needs intensive care. The interviews showed that parents often wonder whether they have done something wrong, and whether it is their fault that their child has a disability or illness. The situation not only changes the lives of the siblings, but also the lives of the parents. They are usually aware that they give less attention to their other children, but often feel that they simply do not have enough time to give both children enough attention. The relationship between parents is also very much put to the test by having a child with a disability or illness. Not all relationships are strong enough to deal with this. The interviews also indicated that parents often do not know that there is something wrong with their other child because they are often so focused on the sick or disabled child. Therefore, it would be helpful for parents if siblings could express how they feel in a clear way.

5.2.3 Experts

Experts indicate that many siblings often seek help too late, when they are already depressed. The initiative to seek help usually has to come from the sibling’s environment. In the case of siblings of children with cancer, it often happens that after the treatment or when their brother or sister has been declared cured, they fall into a black hole because they no longer must look after someone. They suddenly have to take control of their own lives again and put themselves first, which is very difficult

(A. B, personal communication, 29 October 2021). Siblings of chronic patients are especially in need of help when things get too much for them. This usually happens when they reach puberty and have to start looking for themselves. It is important for caregivers or parents to make it clear from the start that they are not alone, and that they can go to a care provider if they need it. Open communication towards the sibling is very important, but for parents it is often difficult. Some of them de problematize the disability or illness, while others problematise the situation and make it worse than it is (M. P, personal communication, 25 November 2021). It is very important for siblings to understand why their brother or sister needs more attention.

It is very important that there is sufficient support for siblings to prevent problems later in life. Because it is a difficult topic to talk about, it is important that it can be approached in a light-hearted way so that it is not too heavy (M. P, personal communication, 25 November 2021). This is still something that we miss at the moment" (A. M, personal communication, 25 November 2021). Children must learn from an early age that it is okay to feel how they feel and to express themselves.

6 CONCLUSIONS

It can be concluded that having a brother or sister with a disability or illness has a huge impact on the life of the sibling. Daring to ask for help appears to be one of the greatest difficulties for these siblings because they often don't want to burden their parents, therefore it is important to explicitly indicate to siblings that help is available for them so that they do not have to ask for it themselves. Each sibling lives in his own unique situation and each sibling reacts differently to the situation they find themselves in. However, it can be concluded that despite these unique situations, their needs are often similar. The main corresponding needs are as follows: correct and sufficient information, acknowledgement, adequate attention, meeting other siblings, to be heard and dealing with it lightly.

Designers could have a great impact for these siblings. There is a great opportunity in designing products that can support siblings of children who need intensive care in expressing their feelings and emotions. Through the use of these products, children can learn at an early age that it is okay to feel how they feel and to express their emotions. The use of these products can reduce mental problems and overload in the long term. As for the limitations of this study, conclusions are drawn from a small population. To be more representative, more siblings as well as experts should be interviewed. The siblings that were interviewed were also adults, this is also something important to keep in mind.

REFERENCES

[1] Sidhu S. (2019) The importance of siblings. Available from: *https://hsc.unm.edu/news/news/the-importance- or-siblings.html* [Accessed 2021, 15 December].

[2] Campens F. (2011) Master's thesis Freeke Campens. Available at: *https://libstore.ugent.be/fulltxt/RUG01/001/893/796/RUG01-001893796_2012_0001_AC.pdf* [Accessed 2021, 9 December].

[3] Moyson T. (2005). And now... Brussels time. Available at: *Oikonde News Bruges* [Accessed 2021, 8 December].

[4] van Dijken A. *Brothers and Sisters* book, 2, 2013.

[5] Bakker R. and Bootsma J. (2018) Educational support for sick pupils Caring about, caring for.... The pupil with a sick sibling.

[6] Poppe L., et al. (2010) Brothers and sisters (bruses) of persons with intellectual disabilities: an exploration of some salient themes, VLAAMS TIJDSCHRIFT VOOR ORTHOPEDAGOGIE. [Preprint]. Available at: *https://lib.ugent.be/catalog/pug01:1169313* [Accessed 2021, 13 December].

[7] Moyson, T. (2011) "Quality of life of siblings of children with disabilities." Available at: *http://hdl.handle.net/1854/LU-2083255* [Accessed 2021, 12 December].

[8] Moyson T. and Roeyers H. (2012) The overall quality of my life as a sibling is okay, but of course it can always be better. Quality of life of siblings of children with intellectual disabilities: The siblings' perspectives, *Journal of Intellectual Disability Research*, 56(1), pp. 87-101. doi:10.1111/j.1365-2788.2011.01393.x.

[9] Vision Paper, B. (2018) Towards fully family-centred child.

DIGITAL KNOWLEDGE TRANSFER FOR ADDITIVE MANUFACTURING USING BLENDED LEARNING

Sebastian KUSCHMITZ[1], Lukas Valentin HOPPE[2], Paul Christoph GEMBARSKI[2], Roland LACHMAYER[2] and Thomas VIETOR[1]
[1]Technische Universität Braunschweig, Institute of Engineering Design, Germany
[2]Leibniz Universität Hannover, Institute of Product Development, Germany

ABSTRACT
Additive manufacturing (AM) processes provide new levels of design freedom during product development as a result of the layer-by-layer build-up process, so that graded lattice structures, internal cooling channels, or other geometrically distinctive design features are taken into account at an early stage of product development. In addition, these complex geometric features can be realized without significant additional effort during the additive manufacturing process while complying with the restrictions of AM. The "Design for additive manufacturing" research field is trying to offer methods and tools to support the product developer in exploiting the AM potentials and to maintain compliance with the restrictions of the manufacturing process to be able to apply these design freedoms in a targeted and benefit-oriented manner during product development. However, due to a lack of AM knowledge and limited software solutions, the application of these methods and tools is not always possible, because necessary AM knowledge is partial or even completely missing. For this reason, teaching and learning offers are needed that systematically impart specific AM knowledge so that these barriers in product development can be overcome. In this paper, the systematic knowledge acquisition for specific AM knowledge is presented using the example of interactive teaching and learning offers. For this purpose, the basics of systematic knowledge transfer for AM will be discussed first to show the state of research. This is followed by the presentation of the interactive learning environment, which makes AM-relevant topics experienceable utilizing interactive 3D models. Finally, a validation of the presented learning environment for the transfer of specific AM knowledge is presented.

Keywords: Additive manufacturing, blended learning, design for additive manufacturing, AM-knowledge, interactive learning environment

1 INTRODUCTION
Additive manufacturing processes provide the users with new levels of design freedom during part design and product development in general. The reason for this is the layer by layer build principle which is applied during additive manufacturing and thus provides users with unique design potentials which, in addition to the realization of undercuts, the manufacturing of distinctive bionic structures, also enable the manufacturing of lattice structures without significant additional effort during the manufacturing process. [1–4] In research, some potentials of additive manufacturing processes have already been identified, so the possibilities of this manufacturing process are also increasingly known in companies. [1,2] However, the exploitation of the potentials is a major challenge for designers and product developers, because necessary knowledge is not sufficiently available, or prior knowledge is required for interpretation. As a result, to exploit and consider AM potentials during part design, users need basic experience in additive manufacturing processes to apply a variety of available methods and tools. [5,6]. In addition to the potentials, the restrictions of the process must also be taken into account for robust and reproducible manufacturing, otherwise, the correct and error-free manufacturing of the parts cannot be guaranteed. [1,2] Due to this, the research field Design for additive Manufacturing tries to develop and prepare methods and tools to support product developers to ensure a systematic knowledge transfer for additive manufacturing [7–14]. Additionally, the methods and tools should also be used in the context of academic education to impart AM knowledge and competencies to engineering students during their education.

This paper presents the knowledge acquisition for specific AM knowledge using the example of interactive teaching and learning offers for the application of infill structures and the implementation of different lattice structures. For this purpose, first, the basics of design for additive manufacturing concerning systematic knowledge transfer are presented, and in the following the acquisition and preparation of specific AM knowledge is explained. This is followed by the presentation of the interactive learning environment for blended learning methods, which makes digital content tangible with the aid of 3D models, and a brief validation of the presented learning environment for the transfer of specific AM knowledge. Finally, a summary and a conclusion are given.

2 DESIGNS FOR ADDITIVE MANUFACTURING

The Design for Additive Manufacturing research field develops methods and tools that support the methodical design process on an ongoing and phase-by-phase basis and provides tools for the identification, application, and implementation of AM potentials while taking process-specific restrictions into account. [2,4,7]

In the DfAM context, one focus is currently on how AM design potentials and process-specific restrictions can be taken into account in the idea and conception phase of the general product development process [2,3]. For this purpose, different solution proposals were developed within the research field, which supports during product development and consist of design rules, checklists with indications of AM potentials, AM-specific knowledge bases [8,15,16] or additional tools like the systematic network of AM design potentials [3] or the matrix of conflicting AM potentials [17] exist. In addition, the empowerment of users is also increasingly in focus, because the possibilities of additive manufacturing as well as the benefit-oriented application of the design potentials can only be realized with the help of benefit- and goal-oriented procedures or instructions. Consequently, the preparation of specific AM knowledge and the development of training and teaching concepts are the focus of current research. [4,5]

In summary, it can be stated that in the research field of design for additive manufacturing, various tools and methods have been developed to support product developers for the benefit-oriented application of AM potentials, so that assistance is available for users with varying application possibilities. Some of these tools have even been implemented digitally, such as the interactive Semantic network of AM design potentials according to Kumke [2], but the majority of the available tools have not been implemented digitally and are available as principle cards, design rules, and process models in analog form. For the systematic knowledge transfer of the benefit-oriented application of AM potentials, significantly more interactive and digital teaching and learning tools should be available, since these, especially in times of corona pandemic and home office, convey the content in a guided manner and thus have significantly less potential for the incorrect application.

In the following, the elaborated tools are explained concerning infill structures as well as the implementation and realization of different lattice structures utilizing additive manufacturing processes.

3 INTERACTIVE TOOLS FOR THE TRANSFER OF AM KNOWLEDGE

Digital and interactive learning tools offer both students and professionals non-linear access to information and are also accessible regardless of time and location. In addition to flexibility, interactive learning environments allow users to learn a topic area at their own pace, adapted to their prior knowledge and subjective level of expertise. Furthermore, alternative learning strategies such as collaborative learning or blended learning methods can be applied, and areas such as lifelong learning and further acquisition of learning material are greatly facilitated. Especially in the context of blended learning, hybrid models are occasionally used in universities, where lectures and interactive tools are used cooperatively in teaching. In order for the interactive tools to be used in a benefit-oriented and targeted manner in teaching, certain prerequisites must be met. [2,15,18]

Besides the methodological aspects, which also have to be chosen sensibly in the context of interactive teaching, there are special requirements for the user interface, the provided preceding and subsequent knowledge as well as for the implementation possibilities of the tools. The preceding and subsequent knowledge must be explicitly adapted to the contents of the lecture and must be designed to be complementary. In this way, animated and interactive 3D models can be visualized and digitally experienced in the area of design theory. The user interface must be designed to be self-explanatory and intuitive so that all functionalities are apparent and easy to understand.

As a result, a homepage was designed within the scope of the studies that provides various interactive courses and tools as well as specific knowledge by means of a learning management system (LMS). Fig. 1 shows the schematic structure of the knowledge system and visualizes exemplarily the access to the contents. Accordingly, the knowledge system has a navigation and access bar to access specific topics. It also identifies the representation area that provides opportunistic and restrictive AM knowledge. In addition, the knowledge system includes lessons on different additive manufacturing topics to learn specific topics through self-study. Users are guided by the LMS and use interactive visualization tools on additive manufacturing processes as well as short videos, texts, or self-tests to consolidate what they have learned and to receive feedback. The focus of the knowledge preparation was on a comprehensible communication of the potentials and limitations of additive manufacturing processes, especially for lattice and infill structures.

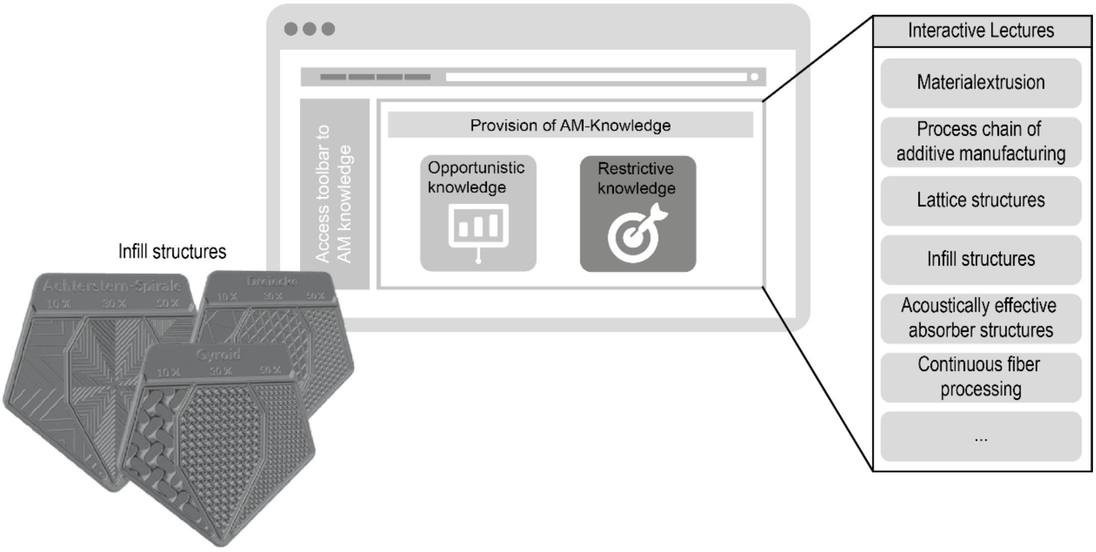


Figure 1. Schematic representation of the Interactive Knowledge System for imparting AM knowledge

The core element of the interactive tools of the knowledge system are varying 3D visualizations of specific AM potentials. In the context of this work, these are different lattice and infill structures that function as visual objects and are intended to convey necessary AM knowledge with the help of additional information. The structure of the interactive digital tools is designed in such a way that, on the one hand, the 3D geometry can be virtually experienced and examined. On the other hand, helpful information and further references are made available directly in the digital tool. Specifically, 3D models are prepared with the help of Web-GL plug-ins and thus made virtually usable. For this reason, the user interface allows users to rotate and resize the geometry data and to obtain further information using descriptions, highlights, or selectable buttons. Taking the infill structures as an example, users can switch between the different infill tiles and thus directly see the geometric shape in terms of form and infill density. In addition, geometry parameters are available that represent the 3D printed part with the selected infill type.

Figure 2 shows different infill structures that can be experienced as part of interactive models in the knowledge system. These infill plates show the name of the infill structure at the top and represent the geometric shape with varying infill densities in the panels below. It can be seen that increasing the infill density leads to smaller geometric features of the structures and thus the infill structure as such becomes more compact.

In the context of the virtual lessons, users have access to various topics which, in addition to basic knowledge of additive manufacturing processes, also include more specific topics such as the benefit-oriented application of AM potentials. In this way, for example, the application and implementation of differently shaped lattice structures can be learned and applied. The structure of the lessons is based on best practices, starting with a short introduction to the subject area, increasing the specificity of the topic and making the content more complex. For this purpose, explanatory videos and descriptive texts are provided to convey the topic as simply and effectively as possible. For better understanding, the topics are also included in the interactive knowledge elements, so that this knowledge should also be conveyed

interactively. Self-tests are available to check the level of knowledge or to monitor the success of the learning objectives, giving users an overview of what they have learned.
By using digital tools, digital data can be prepared interactively and enhanced with the help of additional information that can be retrieved. This possibility offers great potential for independent continuing education, as the methods and workshops can be designed with the help of digital tools in such a way that knowledge carriers do not necessarily have to be present so that the transfer of knowledge can also be sensibly carried out through self-study. The digital tools support this approach immensely and thus also help to improve and promote lifelong learning sustainably.

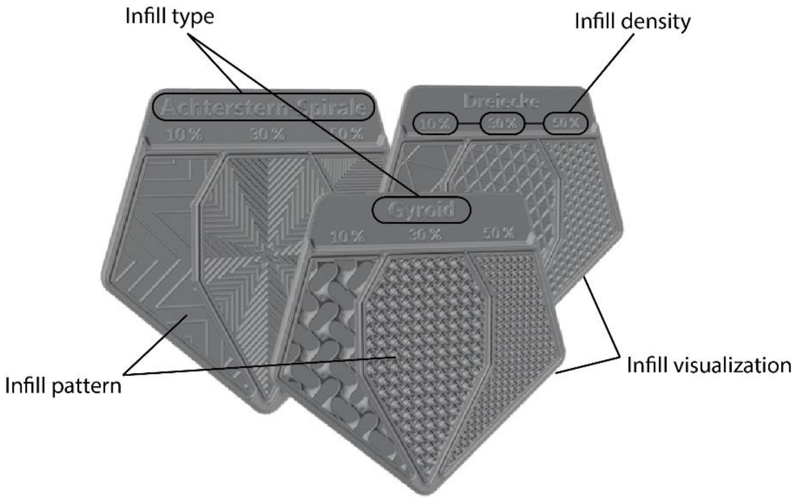


Figure 2. Selected infill tiles for visualization of infill structures and infill densities

4 APPLICATION AND VALIDATION OF DIGITAL LEARNING TOOLS

Systematic knowledge transfer for additive manufacturing is currently often realized with the help of workshops or by providing analog tools and methods. This type of knowledge transfer is possible, but the unguided provision of the tools and methods does not give product developers any guidance on how to use the tools during product development, which also prevents corrective measures. As a result, Digital Tools for Knowledge Transfer offer good opportunities to enable a structured transfer of the acquired knowledge. Blended learning methods are particularly interesting in this context, i.e., approaches to link virtual, digital learning tools with classic learning offerings. In addition, the virtual learning environments, at least in the example presented here, can also be produced as physical objects, making hybrid learning possible.
To evaluate the developed knowledge system, the interactive lessons on infill and lattice structures were made available to students in a workshop format as part of the course "Computer Aided Design". In this way, the useful application, functionalities and usability are to be reviewed and a comparison between digital and analog teaching is to be made possible. The structure of the workshop is divided into a basic introduction to the topic of additive manufacturing processes, so that rudimentary knowledge is available. However, this introduction could also be realized with the help of digital tools. This was followed by a brief presentation of the knowledge system and an introduction to the design task. The students had the task to ensure a benefit-oriented application of the AM potentials and to select suitable grid structures in the context of the topology optimization. For this purpose, a large number of potential lattice structures were available for selection with the tools provided, whose advantages and disadvantages as well as mechanical properties can be displayed with the help of the interactive environments via the geometry and other information. Thus, in this case, the knowledge system served to impart knowledge about specific characteristic values and application scenarios for the corresponding lattice structures. In addition, the students also had the task of preparing additive manufacturing for a given geometry whose application purpose was described. In order to ensure successful manufacturing as well as reasonable usability of the component, a suitable infill structure should be identified that allows material savings while still meeting the mechanical requirements of the component. Fig. 3. shows a selection of illustrative objects that represent different lattice structures and are examined in more detail within the interactive lessons.

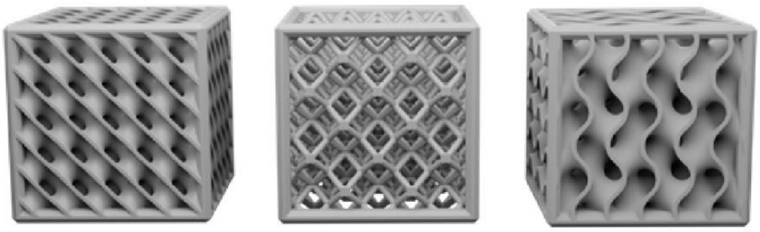


Figure 3. Selected lattice structure cubes for visualization of different lattice structures

The workshop was conducted with 14 participants who first completed the interactive lessons on infill and lattice structures to build up necessary knowledge. Subsequently, the students worked on the design task without further instructions. It was found that necessary information was available and thus initial results could be generated quickly. The selection of suitable lattice structures was well done by the participants and almost all subjects were able to identify useful structures. Also, the selection of suitable infill structures could be done without problems by the workshop participants. The use and application of the knowledge system succeeded intuitively for the workshop participants and did not pose any challenge. As a result, the interactive lessons provided a good opportunity for students to acquire specific knowledge using virtual learning methods. The workshop and the application of the knowledge system fulfilled the expectations and could show that with the help of interactive tools a time and location independent teaching by means of BL methods is possible. Especially the self-tests are in this context a good learning target control for the students to get individual feedback, which normally rarely happens at universities.

5 CONCLUSIONS

Within the scope of this work, an interactive knowledge system for teaching AM potentials using the example of infill and lattice structures was developed. The core element of this knowledge system is formed by virtual and interactive lessons, which are supposed to convey specific AM knowledge. For this purpose, explanatory videos, descriptive texts and interactive geometric data visualizations are used to provide further information on the respective topics interactively. In addition, self-tests are used to provide the users with a learning success control.

Through the use it could be determined that the use of digital learning offers a significantly higher flexibility for the users and still offers specific advantages in terms of guiding the users through the content as well as a profitable interaction with the knowledge to be imparted. In the context of additive manufacturing processes, interactive tools can be used to make visual objects available via the Internet in a cost-effective and straightforward manner, so that 3D printing results can be made available even without a manufacturing facility. The sensible and user-oriented integration of digital and interactive learning offers in workshop concepts and other classic offline learning offers represents a key factor for the targeted and efficient application of these learning offers and was applied in rudimentary form in the context of this contribution. It could be determined that the different offer formats require explicit coordination with each other to achieve the highest possible compatibility as well as a coherent concept. The use of digital learning offers based on Web-GL plug-ins provides the user with a good and uncomplicated possibility to experience the 3D models and to obtain further information.

As a result, the created learning environments offer a good added value to the user when it comes to obtaining information on specific AM knowledge. However, for the systematic transfer of knowledge for AM, these digital learning offers must be implemented in fully comprehensive workshop concepts or use cases, so that a specific development problem is present along the product development process and thus parallels specific development problems in the own company become apparent. In this way, the specific knowledge transfer methods for specific AM knowledge can be combined with real process knowledge for additive manufacturing, and the added value is significantly increased. However, the usability of the interactive tool should still function as a stand-alone tool and thus only address a specific problem or potential during the use of AM. In addition, a combination of digital tools is possible without further. Furthermore, a significantly larger group of test persons should be used for the evaluation of the tools and the entire concept, so that the opinions are more expressive and meaningful extensions and optimizations can be incorporated into this project based on the feedback.

REFERENCES

[1] Gebhardt A. Additive Fertigungsverfahren: Additive Manufacturing und 3D-Drucken für Prototyping - Tooling - Produktion. 5th ed. München: Hanser; Ciando; 2016.

[2] Kumke M. Methodisches Konstruieren von additiv gefertigten Bauteilen. Wiesbaden: Springer Fachmedien Wiesbaden; 2018.

[3] Kumke M, Watschke H, Vietor T. A new methodological framework for design for additive manufacturing. *Virtual and Physical Prototyping* 2016;11(1):3–19. https://doi.org/10.1080/17452759.2016.1139377.

[4] Watschke H. Methodisches Konstruieren für Multi-Material-Bauweisen hergestellt mittels Materialextrusion: Universitätsbibliothek Braunschweig; 2019.

[5] Schumacher F., Watschke H., Kuschmitz S. and Vietor T. Goal Oriented Provision of Design Principles for Additive Manufacturing to Support Conceptual Design. *Proc. Int. Conf. Eng. Des.* 2019;1(1):749–58. https://doi.org/10.1017/dsi.2019.79.

[6] Wegner A. and Witt G. Konstruktionsregeln für das Laser-Sintern. Zeitschrift Kunststofftechnik (WAK) 2012;2012(3):252–77.

[7] Adam G. A. O. and Zimmer D. On design for additive manufacturing: evaluating geometrical limitations. *Rapid Prototyping Journal* 2015;21(6):662–70. https://doi.org/10.1108/RPJ-06-2013-0060.

[8] Bin Maidin S., Campbell I. and Pei E. Development of a design feature database to support design for additive manufacturing. *Assembly Automation* 2012;32(3):235–44. https://doi.org/10.1108/01445151211244375.

[9] Ehlers T., Tatzko S., Wallaschek J. and Lachmayer R. Design of particle dampers for additive manufacturing. *Additive Manufacturing* 2021; 38:101752. https://doi.org/10.1016/j.addma.2020.101752.

[10] Gibson I., Rosen D. and Stucker B. *Additive Manufacturing Technologies*. New York, NY: Springer New York; 2015.

[11] Glasschroeder J., Prager E. and Zaeh M. F. Powder-bed-based 3D-printing of function integrated parts. *Rapid Prototyping Journal* 2015;21(2):207–15. https://doi.org/10.1108/RPJ-12-2014-0172.

[12] Lachmayer R., Gembarski P. C., Gottwald P. and Lippert R. B. The Potential of Product Customization Using Technologies of Additive Manufacturing. In: Bellemare J, Carrier S, Nielsen K, Piller FT, editors. *Managing Complexity*. Cham: Springer International Publishing; 2017, p. 71–81.

[13] Marjanović D., Štorga M., Pavković N., Bojčetić N. and Škec S. (eds.). *DESIGN 2016: Proceedings of the DESIGN 2016 14th International Design Conference*. Zagreb: Fac. of Mechanical Engineering and Naval Architecture Univ; 2016.

[14] Rosen D. W. Computer-Aided Design for Additive Manufacturing of Cellular Structures. *Computer-Aided Design and Applications* 2007;4(5):585–94. https://doi.org/10.1080/16864360.2007.10738493.

[15] Kuschmitz S., Watschke H., Schumacher F. and Vietor T. Bereitstellung von Lösungsprinzipien für die additive Fertigung zur Unterstützung der Bauteilkonzeption in der industriellen Praxis. In: Kynast M, Eichmann M, Witt G, editors. *Rapid.Tech + FabCon 3.D International Hub for Additive Manufacturing: Exhibition + Conference + Networking*. München: Carl Hanser Verlag GmbH & Co. KG; 2019, p. 75–88.

[16] Weiss F., Binz H. and Roth D. Approach to consider Rapid Manufacturing in the early phases of product development. In: Weber C, editor. *Design for life.* Glasgow: Design Society; 2015, p. 1–10.

[17] Fuchs D., Kuschmitz S., Kühlke K. and Vietor T. Identifikation von Zielkonflikten bei der Anwendung von Potenzialen additiver Fertigungsverfahren. In: Lachmayer R, Rettschlag K, Kaierle S, editors. *Konstruktion für die Additive Fertigung* 2019. Berlin, Heidelberg: Springer Berlin Heidelberg; 2020, p. 223–244.

[18] Plappert S., Hoppe L., Gembarski P. C. and Lachmayer R. Application of Knowledge-Based Engineering for Teaching Design Knowledge to Design Students. *Proc. Des. Soc.: Des. Conf.* 2020; 1:1795–804. https://doi.org/10.1017/dsd.2020.300.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

THE BEST OF TIMES, THE WORST OF TIMES; STUDENT DESIGN TEAM FORMATION

Juan RUIZ and Renee WEVER
Division of Product Realisation, IEI department, Linköping University, Sweden

ABSTRACT

In design education, challenge-based approaches where students work on real industry problems are becoming increasingly common. Such education relies heavily on teamwork. Consequently, this requires educators to form teams that can deliver the desired outcome while fomenting learning and collaboration among teammates.

Most of the literature on team formation in design education is focused on larger cohorts, of dozens or hundreds of students, where slackers or free riders are a major concern. In the present study, we focus on team formation within smaller cohorts, of pre-selected, highly motivated students. We use two global networks of collaborating universities teaching design thinking. In each project, a multidisciplinary group of three to five students from one university is teamed up with a similar group of students from a second university along with a corporate sponsor that provides the challenge.

We selected teaching team members from participant universities to interview about their practices regarding team formation. Both the interviewees themselves and their institutions had multi-year experience in forming multiple teams out of a group of pre-selected students. We interviewed 6 teaching team members (from 5 universities) for about an hour each. The interviews were recorded, transcribed, and analysed, to contrast their practices to each other as well as to theory. Practices range from a half-day session to a multi-week warm-up period prior to the proper course.

Our findings are that current practices have evolved through trial and error over time and are only partially grounded in theory on team formation.

Keywords: Team formation, challenge-based learning, design thinking, design education

1 INTRODUCTION

Higher education institutions have long adopted collaborative teaching methods where students work in teams towards a common educational objective, both because of the benefits it presents to the students learning process and to educate professionals that go on to be capable of collaborating with other professionals in working environments. Among these collaborative teaching methods used in design and engineering schools, challenge-based approaches have gained popularity [1] given not only the possibility that students have to collaborate towards a common learning objective but also towards the resolution of a real-world problem.

For all the benefits presented by challenge-based teaching/learning approach it does come with its fair share of difficulties. Any student who has participated in education tasks where they are teamed-up with other students has struggled with the difficulties of collaborating with others. To paraphrase Charles Dickens (1859), working in student teams can be the best of times and it can also be the worst of times. Well-constructed teams, where skills and capabilities are well distributed, and where there is a good chemistry between teammates can enhance both the learning objectives as well as allowing the production of innovative solutions to the proposed challenges. While a poorly constructed student team might on the other hand lead to in-fighting within the team, different levels of production and commitment or the team deciding to partition the work without collaboration with one another.

1.1 Challenge-based projects and team formation

An example of this kind of challenge-based design and engineering education approach are two international networks in which students from different global universities work, in student teams, on product design and development projects. One around Stanford University and their ME310 course and one global network of more than 25 different universities around the world called the SUGAR Network.

In each project, a multi-disciplinary group of 3 to 5 students from one university is teamed up with a similar multi-disciplinary group of 3 to 5 students from a second university along with a corporate sponsor that provides a challenge. Over the course of roughly 9 months these global teams work on researching the problem space, re-framing their challenge, and producing prototypes of design concepts. The challenge for the teaching teams, is to be able to form multiple cohesive teams out of a pre-selected group of highly motivated students that apply to participate in the course. In forming diverse and cohesive teams, teaching teams members assess and use multiple variables or criteria about the students with different degrees of control to form the teams. Among them are skill & background variables, personality & behavior variables, and diversity variables. However, there are also other sets of variables that are outside of the individual teaching teams' control that can also play a role into the forming of teams, such variables can be related to the partner universities teams, as different collaboration might require different skills and other variables can be introduced by the corporate sponsor.
To be able to cope with the challenge of forming these teams, teaching teams have developed their own methods for team formation. These methods have been honed by multiple years of experiential learning [2], small scale experimentation of trial and error and the usage of different theoretical approaches from different fields of study (management, design, psychology, decision making, etc.).

2 TEAM FORMATION BACKGROUND & APPROACHES

2.1 Forming teams

The extant literature describes criteria that could be taken into consideration, how to best recognize-spot-diagnose said characteristics in individuals, and which configuration of these characteristics is more desirable. The first factor, which criteria to consider, shows reasonable unanimity in the literature on educational team formation. While professional skills and expertise remain important, personality and behavioural skills are among the more important elements. Characteristics such as communication skills, effective interaction, project management skills, self-efficacy, autonomy, positive interdependency, among others have a great effect on the team’s ability to properly function [e.g., 2, 3, 4]. As to the last two, how to recognize the criteria and how to utilize them, we can find more dispersion in methods and results.

2.2 Approaches to team formation

When trying to answer the questions of how to recognize the desired criteria in students and how to utilize it to form teams, literature offers a plethora of methods and approaches. Some teachers use randomization or self-selection of teams, but these approaches have been shown to be less effective [3]. Besides those are the purposeful methods and approaches to team formation that attempt to measure certain criteria. These use either of two methods, ***self-assessment,*** and ***observer-assessment***.
Self-assessment methods are based on the use of tools where the participants reply to a series of questions and based on the answers certain criteria can be determined. We can find emphasis in the literature on team formation on these types of methods [3 - 8]. Among these types of approaches the most commonly used are Five Big personality factors, Myers-Briggs Type Indicators (MBTI) and other derivations from MBTI such as Wilde’s Teamology. Self-assessment methods rely heavily on the answers provided by the participants. However, issues arise with regards to the validity of the results obtained, based on possible misrepresentation, self-deception, or purposeful lying [10 - 12]. Secondly, it is not uncommon to find that in groups of students from a similar background there is more possibility for homogenous results on the personality constructs to appear [5]. Thirdly, the use of tools for cognitive and behavioural attribute identification, does not measure compatibility and effective interaction between participants which is shown to be significant in team performance [4, 13]. Finally, for the most well-known method, Myers-Briggs, questions of validity and empirical grounding have been raised [e.g., 14].
Alternatively, though less commonly studied in literature, there are observer-assessment methods. These methods are based on the use of activities designed to reveal behaviours and skills of the students thought practical exercises and interactions with others. During the execution of these activities a teacher observes the participates to attempt to recognize the desired criteria [e.g., 4, 9]. Such methods are among the most utilized in project-based/challenge-based engineering and design education, and the subject of this paper.

3 METHOLOGY AND DATA COLLECTION

To better understand the process of team formation in design and engineering project-based education a group of 6 teachers from 5 different universities, that each participates in the previously mentioned SUGAR Network, were interviewed. All interviewees had multiple years of experience in forming teams of students that participated in the network. The number of students assessed by the different teaching teams at each university ranged from 15 students to 100 students per year and the number of teams created ranged from 2 to 10 teams per university per year.

3.1 Data collection

We used semi-structured interviews with the different teaching teams. Each interview had an average duration of 60 minutes, and during the interview, the participant was asked to recount and explain the process that they follow during their team formation process. Our semi-structured interview protocol covered three main areas of interest. The first related to the activities used by the teaching teams in the process of team formation and how these activities were executed. The second related to the different criteria (behaviours and skills) being observed during the different activities. Finally, the third area related to the process used to create teams using the observed criteria in the different activities.

In the final part of the interview the participates were also asked to reflect on their own process beyond the simple execution. This led to conversations of evolution of their team formation process through the years and their own reflection and evaluation of their team formation process.

3.2 Data analysis

All interviews were conducted digitally, given the different geolocation of the participants, and recorded for analysing purposes. These recording where transcribed and a qualitative analysis software was used to process them. They were codified into the three areas of interest in order to contrast the practices at each university to each other as well as to the existing team formation theory. Furthermore, this codification also allowed to encounter recurring themes in their practices that help to better understand observer-rating based team formation processes and how they differentiate from self-rating team formation tools. These themes were: (1) Practitioner's expertise (2) Small-scale experimentation; and (3) learning from experiences.

4 FINDINGS

4.1 Contrasted practices

Initially teaching teams that were interviewed were deemed to have observer-assessment methods as their primary method for team formation. However, after the interviews took place, it was revealed that most of the teaching teams utilized mixed methods that combined the use of activities that integrated self-assessment as a guide for skills and behaviours to be explored/checked later in observer-assessment based activities. Below we present a contrast between the different teaching teams in three key areas; the activities they use in their team formation process, the criteria used to characterize the participating students, and finally how they use said criteria to form teams.

4.1.1 Activities

In the interview process each teaching team was asked to recount their process for team formation. Each teaching team had a particular set of activities that they use that differ in the particular from each other, however, most had a very similar aim and rational behind them. Most processes began with an application/selection process that was also used as an initial point for recognitions of attitudes and behaviours from candidates. These early moments of the team formation process helped to map a priori assumptions of the students' possible skills and behaviours. Typical activities used by the teacher during this stage were CVs, application letters, psychological questionnaires, and interviews of the candidates. Following the initial mapping of the students and their skills and behaviours, some of the teaching teams went on a stage of 'corroboration' of those initial findings. Teaching teams then explain that in this second stage some specially designed activities in which the students engaged in the resolutions of a task that required the use of typical skills needed during the projects were used. These tasks were normally oriented towards the resolution of design tasks with different levels of complexity and time. Tasks such as redesigning an existing object, building of prototypes for specific users or the use of a common task called 'The paperbike challenge', known to all teaching teams of the SUGAR Network are used. While the students performed these tasks the teachers engaged in deep observation of behaviours and interactions among the students and then these observations were used in a final step of team creation. Following these stages teachers then moved to the final team forming activity/deliberation, which in all cases did not include the student's participation any further. In some cases, the process would be comprised of multiple activities that spanned several months while others used a couple activities over one day.

4.1.2 Criteria

From the interviews it was observed that the teaching teams distinguished three different types of criteria and that each type equally informed the final creation of teams. The three types are (1) professional and practical skills, (2) behavioural and personality and (3) interactions with others.

The projects in which the students participate, are commonly guided by the type of challenge that the sponsoring organization provides. Different challenges require very different skills. These lead to the first group of criteria, professional and practical skills. These types of criteria were more commonly evaluated by activities which require the student to self-report them, such as CV's or cover letters. However, in case of available third-party observations, such as past teachers' assessment of those skills where highly valuable. Following this first set of criteria, the next two groups related more to behavior and personality traits that the participating students exhibited and how they interacted with others. These two sets of criteria, as described during the interviews, played a crucial role in how teams are formed and how they perform. Teachers argued that in many cases, these criteria had a bigger impact on their decision making. Teachers discussed during interviews, that in order to recognize and identify behaviours and interactions, observer-assessment such as interviews, design challenges and one-on-one interactions were preferable. These types of activities provided teachers the opportunity to, early in the process, recognize possible dysfunctional pairings of students and avoid them while creating teams.

4.1.3 Creation of teams

The final step of the team formation process is to actually compose the teams. During the interviews it was noted that the final process of team creation followed a very similar pattern in almost all interviewed teaching teams. Here it is quite important to note, that so far, we have been using the term teaching teams rather than only teachers. Almost all of the interviewed programs in the different universities, where comprised by a group of teachers that participated in the team formation activities and that contributed to the final creation of the teams. The proceeding activity that was described during the interview process was often described as a conversation or deliberation between teaching team members to compare and contrast findings and observations during the assessment activities. In some cases, this conversation was described as a validation of common agreement. In other cases, it served to bring to the table cases where further discussion was needed, if discrepancies between observations existed.

4.2 Thematic Analysis

The thematic analysis was intended to showcase the underlying behaviours that teaching teams seemed to be displaying, that were either implicit or purposeful on their team formation behaviour. The themes were selected for their relevance to team formation from the observer-assessment approach and the role of this observers in the process. The themes are here presented in no particular order.

4.2.1 Practitioners' expertise

The interviewees had in common multiple years of experience teaching multidisciplinary design/engineering projects in which they had been forming teams of students. These many years of experience translate into a vast repertoire of lessons learned and development of skills that allow them to better recognize characteristics in students. The many years of building a library of past projects and students assessed helps them to develop expertise that is then used in the team formation activities.

The projects for which these group of teachers build teams is by its own nature highly ambiguous and complex type of projects. During the interviews, teacher repeatedly mentioned the importance of balancing multiple important factors that need to take into consideration. Yet typically these factors are not always clear or known before teams need to be formed.

"You've seen their CV, you've seen teamwork [activities], you did the interview, you know a bit about the person, but you don't really know it all. But then when it comes to team forming, to the final forming,

it's kind of a mess, because you don't have all the information… You really try to put together all of these layers but in the end of the day, it's the experience that drives [the decisions]".

4.2.2 Small-scale experimentation

As part of the student projects *themselves*, small scale experiments or prototypes are widely used as a tool for problem exploration and resolution. Students build prototypes that then are tested in real or simulated environments that then are used as learning points to inform the next steps of the process. Similar approaches are embraced by the teaching teams when forming teams of students. During the interviews, teachers made references to the use of small-scale experiments in their process for identifying skills and behaviours in the participants and for corroborating possible team constellations.

As previously explained in section 4.1.1, teachers commonly used specially designated tasks to help reveal skills, behaviours and attitudes from the students that would help inform their process of team creation. These activities were also commonly used for prototyping of possible student grouping. Teachers expressed that these team prototypes would then yield learnings about team dynamics and interactions between the students. The learnings from these prototypes are then not only used to test possible constellations but also to gain further knowledge on the behaviour of each individual participant.

"We have more or less an idea of what teams we want, from the initial interviews and the CVs with cover letters that the students have submitted. But typically, we have some doubts in between putting this or that students together, or how certain students will behave when we put them together. So, we then go into the practical exercises, and we start moving students around in the different tasks to see if our assumptions where right"

Some examples of these tests were: (1) groupings of individuals of the same background to eliminate skill advantage on solving the tasks. (2) Students were grouped with others of similar personalities, such as multiple strong leaders in one group, with the intention of revealing how their attitudes and behaviours changed. (3) Teams that had already shown to work well, were given difficult or ambiguous tasks, and then examined on how they dealt with more adverse situations.

4.2.3 Learning from experiences

The final theme that was found from the interviews with the teaching teams related to the evaluation, learning and modification of the process through experiential [2] means rather than formal ones. During the final part of the interviews, teachers were asked about how they reflect, evaluate, and improve their team formation process. From this, it was found that none of them have implemented any intentional or formal reflective process to specifically converse about the process and possible improvements. However, while recounting how their own process has evolved through time, it was often commented that negative experiences, shortcomings from team/class performance or informal and "serendipitous" conversations with other teachers drove decisions to change specific parts of the process.

"I felt more that when we travelled there was a nice, uhm, serendipity about conversations that I would have with [other teachers]. Things like, why did this person behave like this or acted like that? Or did we miss something as a teaching team?"

Additionally, teachers reflected that as they gain experience from participating in team formation processes through many years, their observation skills are honed and changed by observations and decision that they have made in the past.

"Sometimes, you start to see that the people are not behaving like you thought they would, things like a person who you though were a quiet and shy person just takes charge of the team in bad moments. Other times, we have had [students] who presented themselves as very calm and easy going becoming very conflictive and you didn't expect it at all, so it kind of blows up in your face. From cases like that you start to think of things that you may have missed [in the activities] and that helps you see them better in the future" .

5 DISCUSSION AND CONCLUSIONS

As any coach of a sports team knows, the combination of the best individual players does not necessarily make for the best team. Hence, approaches including assessments of team composition have the most potential. In that context, observer-assessment methods provide a deeper understanding of the students and their characteristics which leads to more informed team formation. However, they also present disadvantages to the team formation efforts. They require more time and heavily depend on the abilities of the observer to properly recognize characteristics. Hence, combinations of self-rating and observer-based methods may remain the preferred means of forming teams, as it allows the teaching teams to spot behaviours and skills with self-rating tools and then corroborate thought interactions between students for mismatches that could have been hidden by the participants in the self-rating measuring assignment. Furthermore, in cases where small trials through small assignments and trial team configurations, allows teaching team members to not only observe said behaviours but to also test them with different combination of possible grouping of students.

Our findings show that current practices within the studied design thinking network have evolved over time through trial and error and are only partially grounded in theory on team formation. However, for as far as post-project evaluations on the success or failure of formed teams have been done, they show only limited correlation to how well assessment practices aligned with team formation theory (unjustified success, unexplained fighting). Thus, providing directions for improvement both regarding theoretical understanding of student design team formation as well as for practical assessment sessions.

REFERENCES

[1] Adams S. and Okudan G. E. (2003, July). A comprehensive model for student design team formation and performance in the engineering classroom. In *Proceedings of International Conference on Engineering Education, July* (pp. 21-25).

[2] March J. G. (2010). *The ambiguities of experience*. Cornell University Press.

[3] Estes A., Nuttall, B., Nelson PE J., McDonald M. and Starzyk JD, G. F. (2013). Interdisciplinary design-Forming and evaluating teams. In *2013 ASEE Proceedings* (pp. 23-800).

[4] Potosky D. and Duck J. M. (2007). Forming teams for classroom projects. In *Developments in Business Simulation and Experiential Learning: Proc. of the Annual ABSEL conference* (Vol. 34).

[5] Kress G. L. and Schar M. (2012). Teamology–the art and science of design team formation. In *Design thinking research* (pp. 189-209). Springer, Berlin, Heidelberg.

[6] McClough A. C. and Rogelberg S. G. (2003). Selection in teams: An exploration of the teamwork knowledge, skills, and ability test. *International Journal of Selection and Assessment*, 11(1).

[7] Wilde D. J. (2009). *Teamology: the construction and organization of effective teams (*Vol. 3). London: Springer.

[8] Rodríguez Montequín V., Mesa Fernández J. M., Balsera J. V. and García Nieto A. (2013). Using MBTI for the success assessment of engineering teams in project-based learning. *International journal of technology and design education*, 23(4), 1127-1146.

[9] Luojus S., Kauppinen S., Lahti J. and Tähtinen L. (2017). Forming multidisciplinary master's degree student teams by means of gamification case: *The WeLive design game.*

[10] Holden R. R. and Hibbs N. (1995). Incremental validity of response latencies for detecting fakers on a personality test. *Journal of Research in personality*, 29(3), 362-372.

[11] Paulhus D. L. (1986). Self-deception and impression management in test responses. In *Personality assessment via questionnaires* (pp. 143-165). Springer, Berlin, Heidelberg.

[12] Mount M. K., Barrick M. R. and Strauss J. P. (1994). Validity of observer ratings of the big five personality factors. *Journal of Applied Psychology*, 79(2), 272.

[13] Bergey P. and King M. (2014). Team machine: A decision support system for team formation. *Decision Sciences Journal of Innovative Education*, 12(2), 109-130.

[14] Stein R. and Swan A. B. (2019). Evaluating the validity of Myers-Briggs Type Indicator theory: A teaching tool and window into intuitive psychology. *Social and Personality Psychology Compass*, 13(2), e12434.

SOFT SYSTEMS AND AGILE METHODOLOGIES IN THE SUCCESSFUL DEFINITION OF ACTIVITIES FOR DESIGN ACADEMIC PROJECTS IN TECNOLOGICO DE MONTERREY ABSTRACT

Carlos GONZALEZ-ALMAGUER, Edgar BARBOSA, Claudia ZUBIETA, Carlos GOMEZ, Natalia FRIAS, Rebeca LUGO, Rebeca SUAREZ and Miguel ROCHA
Tecnologico de Monterrey, Mexico

ABSTRACT
Soft systems methodologies are an excellent method for defining activities in traditional project management, such as story design and tasks in agile methodologies. Through a survey applied to former students of industrial engineering, who are working in the industry or on their own business, it is inferred that the main cause of projects is that not finishing in time and exceeding the budget, is an incomplete definition of the project activities. Wilson's Maltese Cross, Checkland's soft systems, as well as other methodologies, allow to define the problem and understand clearly who the project stakeholders are, as well as the definition of the project team, with which the detailed definition of all activities increases the probability of finishing on time. The present work shows the research to reduce the project time and increase the success probability of project management through a dynamic methodology that allows successful management of both, traditional and agile projects.
In the Tec21 educational model, students must solve challenges in a period of 5 weeks, which is the central part of the mentioned model. It has been observed that emphasising managing their projects with a systemic perspective, has reduced preparation times as well as stress, resulting in an increase in the stability of the students as well as the quality of their projects.

Keywords: Soft systems methodology, project management, innovative education, agile methodologies

1 INTRODUCTION
One of the most common questions asked by professionals who manage projects is why do projects fail? The answer has been analysed in various studies by universities, institutes, and professionals in the area. First, failure must be defined as a deviation between what was planned versus what was executed, and these can be categorised in four dimensions: time, budget, quality. and the objective. In a survey applied to former students, students, and professionals involved in project management between August 2021 and January 2022, 57.1% of respondents indicate how time changes in project management, 28.6% objectives, and 14.3% quality. pointing out that the main cause is mainly due to the presence of "blank spaces" which causes delays and cost overruns in projects, according to Dr Márquez (2020) [1] blank spaces are vital activities that are not considered in the planning part, and they have poor communication between team members. In universities, it is common for teachers to ask students for projects in almost all subjects, most of the time in teams.
In the TEC21 educational model, the element is the challenge, and it is resolved with the development of disciplinary and transversal competencies. The challenge is resolved with an academic project that is elaborated within a training unit, lasting 5 weeks, (Institute for the Future of Education 2020) [2], the challenge has three pillars, students, teachers and training partner, which in project management language can be considered as the stakeholders, the international finance corporation (2019) [3] document this model in a case study where the challenge (project) is the centre part of the learning process. Establishing a methodology, whether traditional or agile, to plan, control, manage and document the project is not practical in an educational model, due to the diversity of the type of challenges as well as the training partners, which is the main motivation for proposing the design of an academic project management methodology adapting simple systems methodologies, traditional and agile project management models.

2 DEVELOPMENTS

Currently, the results are often not as expected, because the project does not solve the challenge or problem posed or the approach is not correct, students tend to confuse symptoms with problems, for which they acquire what they in the academy of industrial engineering we call it the hamster syndrome, that is to say, that students enter a continuous cycle of trial and error without being able to advance by specifying results, which has repercussions on the emotional health of the students, appreciating a high level of stress due to finishing projects on time, as well as frustration at not achieving the expected results. At this point, other soft problems can be seen, such as the stability of the workgroup, which does not meet the expectations of being a high-performance team.

Soft systems methodologies have been promoted since 1976 by Checkland (1989) [4], in the applied survey 57.1% know it and of them only 42.9% would use it, although they state they know that they are tools focused on problems that are not (soft systems) and provides various works that allow, in the first place, to describe the problematic situation through the CATWOE of Joham and Metcalfe (2009) [5]. In the CATWOE we identify the client (C), the actors (A), the transformation (T), how the world is seen (W), the owner of the project (O), and finally the environment (E). Following each phase of CATWOE reduces the risk of defining the problem incorrectly. Already with this essential definition, the next step is to elaborate a first level Rich Picture (Rich Picture First Level) in which it is reflected, just as our ancestors did in cave paintings and artists of different times in murals, already whether in buildings or church the situation that is experienced at that moment, the Rich picture is very useful because it's descriptive power, allowing exploring the observer explain the problematic situation (Jardino et al.,2020) [6]. From the RPFL, participatory intervention techniques must be introduced, among them, the technique of nominal groups, which are the basis for identifying and defining the problem. Figure 1.

Because the pillar of the training unit is the challenge and this entails establishing a relationship with training partners (Stakeholders), the participation model between students and training partner must be designed, a TWCA (Two Way Commitment Agreement) where the communication system and the periodicity of the work meetings, visits to the company as well as the confidentiality and treatment of the information. This allows the problematic situation to be drafted and this can be used to define the problem together with the training partner.

One of the most common mistakes of teachers is that we emphasise disciplinary strategies and methodologies for the success of the projects, but we leave aside the transversal competencies. In this phase zero of the project, it is necessary to transform work groups into high-performance teams, providing students with learning activities based on the concept of the value of the team that professor and captain Roberto Sylvester has taught in classes [7] and the introduction of 4 types of thoughts that guide students from the zero phases to the closure of the project and they are:

- Concurrent - Seek to carry out simultaneous activities and reduce linear activities as much as possible.
- Prospective - Define an activity as a process and think about who, how, and what the output will be.
- Systemic - All activities are related to achieving the project.
- Resilient - Maintain cohesion as a team in the face of adversity, delays, and changes.

The next step is to develop the system, which in its essential definition is a set of interrelated elements to achieve a common goal, at this point we propose some innovations and adaptations to the system models, including identifying the departments by colours, as well same as the channels of information flow between each element of the system are represented by arrows that connect them. This part of the system has as the main characteristic that it is internal, where the owner has control of the elements, this is represented by delimiting with dotted lines. On the other hand, the external part is those elements in which there is no control, but they affect the system and are outside the internal part but delimited by a box (frame) that represents norms, laws, and any type of restriction to the system.

A project is created to solve a problem, the methodologies for its solution begin mostly with "Define", but there is a little-explored previous step, the description of the problematic situation, where the abstraction of reality is defined, to later define the problem. The definition begins from a process of searching for the root cause, and different methodologies can be used. In our research, it is proposed to use the model of Kepner and Tragoe (1981) [8] based on answering four key questions: What? When? Where? Extension?

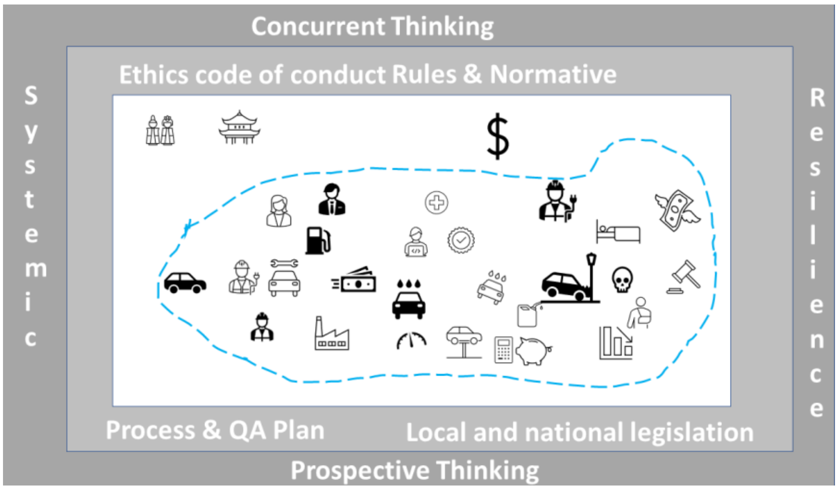


Figure 1. Rich Picture First Level

When the problem is defined, an ideation process begins, in which we use, among others, the methodology designed by González, Saavedra, Lule, Barbosa, Zubieta & Caballero (2021) [9] which merges Design Thinking (DT) with the Design of Experiments (DOE) as well as Engineering Thought (IT) by González & Feijoo [10] to find solutions that can range from simple to innovative and disruptive. If we consider the solution proposal as the project that solves the challenge. The next step is to identify the activities to implement a said solution, it is necessary to conceptualise the system as a model of information flow, for which the use of the Maltese Cross methodology designed by Dr Bryan Wison (1980) [11] is proposed, Espejo and Reyes (2011) [12] explain that this Maltese Cross can be used in a variety of engineering tools to align implementation, organisational and information processes in an organisation, as a continuous process.

In the second phase of the proposal, the systemic map is made, interconnecting the most important elements of the project that can be inferred from the Rich Picture, in this part an ideation exercise based on brainstorming is proposed to generate all the activities that entail the project, this ideation must be structured under the theory of nominal groups to ensure that all the actors or representatives of departments or organisations are present in the design.

When the required activities are finished, they are analysed through the ISM (interpretive structural modelling) methodology to first vote and stay with the most important ones to have the precedence figure. The result of this exercise is usually the milestones.

The definition of project activities is a logical consequence of the definition of the product and the processes that must be carried out for the construction of the studies that make up the project. It is in this part where systems engineering, prospective thinking, and concurrent engineering work to build the project management activities. One of the big mistakes is to generate very general activities, without a clear objective and that does not have to define the person in charge of it or the characteristics and specifications that the activity that precedes it requires; In the same way, the practicality of having activities defined in a general way causes critical activities to be exposed to ambiguity and control over them is lost.

To avoid this ambiguity, systemic maps are used to represent all the activities, their predecessors, as well as those responsible for carrying them out following a systemic thinking approach, that is, never losing the connectivity or the multidisciplinary approach between them. The next step will be to define the specifications of each activity and the document or process that performs them, using the information systems methodology of Wilson (1980) [11] and the systems thinking of Checkland (1993) [13] adapting a representation of the activities, Wilson proposes to map the information through the Maltese Cross, which on the west side (O) or negative x receives the information, on the positive y side (N) represents the activities, the negative y-axis (S) represents the method, document or process in which the information is found, so the information inputs intersect with the activities and their environment, when there is a transformation, new information represented on the axis is released x positive (E) which in turn is delivered to its predecessor through a document, process or file, thus generating a very precise control of the project.

It is important to note that more than one entry of information can affect activity, so it must be defined, we can also call these deliverables of the previous activities, which must be defined according to the characteristics and design elaborated by the owner of the activity that requires them for its process. The importance of the negative or south “Y” axis is notable since it defines the procedure for processing the information and under what format it will be sent to the activity that is requiring it.

The next step is to make a systemic map, identifying the internal system that are the studies that make up the project and that can be controlled by those responsible, and the external systems that are not controllable but that affect our project due to the interaction of vital activities. that due to their dependency can cause failure at a certain moment by not having it identified or proposing the mechanisms to be able to interact successfully with them. In the construction of the systemic map, it is suggested to differentiate the departments or entities with colours to map their activities and be easily identifiable, in this way we can correlate the precedence of information between the different work teams, the internal system is delimited through a line dotted and external systems are outside of it. A vision is proposed to design the system based on project management (Figure 3), the systemic approach, the standards for product development, and eco-design. This model is the foundation for the construction of the Gantt chart, a tool that will allow, through project management, to manage that the activities are completed on time, with the quality and specifications required concurrently and prospectively.

Phase 2 is the administration of the project, through the Maltese Cross we define the activities at the first level, with the systemic map we ensure that they are all interconnected, now it is very easy to identify the resources and predecessors for each activity, the Time calculation is done through PERT, to develop probabilistic models that allow us to reduce the probability of exceeding the planned time and budget.

In traditional methodologies, the guidelines dictated by the PMBok for project management should be followed, but it is at this point that we can merge the agile methodologies proposed by Dr Rocha (2021) [14] who mentions that the success of a project with complex problems, maybe due to the establishment of a continuous cycle of delivery of value to the client, prioritising the needs and interaction with the client, to create high-value products. A work dynamic must be established with constant interaction with the client to achieve a complete understanding of the situation and define the objectives, activities, deliverables, and scope of the project. Obtaining customer and student satisfaction.

Agile methodologies in the project management model make great sense in phase 0, which is the definition of the project. In a survey applied to 350 students, we found that 87% of them mention that it is not easy to understand the theoretical concepts of the projects. soft systems, according to Kumar, Hale & Hale [15], agile methodologies cause the application of the theory to be fast and disruptive by encouraging students to innovate in the phases of ideation and collaborative work, which in our methodology is reflected using online tools to reflect and contextualise the problematic situation and finally in simplified matrices to be able to define the problem. With the agile approach, the Maltese Cross is the most useful tool, but while students consider it more time-consuming and complicated, it becomes easy to implement to define project activities with all predecessors and resources correctly identified.

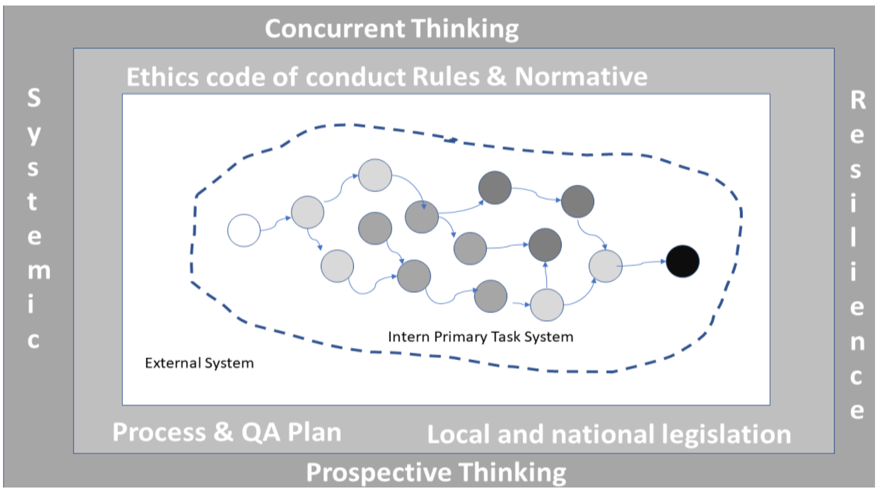


Figure 2. Systemic Map. Own source

3 RESULTS

A research protocol was designed based on the comparison of two training blocks, the IN2004 in which the students elaborated their challenge "freely" against the IN2006 block in which the students followed the methodology presented in this paper. For both training units, the null hypothesis was defined that the grades were statistically similar, so the methodology in student learning was not significant, and the alternative that was significant. If the difference was positive, we could conclude that the methodology is significant in learning. The variable of learning interest was analysed by comparing the grades obtained in the challenges. In both blocks there were the same students and the same teachers, but the method to develop the project changed. 16 teams were evaluated for the population corresponding to IN2004, the average was 84/100 points, while for IN2006 it was of 90.31. Making a comparison of two means with Student's T, we found that the acceptance zone was from -0.9054 to 0.9054, and the result of to was -1.38, with which the method proposed to elaborate the project that solves the challenge is significant.

For the variable of interest, ease of use by the student and reduction of stress (emotional stability) in the student, a survey was applied to the 62 students who took both courses with the following results, for the question. Do you consider that the methodologies of systems help define a problem effectively? 93.75 answered yes. Do you consider that thanks to the use of soft systems methodologies you were able to identify the problem to be solved in less time? 90.62 responded affirmatively, and finally for the question, Did the use of soft methodologies help you define, deliver the challenge/project on time and with quality during UF2006B? 84.36% answered yes. Therefore, our hypothesis of placing more emphasis on the definition of the problem through soft system methodologies to develop projects efficiently has been verified.

4 CONCLUSIONS

Soft systems methodologies are applied to undefined problems, including them in the project definition stage which allows reducing gaps in both time and budget. The activity definition part had already been implemented in school projects lasting one week with excellent results. Designing a project definition methodology that will help students deliver quality work in short periods has been a challenge, but now getting them to use it leads us to propose future work, such as an online platform or application; in order to allow students to make this essential part of the project more attractive, helped with the introduction of agile methodologies.

ACKNOWLEDGMENTS

The authors acknowledge the technical and financial support of the Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

REFERENCES

[1] Márquez L. A. (2020). Espacios en blanco. *Diseño e innovación de modelos de negocio*. Tecnológico de Monterrey. Available: https://es.coursera.org/learn/diseo-e-innovacin-de-modelo-de-negocios

[2] Observatory, IFE, World Bank shows worldwide Tecnológico de Monterrey's Educational Model Available:https://observatory.tec.mx/edu-news/world-bank-tec21-tec-de-monterrey-educational-model [Accessed on 2022, 10 February], (2020) 7 February.

[3] International Finance Corporation,World Bank Group,Case Study:Tec de Monterrey. Available: https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/education/publications/tec+de+monterrey [Accessed on 2022, May 10], (2019) December.

[4] Checkland P. B. (1989). Soft systems methodology. *Human systems management*, *8*(4), 273-289.

[5] Joham C., Metcalfe M. and Sastrowardoyo S. (2009). Project conceptualisation using pragmatic methods. International Journal of Project Management, 27(8), 787-794.

[6] Jerardino-Wiesenborn B., Paucar-Caceres A. and Ochoa-Arias A. (2020). *A Conceptual Framework Based on Maturana's Ontology of the Observer to Explore the Checkland's Soft Systems Methodology*. Systemic Practice and Action Research, 33(5), 579–597. https://0-doi-org.biblioteca-ils.tec.mx/10.1007/s11213-019-09502-y.

[7] Notinor, Aprendiendo liderazgo con un aviador héroe de Malvinas Available:https://notinor.com/jujuy/aprendiendo-liderazgo-con-un-experiencia-de-vida-extraordinaria/ [Accessed on 2022, 25 February], (2015) 29 June.
[8] Kepner C. H. and Tregoe B. B. (1981). The new rational manager.
[9] Gonzalez Almaguer C. A., Caballero Montes E., Acuña López A., Zubieta Ramírez C., Saavedra Gastelum V., Barbosa Saucedo E. A. and Lule Salinas M. (2021). Design Thinking and Design of Experiments: The Fusion of the School of Design and Industrial Engineering to Create Learning Experiences in the Tec21 Educational Model, In DS 110: *Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021), VIA Design*, VIA University in Herning, Denmark. 9th-10th September 2021.
[10] Gonzalez Almaguer C. A., Feijoo H, Manriquez J, Dias A. C. and Grullon L. Methodology Focus for the Elaboration of Social Development Projects in Marginal Areas in Mexico Based on Industrial Engineering Technics. 19th International Congress on Project Management and Engineering Granada, 15-17th July 2015.
[11] Wilson B. (1980). The Maltese cross-a tool for information systems analysis and design.
[12] Espejo R. and Reyes A. (2011*). Organizational systems: Managing complexity with the viable system model*. Springer Berlin Heidelberg.
[13] Checkland P. (1993). Systems science. In Systems Science (pp. 7-10). Springer, Boston, MA.
[14] Rocha M., Barbosa E. and Gonzalez C. (2021). Agile Management for Industrial Engineering Capstone Projects – Overcoming the COVID 19 challenge. *Proceedings of the International Conference on Industrial Engineering and Operations Management*. Monterrey, Mexico, November 3-5, 2021.
[15] Kakar A. K., Hale J. and Hale D. Teaching Theories Underlying Agile Systems Development (2012). Proceedings of the 2012 AIS SIGED: IAIM International Conference on Information Systems Education and Research. 6. https://aisel.aisnet.org/siged2012/6

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

STRATEGY TO LINK AND DEVELOP SENIOR DESIGN STUDENT'S PROJECTS WITH LOCAL INDUSTRY

Mariano GARCÍA[1], Rodrigo CHAVEZ[1] and Alejandro ACUÑA[2]
[1]Architecture, Art and Design School, Tecnologico de Monterrey, Mexico
[2]Architecture, Art and Design School, Institute for the Future of Education, Tecnologico de Monterrey, Mexico

ABSTRACT
Professional Insertion Project is a subject considered as "Design Study" of the ninth and last semester of the degree in Industrial Design of the 2011 and 2017 programme (valid until 2023) at the Tecnologico de Monterrey Campus Querétaro. It is executed as a Capstone Project and its objective is to integrate into the process of designing products, services and experiences, management skills, negotiation and professional connection with companies in the local industry for the student [1].
Even though in 2020 the state of Querétaro was ranked # 8 at national level for the development of its manufacturing industry, the work of a product designer is not very widespread and understood, unlike other countries, where the relationship between designers and companies is highly integrated and, in most cases, very profitable. That is why, and with the aim of increasing the employability of our graduates, we have designed a strategy for linking with local companies and spreading the relevance and value of design in their economic development, generating medium and long-term projects in which the company, the university and our students interact.

Keywords: Capstone project, educational innovation, design entrepreneurship, design for value, design study project

1 INTRODUCTION
In many national and international universities, Capstone Projects are used to place students in the final stage of their training, closer to the reality of the professional world, very different from the academic environment [2]. Since 2011, in Querétaro Campus, this course has offered students the opportunity to develop their Professional Insertion Project in three modalities:
a) Designing for a real client, whom we call "Training Partner" assigned by the institution.
b) Designing for a real client attracted by the students in an area of their interest.
c) Designing for a personal entrepreneurship project. Incorporated since August 2018 and usually started in some other subject during student's bachelor's degree.
Throughout these 10 years, we have improved the selection of projects to guide those from the first conception towards their successful development, always supported by the design process structured by the professors of the Industrial Design Programme of Campus Querétaro (Figure 1). This process has allowed us to identify the correct starting point, effective communication with companies and thereby ensure that students complete their project in a period of 16 weeks, (the equivalent of an academic semester) through which the students' graduation skills will be evaluated.
We have applied this model with very good results in the course of Professional Insertion Project at the Querétaro Campus, but it has also helped us to standardise the design process for lower-level Design Studies subjects and to standardise communication with students, professors, and companies with which we have developed linkage projects.
The objective of this article is to disseminate the work of these years of application and constant adjustments that are described below.

2 METHODOLOGIES

The Professional Insertion Project class has been taught under a Capstone Projects scheme. Lack of official definition but understood as a course related with a training partner in a real project, from a client or company. This course is the last of the Design Studio sequence and it's expected that the students develop autonomy in decision-making, project manager skills and reach the highest level of quality, complexity, and specification in their university studies in industrial design [3].

2.1 Roles involved in the strategy

In addition to the students, there are three main actors who are an important part of monitoring and guaranteeing the objectives:

1.- Professors of the Professional Insertion Project course, who are in charge of advising the students and providing the concepts that accompany them step by step during the development and management of the project. Using as an example the situations that arise with the training partners to relate them to the theoretical and practical contents of the course.

2.- Academic Linkage Coordinator (A.L.C.) which depends on the Academic Liaison Office (A.L.O.) and serves as contact with the training partners and who accompanies the students, monitoring the fulfilment of objectives, times and deliverables that guarantee the success of the project.

3.- Training Partner. The company is our client. It is responsible for providing the problem to be solved, managing the information and economic resources to guarantee the execution of the project. It is also responsible for providing feedback to the students.

2.2 Attraction of projects

One of the tasks that has represented the most effort is the attraction of projects, which come to the course in three main ways:

1.- Thanks to the prestige that Tecnologico de Monterrey has in the city of Querétaro and because it has no cost for companies, training partners candidates approach the institution through the Academic Liaison Office (A.L.O.) and present a document in which they must fill out the following data: sector to which the company belongs, size in number of employees, name, description and objectives of the project, and the hours that calculated the student will have to invest per week for its development.

The A.L.O. has an Academic Linkage Coordinator (A.L.C.) for each school in campus and is responsible for receiving and analysing requests from companies to evaluate which programme the project can be assigned to. The Schools at Tecnologico de Monterrey are Architecture, Art and Design, Social Sciences and Government, Humanities and Education, Engineering and Sciences, Medicine and Health Sciences and Business. Once this first analysis is done, the A.L.C. approaches the teachers of the subjects who have previously declared that they want to develop a linked project. If the academic achievements and the expectations of the training partner coincide, the project is assigned to the requesting course.

2.- The students propose the project they want to develop for a company or institution. This strategy develops in student's skills to promote their own work as well as the benefits that design brings to companies.

3.- The students propose a project as an entrepreneurial initiative. Many of the students want to start with their own project and take advantage of the course to develop the initiative, design and business. To do this, students must prepare the same application document that is required of external companies. It is important to mention that to support the students, the Design Department hires one or two external consultants, recommended by the Business School to accompany the students to structure the project and validate its financial and performance feasibility.

2.3 Selection of projects

Although there is no typology required for the projects to be developed in the course, we have detected some constants to accept them, in addition to having filled out the application document, the projects are expected to comply with:

1 Have a well-defined problem, need or opportunity and declare the intention to develop or manufacture it in the future.
2 Have, at least in a preliminary way, research of the market and the context.
3 Every project must have available resources, in more than one of the following areas:

a) Human capital. Have a project leader with the necessary knowledge and decision power. b) Money allocated for the development of models and prototypes. c) Materials and manufacturing processes available in the company that guarantees the future production of the proposal. d) Time. It must be a design opportunity to be developed in a maximum time of 16 weeks. The training partners must dedicate approximately 2 hours per week, to review the progress of the students.

2.4 Assignment of projects

The pre-selected companies are invited to a virtual meeting with the professors and the A.L.C., to present the project and verbally explain the resources they have for its development and where professors resolve any question. In this interview which works as a second selection filter, teachers can feel the company's commitment, explaining the agenda, policies, and academic scopes. In case that professors identify that the project meets all the previously described requirements, we ask the training partners to present their project to the students, during the second-class session of the semester, where the students will be able to select the project, they will develop during the semester. The first-class session of the semester is dedicated to explaining the syllabus and the guidelines of the class. The students do not have knowledge of the available projects yet, except those who have submitted the request to develop an entrepreneurship project or have been invited to a company. For the second session, professors and the A.L.C. organise all the selected companies to present their projects. Before the presentations, the teachers point out to the students that it is a unique opportunity to receive all the clients at the same time, and that it is very important that they ask the questions they consider completing the design brief.

All students see all the presentations and answer a format online, selecting their 3 or 4 favourites, arranging them according to their preference. After class, teachers analyse the students' responses and, according to their preferences, organise the teams. Although the type of projects varies, we have opted to do projects in teams of two students. This allows us to guarantee that the two members will be involved in the project and reduces the possibility that only one does the work, this due to the amount of work that this represents. Once the projects are assigned, the students are informed of this assignment, so that they can immediately start with the first stage of the design process, which consists of identifying the problem or need to solve, starting the project with a first meeting and interview with the company or training partner. It is in this session where students begin to fill out what the A.L.O. calls "Technical Proposal" that works as a contract between the team and the company. In this document the project, objectives, scopes, resources, and important dates to be met are defined. This document is compiled by the students and signed by the companies, the students, the Academic Liaison Coordinator, and the professors involved in the project. The A.L.C. is responsible for gathering the documentation from all the teams. When the above requirements are met, ask them to sign a contract and confidentiality agreement that formalises the relationship. Although throughout the semester the contact is directly between the students and company. The A.L.C. supports them in case of having some difficulty in communicating or complying with the agreements.

2.5 Project development throughout the semester

The Department of Industrial Design of the TEC de Monterrey Campus Queretaro developed a Design Process that is used throughout the bachelor programme and that is suggested to all teachers of design-study courses.

Process has 6 general stages, that are the structure for the course:

GET READY, DIVE IN, ANALYSE-PRONOUNCE, CREATE-PROPOSE, DELIVER, and IMPLEMENT-EVALUATE. Throughout the semester there are two partial evaluations and a final one. In addition, professors use a rubric that is provided to students so that they can follow and complete each stage of the process. As all the projects are different, the challenge for each team is to be able to apply the process to the project and manage all the information to generate a design proposal that meets the requirements and expectations of the training partner and teachers (Figure 1).

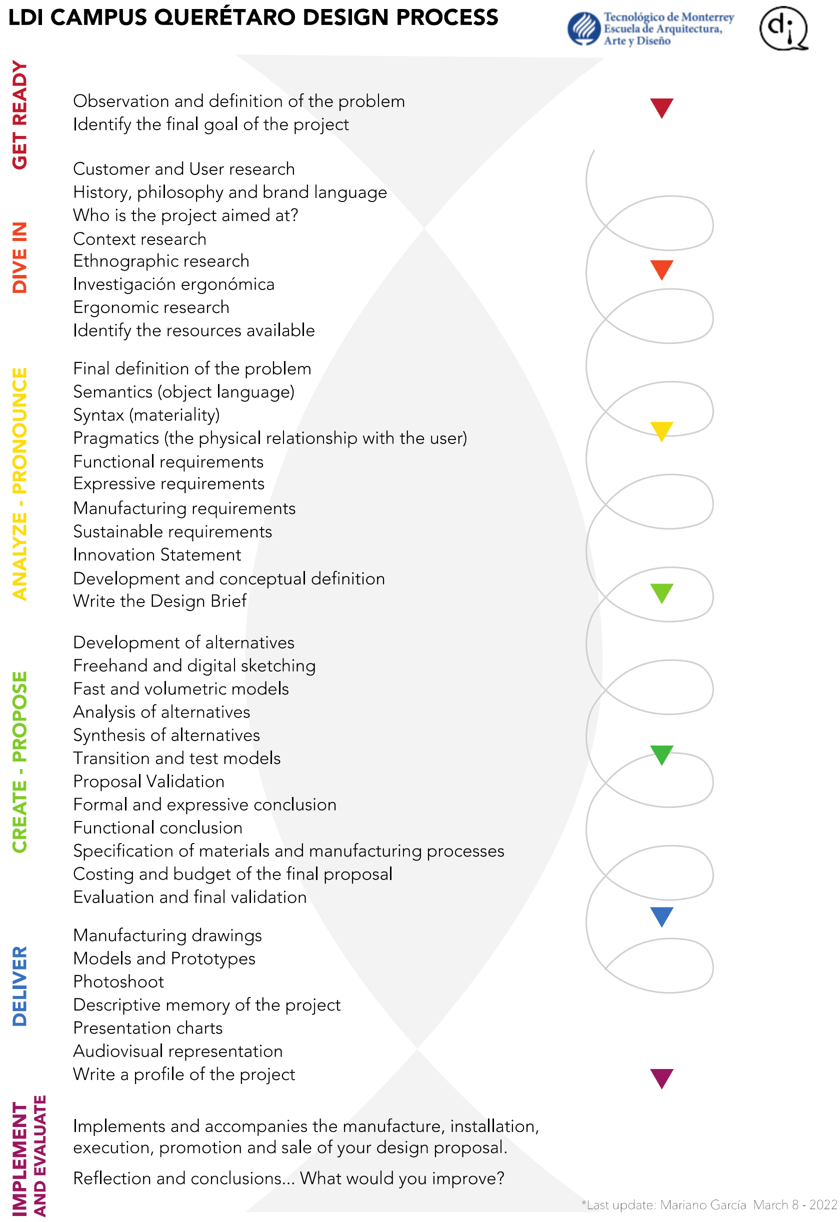


Figure 1. Industrial Design Campus Querétaro Design Process

2.6 Final delivery and presentation

At the end of the semester, all teams are expected to deliver a set of deliverables. Although each team uses their resources as they prefer, it is expected that the level of its execution will be as homogeneous as possible among all the teams. It is important to remember that in this final delivery all the competencies that an Industrial Designer must have to practice the profession properly are evaluated [4].

The first evaluation with the final proposal is made in the School of Architecture, Art and Design final exhibition (Expo-EAAD). In this exhibition of all the projects of the industrial design programme and the school, the quality of presentation and commitment is evaluated, in addition to being a reference for all the lower semesters students and external guests. The academic assessment is done in two presentations: 1.- Presentation to professors and professional guests. In this presentation, the teams present their design process and results in an open and direct way. Feedback is given to the teams so that they consider the comments and correct any detail of relevance. 2.- For the second presentation, which will be with the training partners and the A.L.C.

In both presentations, students present three deliverables. 1.- The process-book that contains the evidence of how each stage of the process was developed. 2.- A set of technical drawings that specify all the material characteristics and manufacturing processes of the product. 3.- The prototype of the design proposal, that is the tangible evidence of the solution. After this last presentation, the final evaluations are carried out by all those involved, and an average is taken to determine the final mark of each team [5].

3 DISCUSSIONS

During the years of the implementation of the strategy, we have had the opportunity to reflect on many aspects, and realise that our strategy begins to have a positive impact in students experience:
Having followed our design process as a working method during the semester and having given timely follow-up to each of the stages is seen in a positive perception of the course by the students. Where 0 is the worst and 5 is the best (Figure 2).

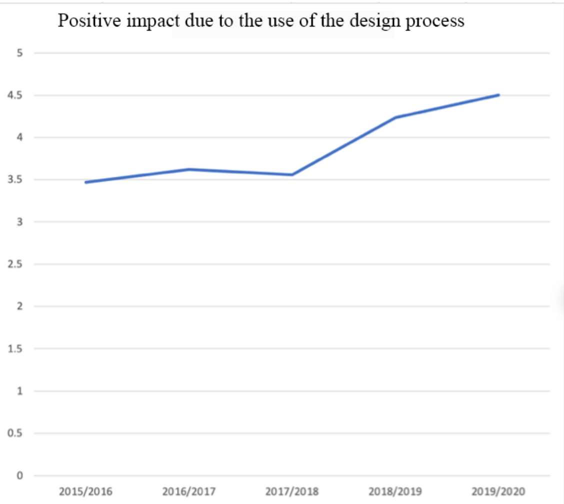


Figure 2. Positive impact due to the use of the design process

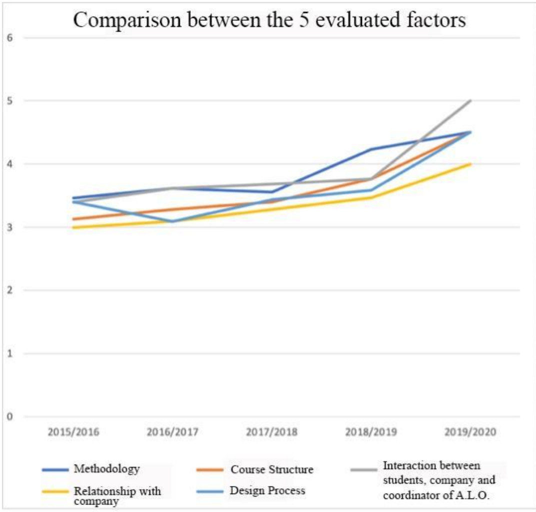


Figure 3. Comparison between the 5 evaluated factors

We have also noticed a positive increase in other factors aligned with following a clear design process, such as the relationship between students and the company, the structure of the course, and the communication achieved between students, the company, and the A.L.C. (Figure 3). Since the teachers have the interviews with the training partners, we have received more financial resources from the companies to produce models and prototypes.
Previously, for the final academic presentations, we brought together the professors and the training partners in the same session. However, approximately 5 years ago we decided to separate them, since we consider that it is better that the students first receive the teacher's comments, so they have the possibility of correcting any details for the presentation to the training partners a couple days later. Another reason for having separated the presentations is because we identified that students are more likely to receive comments from teachers without being pressured to make a good impression on clients.
Regarding the learning outcomes, according to the surveys collected by the A.L.O. among the students, we rescued some interesting comments:
"I like that these types of projects exist, since we can get used to the idea of what awaits us after graduating. This way we do not leave empty-handed and the fear of uncertainty of what it means to start working is reduced.", "Excellent learning to be able to negotiate and propose solutions to a real client.", "It's good that there exists this link between students and companies, their work creates a great impact on the experience of students and for companies it is an opportunity to interact with fresh ideas", "I think it is a very good programme to develop better skills in the field of real work. I am leaving with a lot of experience in the area and also with some areas of opportunity that I have to correct.", "A very interesting project, since it broadened my perspectives about what it is to work, through academic links,

the requirement was always essential for the development of the project, and the fact that there is a link with a company, means that as students commit ourselves to deliver and develop a quality project, to apply knowledge in the future and in our present."

We have realised that we can improve in:

The organisation of the teams, according to the personality profile of the students, not only to the declaration of their preferences, for which we will have to explore some way of identifying it.

It has been good to let the students take charge of establishing how often they meet with the training partner during the semester, and we have noticed that those teams that request more meetings tend to ramble longer and take a long time to make decisions, as opposed to those who use the more sporadic meetings to present the results of their decisions.

During these ten years, approximately 430 students have taken the course under this scheme, they have developed over 210 projects, requested by about 175 companies of various sizes in the city of Querétaro.

In the surveys that the A.L.O. applied to the training partners of the 10 semesters between August 2013 and May 2018, the following results were obtained:

93.4% of the companies declared that the project developed by our students was already being implemented or would be implemented in a maximum of 8 months. 99% of the companies responded that they are interested in developing another linking project.

35% declared "YES" to the question "Do you plan to hire a student who worked with you this period?".

These data show us the important gap that still exists between the very positive satisfaction shown at the end of the project and the lower possibility that our students will be hired at that time by the training partner. Among the reasons that mention why they would not hire them, they highlight; the lack of economic resources and that there are not available vacancies, however, they mention that the first step could be to hire them part-time, as outsourcing or as interns, and, when a vacancy opens, our students would be considered as the first option of hiring.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

REFERENCES

[1] *The Glossary of Education Reform. Capstone Project Definition*. Available: https://www.edglossary.org/capstone-project/ [Accessed on 2022, 12 March] (Year Created 2016/Update, 23 March).

[2] Alvarez-Fuentes M., Ortiz I. and García D. *Capstone Projects for Industrial Designers, a Model*. *Tecnológico de Monterrey Campus Querétaro*, 2015.

[3] Green L. N. and Bonollo E. *Studio-based teaching: History and advantages in the teaching of design. World Transactions on Engineering and Technology Education,* 2003, 2(2), 269–272.

[4] Casakin H. and Kreitler S. *Correspondences and Divergences between Teachers and Students in the Evaluation of Design Creativity in the Design Studio. Environment and Planning B: Planning and Design*, 2008. 35(4), 666-678.

[5] Everhart D., Sandeen C., Seymour D. and Yoshino K. *Clarifying Competency Based Education Terms: A Lexicon. Blackboard.* Available: http://bbbb.blackboard.com/Competency-based-education-definitions. [Accessed on 2022, 12 March].

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

UNMASKING BIASES IN DESIGN EDUCATION

Annemiek VAN BOEIJEN
Delft University of Technology, The Netherlands

ABSTRACT
This paper presents two master graduation design projects that address *unconscious biases* (UB) in the context of design education related to two topics: gender and skin colour. In addition to their sensitivity to exclusion and injustice, two design students brought in their analytical, design research and creativity skills to find solutions for design education. The projects revealed UB regarding the two topics of both teachers and students. The databases with examples from the real world and a poster campaign helped them to unlock these biases, and to understand that implications of prejudice are critical. The developed model, method, and guidelines provided them with lenses to discover biases, and also to have opportunities to find solutions by design. Evaluation of training material showed the need to have a language to talk about these sensitive topics in a nuanced way. Finally, these cases show the possibility of involving students in the development of curricula that strive to unmask biases.

Keywords: Biases, design education, diversity, inclusion, gender, skin tone, filter bubble

1 INTRODUCTION
Diversity, equity and inclusion have been a focus of attention in product design processes for decades, and today the attention for these themes is still relevant and even more compelling. Through the internet, migration and other developments that enhance globalization, awareness about the issue of exclusion increases rapidly. Social movements, such as 'Me too' and 'Black lives matters' influence the discourse at the same speed. The interest in the problem of exclusion in the current era is recognized by a large group of people and by our design students. Attention is shifting from exclusion due to physical barriers, such as in the design of public spaces that are, for example, unsuitable for wheelchair users, to interests in social and psychological barriers, such as minority groups that confronted with biased labour selection procedures or by AI driven apps that exclude user groups. This is reflected in an increasing attention in design education to not only physical ergonomics, but also to perceptual and cognitive ergonomics. Less attention is paid yet to social and emotional aspects of inclusion [1] and exclusion caused by unconscious biases (UB), that is the learned stereotypes that are natural, automatic, unintentional, and so deeply engrained that they can easily influence one’s behaviour [2]. Stored experiences – a.o. in education – in the human brain later influence behaviour and can trigger the conformation to harmful stereotypes [3]. Avoidance of UB is sought in teachers moderating the classroom culture, using psychological mechanisms, such as awareness, motivation, individuation, and empathy [3]. Focus is often on teachers and teaching activities such as grading and education material, and less on the content, in our cases design. This paper shows how design and design students could be actively involved in shaping open mind attitudes and possibilities for the reduction of UB. The context is a 1st year bachelor at a Dutch design school. It addresses the question: How can design education broaden design students’ views, increase their sensitivity for unconscious biases, and motivate them to find design solutions that overcome these biases? Answers are based on two cases, *master graduation projects*; 'One Size Fits Some' about unconscious biases regarding sex and gender [4]; and 'Beige by Default' about skin tone exclusion [5]. Both students are Dutch, the first raised in The Netherlands, and the 2nd in Curacao and with a dark skin herself. The projects were with self-initiated design goals, and each supervised by two Dutch academic staff members and with external parties that were consulted during the design process.

2 THE CASES – APPROACHES AND OUTCOMES
The author was part of both supervisory teams, which influence the objectivity of the work, though made it possible to monitor the projects in detail. The design process (including literature research, interviews with staff members and bachelor students, and evaluations), and (intermediate) findings from research

and design of both projects were extensively reported and presented in a poster and oral presentation (video). Below, the two cases are explained and with references to relevant literature.

2.1 **One Size Fits Some –** UB regarding sex and gender

A father is changing a diaper for his son in a public toilet, while squatting on the ground, because he is not allowed to use the baby facility in the ladies-room. A musician cannot play a music piece of Rachmaninov, because both the dimensions of the piano keys and the composed music (the chords) do not attune with the size of her hands [6]. A transgender person is confused when using icons in a smart phone. The icons represent gender stereotypes only [7]. A female user of voice recognition feels underserved, because her voice is less accurately processed by voice recognition software and artificial intelligence assistants, due to software trained on datasets in which women are underrepresented [8]. These are a few examples of designs that do not include considerations related to gender and sex. The consequence is that a large part of the potential users feels excluded. Assuming the examples are results of designers' unconscious biases, research has been done on how to prevent these biases. In her project Maartje van Proosdij collected and analysed a considerable number of products and services with functions and properties that exclude groups of people. Gendered Innovations [9] and Invisible Women [8] provided many examples. She developed a model, three lenses that help designers to overcome undesirable effects. One lens 'Associations' refers to the designer's own associations with and preconceptions about the related topic. Reflection and discussion with team members about first associations and presumptions about possible users and context of use should deconstruct prejudices. Another lens is 'Standards' and refers to norms and standards developed, for example, in the industry to increase efficiency, such as for car crash test dummies with dimensions based on data from a data base with anthropometric data of white male men. Current standards that might be relevant for the design project need to be identified and evaluated for their inclusiveness. The last lens is called 'Behaviour' and invites the designers to study current (public) opinions and behaviour of the targeted people. With the support of research methods such as interviews, observations, role play, personas and cultures, the context of intended users, their social roles and expectations need to be explored. This should provide a better understanding of the target group and helps to understand and predict possible excluding behaviour more accurately.

Furthermore, five semi-structured interviews in one-hour video calling sessions were conducted (recorded, transcribed and clustered). These were with the course coordinators (four male, one female) of five courses (related to design, technology, people, and organisation) under construction for a new bachelor curriculum. None of the courses considered the influence of gender and sex explicitly. The course coordinators seemed already overwhelmed with content that needed to be addressed in their course. '*During the interviews nearly all course coordinators voiced beliefs that could be considered gender biased. Many of these beliefs were related to how male and female students, were in essence different. For example, it was said that girls are better at planning, and boys are better in taking control over a project, or that women are more motivated by social needs, and men by competition. These beliefs might be affecting the way the course coordinators set up, and teach their courses.*'[4, p.41]

Figure 1. One Size Fits Some: The poster campaign to sensitize design students for the topic (left) and the model (right) to help design students to reveal possible biases; three lenses (associations of the designer, current (product and other) standards to be studied, and current behaviour related to gender – by Maartje van Proosdij [4]

Therefore, Maartje decided to start with a bottom-up approach by creating awareness among students. To involve students, she organised two creative sessions, a conversation with students that were about to start their industrial design bachelors and concept testing. She developed the 'Become Average' advertising campaign for first year design students, consisting of four *posters* and a *website* with examples, references and the gender bias model (see Figure 1). The final design was evaluated with seven design students (four male and three female; four bachelor students, of which were freshmen; and three master students) from which was concluded that except from some small improvements the effect is promising. Unfortunately due to covid the poster campaign could not be executed, though Maartjes work received attention; it was selected for the online exhibition Voices of Women in Science [10] and as illustration in an interview for the documentary series Reference Man [11].

2.2 Beige by Default – UB regarding skin colour

A ballerina cannot find ballerina shoes that matches with her skin colour. They are rarely available in the market [11]. Children learn that the colour 'flesh' on a crayon is for colouring skins, a light colour by default. Several soap dispensers do not work for hands with a dark skin [12]. Like the One Size Fits Some project, Cindy Jantji studied in her Beige by Default [5] project how products are designed with an unconscious bias, that is here the Caucasian skin colour as a default in mind, and - deliberately or not - excluding people from usage and from a sense of belonging. She developed a lens, a strategy and a website with product examples to address the issue in design education. First, she identified three reasons to match products with a person's skin colour: 1. *Reduction of the social stigma*, for example, healthcare products, such as compression stockings to combat varicose veins attune with the skin colour to make the user less outstanding; 2. *Increase of intrinsic acceptance*, for example, when the user must accept the product as part of the body, such as with a prosthetic leg that replaces the wearer's leg; and 3. *Enhancement through illusion*, for example, in ballet, the pointed shoes match the colour of the skin to create the illusion of long, elegant legs. From further analysis of collected products, she identified four categories of issues that are important to designers to know: 1. Inadequate colour selection (see above); 2. Failing technology and software; 3. Undereducated service providers; and 4. Unequal communication & representation. For each issue she developed design guidelines regarding: Target group definition (e.g., bystanders can become victims of UB, for example, pedestrians that are not detected by self-driven cars); User research aim and execution; Skin tone knowledge; Level of education of actors in a service; Product evaluations during the design process. The guidelines are formulated in the form of questions to check possible biases and stimulate action. From an analysis of a first-year bachelor curriculum and 6 interviews with teachers (experience with professional design practice, master between 1989 and 2012, male, one with dark skin tone) she concluded that course developers do not pay attention to the issue of skin tone exclusion by design. The interviews revealed that teachers were shocked by examples. They never thought about the topic. Some of them stated to be nervous or know other teachers who are uncertain to talk about such a sensitive topic in the classroom, because they are worried to say something wrong. Therefore, she developed the Skin Tone Inclusivity Lesson Plan with the aim to: Raise awareness; trigger self-reflection; trigger self-awareness; and finally, trigger inclusive design behaviour. With the help of cards, students are led through a few hours session that leads to an understanding of the skin tone inclusive design guidelines. Using the three designed components, the Beige by Default website, the card set, and the skin tone inclusive design guidelines, the students complete different activities to ultimately reach a more inclusive design behaviour. The session was appropriated to similar sessions in which student reflect on a certain key concept in the 1st year bachelor course Understanding Humans.

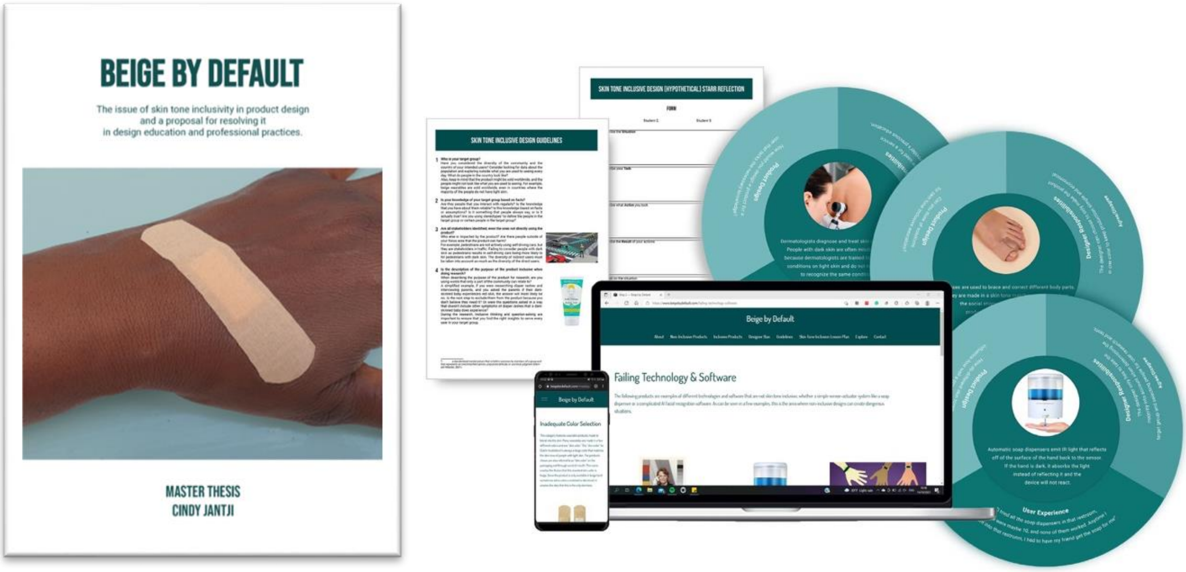


Figure 2. An impression of Beige by Default: Cover of the report (left) and educational material; a database with examples, a card set as conversation starters, and guidelines – by Cindy Jantji [5]

The final result was evaluated with two experienced teachers in two online interviews. Overall, the feedback was positive, though more extensive testing of the card set and working with guidelines, followed by another design iteration, is needed.

3 EVALUATION & DISCUSSION

The *reports* with the design process and results and the *video presentations* of the two cases, and *feedback from the supervisors* were analysed and complemented with additional literature on unconscious biases, resulting in the following insights.

3.1 The power of examples

In both cases the master students first started collecting and analysing product examples. They were clustered in a - for designers - meaningful way and together with the knowledge, they were made accessible via online databases. The examples helped both students and teachers to better understand how unconscious biases in society manifest themselves. Analysis led to guidelines and the examples were put together in such a way that they could be valuable to other students. A disadvantage of the collected examples is that they could be outdated, something from the past, and therefore lead to denial of present biases. Another problem arises if they do not match with the students' projects. An exemplary case can suddenly undermine the aim to make students sensitive to possible prejudices because it is outdated. It is therefore important that examples are accompanied with credible reference and the historical context.

3.2 The need for lenses to see what is hidden

Examples are exemplary and students will not always be able to make or ignore the translation to their own project. A model as developed for the gender bias project could support this translation and reveal some practices that would otherwise be hidden and overlooked in a design project where a multitude of aspects usually preoccupy the designer. Previous research shows that designers need tools to organize the many aspects of design, have a language to talk about and collaborate in teams [13]. The gender bias model offers three lenses to ask unconscious biases specific questions and to structure thoughts and insights. Obviously, such models are simplifications of the real world, and if we don't know their meaning and put them into context, we run the risk of students misinterpreting the models and using them as quick-fit tools, acting as masks rather unmasking the UB.

3.3 Interventions need to be appropriated to courses

Examples and lenses are not sufficient to overcome UB of both students and teachers. Interventions are needed to raise awareness, trigger self-reflection and self-awareness; and learn inclusive design behaviour. A session as suggested in the skin tone project would be a solution, however, a barrier is the many topics already addressed in courses. Teachers are not always receptive to new learning objectives and activities. Therefore, teachers need to be supported to intertwine the mission of UB with ongoing teaching activities. Websites with easy to find examples and campaigns run by students could be a first step to the bottom-up approach in which students co-develop courses.

3.4 Language and representation matters

It was surprising that the interviewed design teachers seemed to be unable to add much nuance when discussing the topics of gender and skin colour. Apparently, they too lacked a lens and the language to talk about these topics. Even though they knew that the topics were about avoiding prejudice, stereotype claims were made. Also tests with design students revealed the importance of the development of a sensitive attitude and language. For example, the skin tone project reported that discussion in class sometimes caused friction, whether it be teachers or students who were afraid to say the wrong thing, or students feeling uncomfortable with the way the topic is handled. Several teachers indicated being nervous or knowing other teachers who are nervous about sensitive topics in the classroom because they are worried, they might say the wrong thing. A safe space and appropriate language are needed for the students to learn, but teachers also need a safe space to teach.

4 CONCLUSIONS

The question for this exploration was how design educators could broaden the design students' views, increase their sensitivity for unconscious biases, and motivate them to find design solutions? The studied cases revealed that design teachers themselves are not always aware and do not explicitly address the topic in their work. A first step is to discuss and review own practices and start with the 'low hanging fruit' that is check examples, visuals, and language and examples used in lectures, assignments, study guides and other study materials for possible UB. The results from the cases could be used to raise discussion among teachers. Furthermore, students could be stimulated to co-develop courses. Not only their analytical, design research, and creative skills can be of great value, also their sensitivity for exclusion can help to unravel and see the unseen. These students could serve as barometers that identify underserved issues in society. They help to rethink values and practices in design education and – even more important – to critically reflect on the effect of their designs in society. The attention for diversity, equity, and inclusion in organisation focus usually on HR related concerns and activities, such as selection procedures. Less attention is paid to biases in material culture. The cases show how designers could help here to fill the gap and built bridges, providing real life examples, guidelines, models, training materials, and campaigns.

Hopefully this paper feeds further discussion on this topic and the difficulty not to have biases, but to find and accept them, and to reveal them rather than to hide or overlook.

ACKNOWLEDGMENT

Special thanks to the master students Maartje van Proosdij and Cindy Jantji.

REFERENCES

[1] Boess S. U. (2018). Design for self-inclusion: supporting emotional capability. *Design Research Society conference*, 25-28 June 2018.

[2] Noon M. (2018), Pointless diversity training: unconscious bias, new racism and agency, *Work, Employment and Society*, Vol. 32 No. 1, pp. 198-209.

[3] Dee T. and Gershenson S. (2017). Unconscious Bias in the Classroom: Evidence and Opportunities, 2017. *Stanford Center for Education Policy Analysis*.

[4] van Proosdij M. (2020) *One size fits some: Gender bias in design, and how to address it in design education. Master thesis, faculty of Industrial Design Engineering*, Delft.

[5] Jantji C. (2021) *Beige by Default: The issue of skin tone inclusivity in product design and a proposal for resolving it in design education and professional practices. Master thesis, faculty of Industrial Design Engineering,* Delft.

[6] Boyle R., Boyle R. and Booker E. (2015, July). Pianist hand spans: gender and ethnic differences and implications for piano playing. In *Australasian Piano Pedagogy Conference, Melbourne*.

[7] Kim E. (2019, October 29). Visible Women: Gender in Iconography. The noun Project. Retrieved at *https://blog.thenounproject.com/visible-women-gender-in-iconography-c6518ec1ddb8.*

[8] Perez C. C. (2019). Invisible women: Exposing data bias in a world designed for men. *Random House.*

[9] Schiebinger L., Klinge I., Sánchez de Madariaga I., Paik H. Y., Schraudner M. and Stefanick M. (2011). Gendered innovations in science, health & medicine, engineering and environment Retrieved November 2021 from *www.gendered innovations.stanford.edu.*

[10] Academic Heritage (2021). Voices of Women in Science. Retrieved May 2022, from *https://heritage.tudelft.nl/nl/exhibitions/voices-of-wis*

[11] Frankenmolen S. (2022). Reference man. Retrieved May 2022, from *https://www.npostart.nl/reference-man/BV_101407436*

[12] Anderson R. (2021, February 15). Ballerina's reaction to pointe shoes matching her skin tone goes viral. Good Morning America. Retrieved May 21, 2021, from *https://www.goodmorningamerica.com/living/story/ballerinas-reaction-pointe-shoes-matching-skin-tone-viral-75830211*

[13] Plenke M. (2015, September 9). The Reason This "Racist Soap Dispenser" Doesn't Work on Black Skin. Mic. Retrieved May 2, 2021, *from https://www.mic.com/articles/124899/the-reason-this-racist-soap-dispenser-doesn-t-work-on-black-skin*

[14] van Boeijen A. G. C., Daalhuizen J. J. and Zijlstra J. J. M. (2020, Rev. ed.). *Delft Design Guide: Perspectives-models-approaches-methods.* Amsterdam: BISPublishers.

PROBLEM SOLVING RACE: GAMIFICATION TO SOLVE INDUSTRIAL ENGINEERING PROBLEMS IN THE DISTANCE AND CLASSROOM LEARNING

Carlos GONZALEZ-ALMAGUER, Claudia ZUBIETA, Elvia ROSAS, Claudia RIVAS, Angeles AGUIRRE and María LULE
Tecnologico de Monterrey, Mexico

ABSTRACT
In the Tec21 educational model [1], one of the core competencies is problem-solving, which is also one of the most requested skills by companies for hiring candidates. Solving problems is a priority competency in training the Tecnologico de Monterrey students. This paper describes the academic experience of a gamification design using problem-solving in a role game.
The objective was to redesign the primarily theoretical course to be more empathetic to the confinement situations of students during the pandemic, leveraging available educational technology using gamification. Thus, we created a board game called Problem-Solving Race (PSR), which has evolved into an online game students can play to develop this and other competencies for the graduation profile that we seek in our students. The university's "Virtual Campus" platform (using virtual reality technology) facilitated the gamification for a practical experience that highly engages the students.

Keywords: Gamification, educational innovation, problem-solving, higher education

1 INTRODUCTION
Design is everything. Structuring a class to share learning with students requires a well-planned design process. Before the COVID 19 health emergency, course designs were primarily aimed at classroom exposition or workshops. Few university teachers were prepared to conduct their classes 100% in a remote modality, generically termed "distance learning."
Since 2003, the School of Engineering and Sciences of Tecnologico de Monterrey has been seeking ways to combine the theoretical topics of industrial engineering classes with practice laboratories. This gave birth to a weekend experiential workshop, once during the semester, where students enrolled in "Design of Experiments" and "Design of Work and Statistical Quality Control" attended an integrative six-hour workshop to solve a fun and playful challenge in which the teachers ensured that the students put into practice their classroom learning. The workshop aligns with the Tec21 educational model [1] that migrates traditional learning to challenge-based learning to acquire competencies through practice activities that simulate real scenarios.
In 2008, Meccanos [2] were integrated to solve these challenges, which allowed designing activities to do in the class; in 90 minutes, the students could combine practice and theory. In 2013, the virtual plant was born where the first attempt was made to gamify all the processes of a car assembler and expose the best practices of industrial engineering techniques. Teams competed to assemble cars with the most competitive profits and meet the production, management, and quality standards of a current car manufacturer.
Gamification alone makes students very competitive. Specific training unit strategies and tactics applied in the classroom allow students themselves to seek through indirect learning the best techniques and practices that permit them to win. Board games are popular among students of all ages because they develop the ability to work individually and as a team. In that competitive and relaxed environment, learning is attained more individually, according to Ocanto 2009 [3]; in neuroscience, it is known that enthusiasm and total attention to the activity results in more irrigation of blood throughout the brain. This oxygenation creates the necessary conditions for more extended-duration learning.
When the university closed and students went home due to the pandemic's confinement, the interactive face-to-face learning and socialization were broken. Techniques and design knowledge had to fit

distance learning platforms that allowed student interactions and gamification experiences. Managing and resolving how to promote learning had to consider a factor not conceived before the pandemic and as time pass by the relevance of emotional stability increased.
The main purpose of the design focused on making an online simulator for the virtual plant. The project had a release time of 15 months, therefore, concurrent strategies had to be established. One of them was to solve small challenges through knowledge capsules in a board game called *Problem-Solving Race*. The research development process and results are detailed in this scientific essay.

2 DEVELOPMENTS

To develop this educational innovation, we conducted an immersive, empathetic exercise (from the students' perspective) involving the topics and subjects in which gamification would be applied. The methodology proposed by González, Saavedra, Caballero, Acuña, and Lule 2021 [4] of EPDE was its model in which the design of experiments is merged with *Design Thinking*, taking as the transcendental variables the involvement in class (*engagement)*, the learning of specific training unit topics (*learning)* and, finally, the development of transversal and graduation competencies.
Using thought engineering, we began to analyse the appropriate parameters for each variable. Based on *engagement,* we found that gamification was the most reliable technique. The first problem-solving activity designed for the online class with 329 students used mini-challenges that were solved using different platforms and software. For the variables of learning and competencies development, the objectives were achieved. However, the students expressed their annoyance in their comments because many hours were required to solve these challenges, and being a remote team activity, not all students were able to participate significantly under this modality.
A more profound empathetic study detected a variable that was not being considered, emotional stability. We found that the reason for this problem was that each student during confinement had a unique home and study environment that influenced the full development of their educational process. In 2020, the university began the implementation of a new educational plan. Its most crucial element, the challenge, was very much affected by the Covid19 confinement. The challenge had to be addressed collaboratively among the students, teachers, and external training partners, who open the doors of their facilities for students to solve real-world problems.
Each school semester is divided into five-week learning blocks in which students solve a challenge with the training partner. The topic modules provide the information and theory to support resolving the challenges. Due to the confinement, this educational strategy had to be modified for remote work and resolving the challenges without affecting academic quality.
We applied surveys at the beginning of each training unit to find out the appropriate parameters for the *engagement* variables. Exploratory questions aimed to find out the students' hobbies, sports, and extracurricular activities, their emotional state resulting from confinement and online classes, and what they do not like a teacher to do in distance learning.
Thus, we found that the classes should have multi-level gamification components [5] from a low level, using Kahoot, Socrative, and Mentimeter platforms to compete for the best responses, to activities designed for a role-playing game when in 90 minutes, the students solve the challenges with an adequate balance between playfulness and technique. Recent studies like the one presented by Welbers 2019 [6] have reached the same conclusions as ours.
As teachers, we create academic activities that help students learn and enjoy. What does the concept "Wow" mean in an educational lesson? Desmet, Porcelijing and Dijk [7] define that, in essence, "Wow" is nothing more than a simple verbal exclamation, so an academic *Wow Experience* is a combination of pleasant surprise, fascination, and increased learning. This work describes how we designed an academic activity using gamification to solve problems in a board game.
After making several prototypes and testing them in *focus groups* with students from different curricular programmes ("careers") and semesters, we created the *Problem-Solving Race (PSR).* It has four modalities, the board game with 21 and 42 stages and the virtual one with 21 and 41 stages. It is related to the philosophy of the marathon and a board game widely used by children in Mexico called Snakes and Stairs [8], a Western version of a game created in India in the sixteenth century called Gyan Chaupar or Leela. It was known as The Game of Knowledge and imparted the philosophical teachings of its culture.
For each class, depending on the specific topic that the teacher wanted to gamify, a problematic situation (not to be confused with a problem) and three key moments were designed when the work teams were

formed, and the problem was defined. The second stage, ideation, was oriented to information analysis and learning of specific topics. The third stage was the solution, where students presented their solutions to the problematic situations. Figure 1 shows different steps of the PSR using augmented and immersive reality as well the board table game.

Figure 1. Some steps of PSR using AR and IR, at the board table

The graduation skills developed during this activity are teamwork, critical thinking, problem-solving, and communication.

The most important competency that the PSR develops in the student is the solution of problems because it is focused on learning different methodologies and techniques, depending on the topic underlying the problematic situation that the student encounters during the activity.

For the problem definition, we relied on the Soft Systems Methodologies (SSM) proposed by Checkland [9] and the technique of Kepner and Tragoe [10]. Their proposal focused on considering a problem as a deviation between what *should be* and what *is*. Four questions were answered that ultimately helped frame the definition and the problem statement. It calls to mind Einstein's famous comment that by knowing the problem, you have 99% of the solution.

During ideation, students learn design-of-experiments techniques, statistics, and data science directed by specific problem-solving techniques such as Design Thinking [11], DMAIC, eight disciplines, and others that allow students to create feasible solutions. Students test their proposals and prototypes in the solution stage, adjust parameters, and present a final solution.

Each learning stage utilizes agile project management with different *springs* that allow students to have concurrent learning individually and as a team. For challenges focused on the aerospace and automotive industry, augmented and virtual reality practices potentiate learning in students by providing active experiences instead of passive theoretical learning. To explain the techniques and methodologies, we created short videos that students can consult and simple explanations in PDF documents.

After creating the PSR, the subsequent development challenge was to create the platform so that it could be used in remote classes. The first pilot runs of gamification were made through the Zoom platform with individual sessions where students solved specific challenges in their group activity placed in the CANVAS learning platform. The videos' PDF files were accessed through a Google drive.

Twenty percent of the activities in the stages were playful with no apparent connection to the problem situation or challenge. Nevertheless, these activities were to develop transversal competencies.

The lesson required at least two teachers and 3 assistants to attend the activity simultaneously, using a *script* with times that had to be followed rigorously to complete the gamification in 90 minutes. In November 2020, this immersive reality of the "Tec Virtual Campus" was introduced through the Virbela platforms [12], providing a metaverse world of possibilities. Students could interact as if they were in the classroom, completely engaged.

On this platform, we replicated the stages of each activity or adapted them to the different Tec Virtual Campus scenarios. The students began by entering a reception in a *Conference Hall* for the time of definitions. Before the activity, the students were trained to use the platform installed on their personal computers; then, they designed their avatar and personality to use in their group. In this definition stage, a high-performance work team was formed, also having unique characteristics. Through the screens and walls, the students obtained the problematic situation information; they could also see it on their CANVAS platform.

After the reception in the Conference Hall, the students moved to an *Exhibit Hall* where, concurrently, there were videos with detailed explanations of the problem situation, techniques, methodologies, and

augmented reality lessons [13]. Thus, students learned as a team together and not individually, sequentially, optimizing research times.
After defining the problem, the students played on the *Soccer Field* and the *Beach*, where they found clues in the speedboats while having fun as if they were really at sea, collecting and learning indirectly from knowledge capsules, and then moving to the *Lighthouse* where the ideation stage took place in a very relaxed scenario and a view of the sea.
After this creative process, another playful moment took place on the beach stage, where the students had to do a group choreography to music selected by the teacher. This crucial stage strengthened teamwork and coordination among the members, preparing them to move to the prototype test and final presentation in the conference room.
All this and the physical and virtual gamification through Zoom followed a rigorous time *script* to pass through all the stages and finally solve the defined problem.

3 RESULTS

The research protocol was divided into two parts, the quantitative variable that measures the learning of the topic and subtopics presented during gamification and the qualitative variables of student *competency development* and *engagement*.
We applied an individual student knowledge test in each group before the gamification and another exam after it to measure the learning variable. The *paired student's t-test* was used to compare both exams. The null hypothesis declared that the average score of each test was statistically the same, and the alternative hypothesis that it was different, so it could be inferred that gamification produced significant learning among the students.

Paired T- Test

Statistics

Variable	N	N*	Mean	SE Mean	StDev	Variance	Minimum	Q1	Median	Q3
Before SRP	36	0	81.22	3.22	19.31	372.86	13.00	79.25	87.00	100.00
After SRP	36	0	97.472	0.870	5.218	27.228	87.000	100.000	100.000	100.000

Variable	Maximum	Mode	N for Mode
Before SRP	100.00	87, 100	10
After SRP	100.000	100	29

Test

Null hypothesis H_0: μ_difference = 0
Alternative hypothesis H_1: μ_difference ≠ 0

T-Value	P-Value
-5.31	0.000

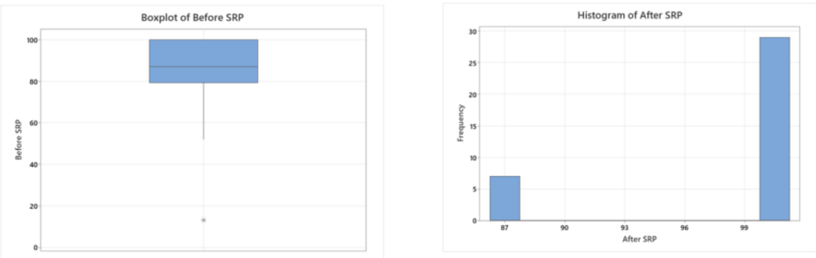


Figure 2. Descriptive statistics and paired T-test

Figure 2 shows the results obtained for the Systems Dynamics class, which used a PSR game about generating electrical energy through hydroelectric sources; the students had no previous experience or knowledge in this area. The before-gamification exam result was a mean of 81.22 out of 100 points, which increased to 97.47 after applying the gamification. The paired T-test produced a statistic of -5.31 with a sample of 36 students, so we could infer at 95% of confidence level that the gamification did have a statistically significant difference for the students' learning variable: since the p-value was 0.000.

4 CONCLUSIONS

The gamification of challenges or problems designed in lessons within the Tec Virtual Campus platform managed to create a different experience for the students, motivating them to participate and to engage, as indicated by the improvement in the learning variable. Gamification generated highly significant learning, allowing the students to apply their semester knowledge in real cases in a funny way.
Competing in a sporting event or contest motivates and leads to an excellent result. Gamification also motivates, but for positive results, a high dose of creativity and social commitment is necessary for the students.

If we call this a "Wow" experience, the equation would be:
Wow= Experience (Gamification + activity + creativity) ^ Virtual Campus
Where gamification, activity, and creativity are summed and mounting it on the virtual campus potentiates it, so the experience becomes unique.

ACKNOWLEDGEMENTS

The authors acknowledge the technical and financial support of the Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

REFERENCES

[1] Observatory, IFE, World Bank shows worldwide Tecnológico de Monterrey's Educational Model Available: *https://observatory.tec.mx/edu-news/world-bank-tec21-tec-de-monterrey-educational-model* [Accessed on 2022, February 10], (2020) February 7.
[2] *The 22nd International Conference on Engineering & Product Design Education* (E&PDE 2020). STEM Competency-Based Learning for Engineering and Design Students of the Educational Model TEC21. VIA University in Herning, Denmark. 10th and 11th September 2020.
[3] Ocanto I. La creación de imágenes mentales y su implicación en la comprensión, el aprendizaje y la transferencia.SAPIENS vol.10 no.2 Caracas dic. 2009.
[4] Gonzalez Almaguer C. A., Saavedra V., Acuña López A., Caballero Montes E., Zubieta Ramírez C., Lule M. and Barbosa E. Design Thinking and Design of Experiments: The fusion of the school of design and industrial engineering to create learning experiences in the Tec21 Educational Model. *Proceedings of the 23rd International Conference on Engineering and Product Design Education* (E&PDE 2021), VIA Design, VIA University in Herning, Denmark. 9-10 September 2021.
[5] Varannai I., Sasvari P. and Urbanovics A. The Use of Gamification in Higher Education: An Empirical Study. (IJACSA) *International Journal of Advanced Computer Science and Applications,* Vol. 8, No. 10, 2017.
[6] Welbers K., Konijn E. A., Burgers C., de Vaate A. B., Eden A. and Brugman B. C. Gamification as a tool for engaging student learning: A field experiment with a gamified app. *E-Learning and Digital Media*. 2019;16(2):92-109. doi:10.1177/2042753018818342.
[7] Desmet P. M. A., Porcelijn R. and van Dijk M. B. HOW to design WOW Introducing a layered-emotional approach. *Proceedings of The International Conference on Designing Pleasurable Products and Interfaces*, October 24-27, Eindhoven, pp. 71-89.
[8] Ayala P., Carranza A. and Nicolini D. Serpientes y escaleras. Lecciones de expresión creativa y pautas de narrativa gráfica. ARTSEDUCA Núm. 9, September de 2014.
[9] Checkland P. B. (1989). Soft systems methodology. *Human systems management,* 8(4), 273-289.
[10] Kepner C. H. and Tregoe B. B. (1981). *The new rational manager.*
[11] Liedtka J. Why Design Thinking Works. Innovation. *Harvard Business Review*. From the September – October 2018 Issue.
[12] Häfner P., Häfner V. and Ovtcharova J. (2013) Teaching methodology for virtual reality practical course in engineering education. *Procedia Computer Science.*
[13] Akçayır M. and Akçayır G. Advantages and challenges associated with augmented reality for education: A systematic review of the literature, *Educational Research Review,* vol. 20, p. 1–11, 2017.

TOWARDS VALUE-DRIVEN EXPERIENCE DESIGN BY MINDING THE GAP BETWEEN VISUAL-OLFACTORY PERCEPTION

SuKyoung KIM
Sapporo City University, Japan

ABSTRACT
Intuition and insight are two processes that link the tacit and the explicit knowledge, which are relevant to idea sharing in the design process for evolving critical values into an innovative design. Experiences to link the tacit and the explicit knowledge easily enhance and foster more valuable and creative thinking. The present research aimed to verify unanswered questions focused on multisensory stimulation and integration as follows. Q1: Visual or olfactory stimuli influence the same way regardless of whether it is *unimodal* or *multimodal*? Q2: Is *liking* the only intuitive value compared to other semantical values such as *freshness, weightiness* and *experience*? The current research presented significant findings which answer the above-mentioned questions. A1: Visual knowledge is more solid and influenceable than olfactory knowledge in *unimodal* conditions, whereas olfactory knowledge is more solid and influenceable than visual knowledge in *multimodal* conditions. A2: *Liking* is a more clear and effectible value to verify the impression of the perceived stimuli. And the worthiest finding from the results is that *liking* is relevant to experience. The evaluation results of *liking* show similar trends as experience, and vice versa. Further research should clarify in further research whether *liking* correlates with sensitivity or not in the structured sensory and leads the subjective evaluations to modify specific evaluation values. The findings of this research are worthy as they provide a hint to enhance value-driven design factors to foster more valuable and creative experiences which will be beyond our expectations.

Keywords: Multisensory, cognition, interference

1 INTRODUCTION

1.1 Rethink human being
There can be no doubt that all human knowledge begins with experience. Humans experience external features through their senses such as vision, olfaction, audition, etc., and understand the external world. I. Kant explains that although all our knowledge begins *with* experience, it does not follow that it arises *from* experience. Even human knowledge is a compound that humans receive through impressions, we don't distinguish from that raw material until the long practice has made us attentive to it and rendered us capable of separating one from the other, and the accumulative knowledge is in relation to intuition. The question is that, how does an individual's experience affect or be affected in relation to knowledge and intuition?

The present research focused on clarifying the role of individual experiences in modifying *the innate subjective filter*. *The innate subjective filter* postulates influenced and changed by the experiences considering the variety of subjectivity. *The model of explaining the relationship of an innate subjective filter and the individual modification process by the experiences* by Kim et al. (2012) [1], clarifies the reason why affective values are significant in design and how designers can investigate those subjective evaluation results as deceive values. The updated version of this model is presented in Figure 1. It presents the *kansei* process i.e., synthesized affective data of how human sensory receptors (eyes, ears, nose, and so on) receive stimulants as an external feature from the environment, and how the perceived data is integrated into the brain through the filter-dependent affective output. The synthesized information in the brain comes out as reactions such as emotion or intuition, which act as the scale of aesthetic and logic of the individual. Logic comes out as beyond judgment that is relevant to the choices and empirical results whereas, aesthetic comes out as judgment that is relevant to desires or examples. These two outcomes influence perceptual and conceptual fluencies such as familiarity, preference, aesthetic feeling, and so on. In addition, they also interact to impact subjective evaluations of new designs through the individual experience that is based on one's new understanding. Perceptual fluency originates from external feature conditions of the filter whereas conceptual fluency originates from the evolved phase of the filter (Figure 1).

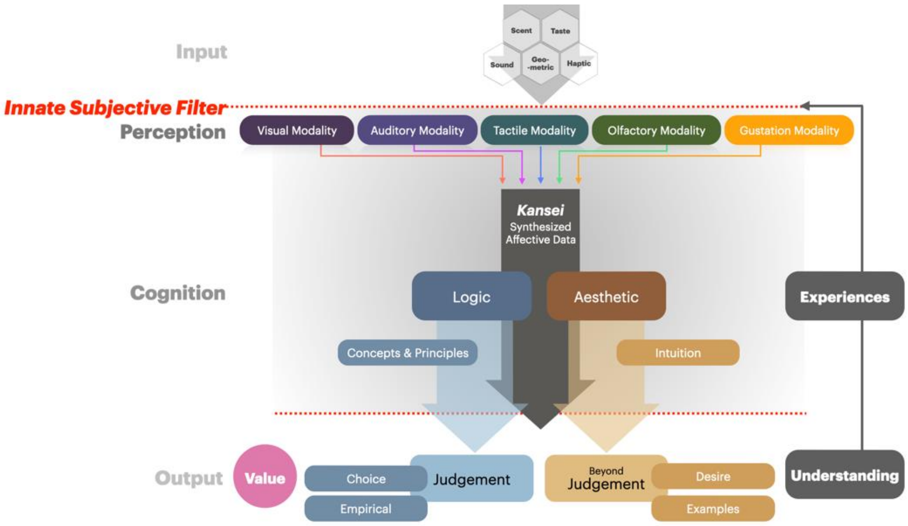


Figure 1. The model of explaining the relationship of an innate subjective filter and the individual modification process by the experiences

The innate subjective filter postulates modification of subjective evaluation with one's experiences and the changes separate each individual to be one unique filter. Figure 2 presents an example of why subjective evaluations depend on the filter to the same stimulus even if the same individual evaluates it differently. In case of an individual who focuses on the colour of the stimulus (in this case an apple), the colour red will be a critical value in their evaluation. Whereas an individual who focuses on the taste of the stimulus may focus on sweetness as the most critical value in their evaluation. Even though it is the same stimulus that was perceived, the cognized data were interpreted differently by individuals.

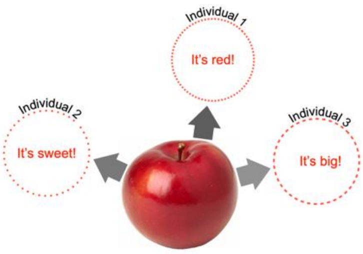


Figure 2. The relationship of an innate subjective filter and the subjective evaluation to the same stimulus

1.2 Rethink design

To rethink the notion of the transformative design for the future not so far, it should be understood that the user' expectation of the design needs more focus than what design is per se. User research is about understanding the users, their needs and experience, and about designing a user's interactions with a product from moment to moment. A user's experience is the cumulative effect of many factors, some that the designer can control, and some that the designer can't control. How to design what the users want and need? Design has mainly been discussed in industrial design and engineering design. However, society is already saturated with various high-end technological products and design is continually reconfiguring itself from object-centred to human-centred. Current design does not only produce form-function-based objects but also places importance on what the users expect from the objects or services, i.e., experience design. Therefore, clarifying the meaning of perceived data of the users will help gain more understanding as to why design needs to place emphasis on multimodal perception.

2 METHODS

As to the importance of experience unanswered questions are twofold: How to determine cause-and-effect relations of the perceived information and the evaluation results in accordance with our daily life? How to implement the perceived information in user experience design? To answer these questions, the present research aims to verify two questions focused on multisensory stimulation and integration as follows. Q1: Do visual and olfactory stimuli influence the participants' evaluation value the same way regardless of whether it is *unimodal* or *multimodal*? Q2: Is *liking* an only intuitive value unlike other semantical values such as *sweetness*, *freshness*, *weightiness*? Twenty-four Japanese participants attended in the visual experiment and thirty-six in the olfactory experiment. The olfactory experiment was conducted in three groups (twelve participants in each group) and each participant evaluated fifteen stimuli.

2.1 Procedure

The current research aimed to clarify the gap between the visual and olfactory stimuli. In the experiment, forty-five essential oils and their representing photos were used as olfactory and visual stimuli. The essential oils were categorized into three groups namely, sweets (brownie, bubble gum, candy corn, caramel corn, chocolate, chocolate mint, coconut cream, coffee cake, cotton candy, cupcake, marshmallow, orange creamsicle, orangesicle, peaches & cream, pina colada), fruits (apple, banana, black oak currant, coconut lime verbena, cranberry, cucumber melon, lemon, mandarin, mango, orange, peach, pineapple, red cherry, strawberry, tropical passionfruit) and flowers (azalea, freesia, gardenia, honeysuckle, jasmine, lavender, lilac, lily, magnolia, peony, plumeria, rose, sweet pea, violet, ylang ylang) . The subjects were instructed to make the ratings using the subjective states, which are: Each trait below the stimulus that you will use to rate your feelings about the stimuli. The evaluation traits are in five: *sweetness*, *freshness*, *weightiness*, *liking*, and *experience*. The evaluation implemented a 6-point character rating scale as follows: *strongly disagree*, *disagree*, *slightly disagree*, *slightly agree*, *agree*, *strongly agree*.

2.2 Analysis & results

One-way ANOVA was used to analyse.

<u>By sensory modality differences in each evaluation values</u>

All evaluation values *sweetness*, *freshness*, *weightiness* (in the left / the middle / the right of Figure 3), *liking*, and *experience* (in the left / the right of Figure 4) present the significance by modality differences of visual and olfactory. All visual stimuli were evaluated higher than olfactory stimuli and the biggest difference by modality was observed for the evaluation value *liking*. It means that visual is more affectable than olfactory in the evaluation process. Moreover, the clearest value to verify modality differences between visual and olfactory was observed for the evaluation value *liking*.

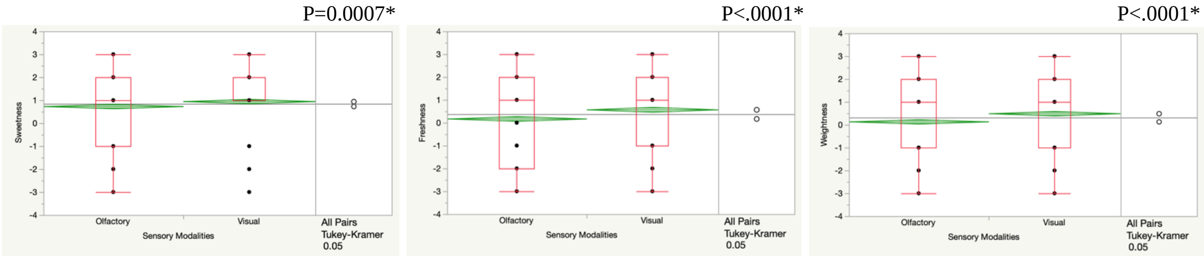


Figure 3. The results in sweetness, freshness, weightiness by sensory modalities

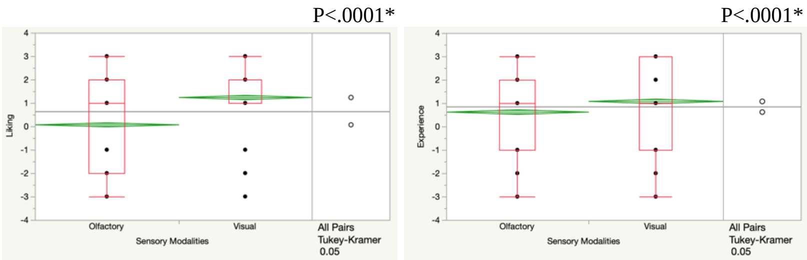


Figure 4. The results in liking and experience by sensory modalities

By the characteristic in visual stimuli in each evaluation values

All evaluation values *sweetness*, *freshness*, *weightiness* (in the left / the middle / the right of Figure 5), *liking*, and *experience* (in the left / the right of Figure 6) by characteristic categories in visual evaluations. In *sweetness*, the three categories such as *sweets*, *fruits*, *flowers* showed significant difference in each category. Whereas *freshness* and *weightiness* did not show any significant difference between *fruits* and *flowers*. *Fruits* are the most preferred of three characters in *liking* and *experience* evaluations in visual.

P<.0001*
Ordered Differences Report (Level)
Sweets - Flowers P<.0001*
Fruits - Flowers P<.0001*
Sweets - Fruits P<.0001*

P<.0001*
Ordered Differences Report (Level)
Fruits - Sweets P<.0001*
Flowers - Sweets P<.0001*
Fruits - Flowers P=0.4137

P<.0001*
Ordered Differences Report (Level)
Flowers - Sweets P<.0001*
Fruits - Sweets P<.0001*
Flowers - Fruits P=0.0925

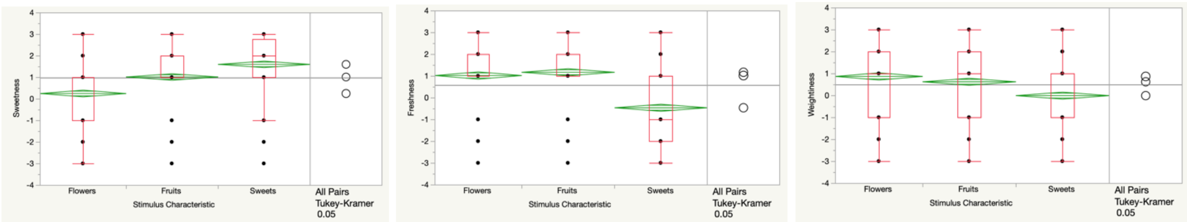


Figure 5. The results in sweetness, freshness, weightiness *by the characteristic in visual*

P<.0001*
Ordered Differences Report (Level)
Fruits - Flowers P<.0001*
Sweets - Flowers P=0.0022*
Fruits - Sweets P=0.0076*

P<.0001*
Ordered Differences Report (Level)
Fruits - Flowers P<.0001*
Sweets - Flowers P<.0001*
Fruits - Sweets P<.0001*

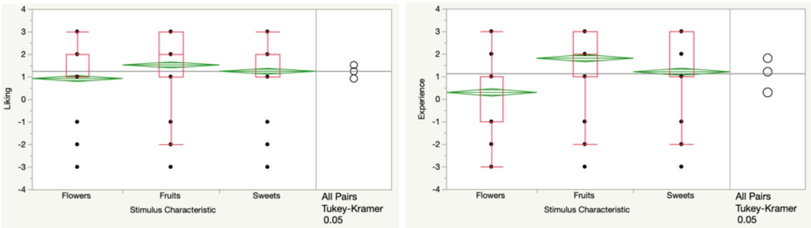


Figure 6. The results in liking and experience by the characteristic in visual

By the characteristic in olfactory stimuli in each evaluation values

Only *liking* did not show any significant difference and excluded from the trends. *Experience* showed significant difference between each characters excluding *fruits* and *flowers*. It postulates that the olfactory similarity of *fruits* and *flowers* influence not only visual evaluation but also olfactory evaluation. In *sweetness*, each of the three categories showed significant difference. Whereas, *freshness* and *weightiness* show the opposite trend to *sweetness*, which was also observed in visual evaluations. And also, no significant difference was observed between *fruits* and *flowers*. It postulates that the olfactory similarity of *fruits* and *flowers* influences not only visual evaluations but also olfactory evaluation.

P<.0001*
Ordered Differences Report (Level)
Sweets - Flowers P<.0001*
Sweets - Fruits P<.0001*
Fruits - Flowers P=0.0014*

P<.0001*
Ordered Differences Report (Level)
Fruits - Sweets P<.0001*
Flowers - Sweets P<.0001*
Fruits - Flowers P=0.9757

P<.0001*
Ordered Differences Report (Level)
Fruits - Sweets P<.0001*
Flowers - Sweets P=0.0002*
Fruits - Flowers P=0.9730

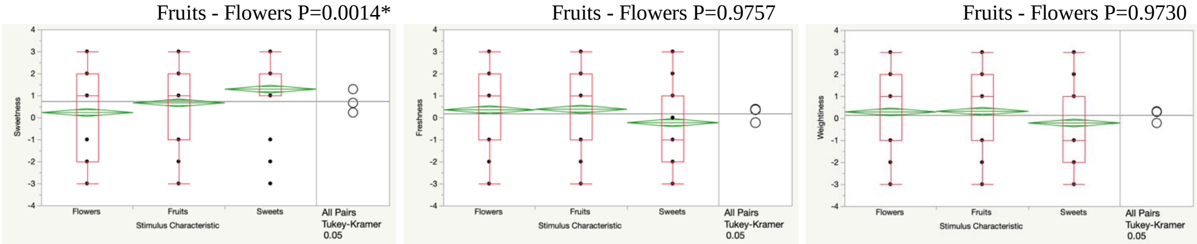


Figure 7. The results in sweetness, freshness, weightiness *by the characteristic in olfactory*

P=0.3280

P=0.0020*

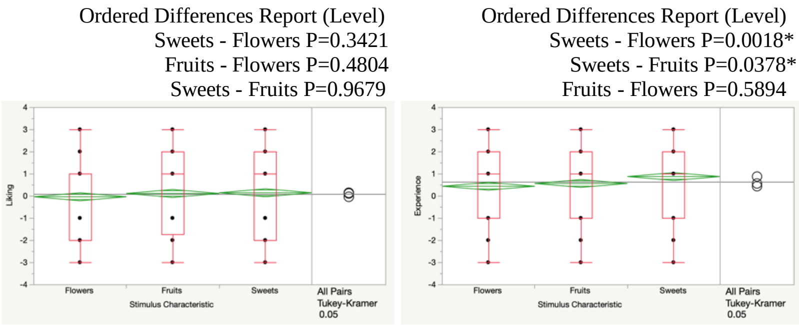


Figure 8. The results in liking and experience by the characteristic in olfactory

2.3 Considerations

The results of the current research present that: (1) All evaluation values present significant modality differences. In *liking* evaluation, visual and olfactory differences present the biggest gap and enhance the influence of the visual stimuli. It postulates that visual stimuli are more affectable than olfactory stimuli. However, the previous research by the author presents different possibilities for this discussion [2]. In the previous research, which was supported by JSPS KAKENHI16H07097, olfactory stimuli which were evaluated positively influenced all evaluation values such as *sweetness, freshness, liking.* Whereas visual stimuli which were evaluated positively affected partly its traits on the evaluation when the modalities presented at the same time. It is a reasonable postulation that in unimodal perception, visual stimuli are more affectable than olfactory when presented independently. However, in multimodal perception, olfactory stimuli are more affectable than visual when presented dependently. (2) Regarding *sweetness*, the three categories' *sweets, fruits, flowers* show the significant difference between the categories. Whereas *freshness* and *weightiness* do not show any significant difference between the category's *fruits* and *flowers*. In the previous research mentioned above, *sweet trigger* stimuli, which are relevant to the three categories in the current research, was the most affectable value in both visual and olfactory independently. Although, there was no significant difference in *sweetness* evaluation. It is reasonable to postulate that *sweet trigger* is the most various and complex bias excluding *sweetness* per se. (3) All evaluation values *sweetness, freshness, weightiness,* and *experience* present significant difference by characteristic categories in olfactory evaluations but only *liking* does not show any significant difference and is excluded from the trends. It postulates that *liking* is influenced by the individual preference not by stimulus characteristics. In *sweetness,* each of the three categories show the significant difference, whereas *freshness* and *weightiness* show the opposite trend to *sweetness* which was also observed in visual evaluations. It does not show the significant difference between fruits and flowers as well. It postulates that the olfactory similarity of *fruits* and *flowers* influences not only visual evaluations but olfactory evaluation as well. And *sweet trigger* influences perceived stimuli to *freshness* and *weightiness* differently.

3 DISCUSSION AND CONCLUSION

The current research aimed to verify unanswered questions focused on multisensory stimulation and integration as follows. Q1: Do visual and olfactory stimuli influence the participants' evaluation value the same way regardless of whether it is *unimodal* or *multimodal*? Q2: Is *liking* an only intuitive value unlike other semantical values such as *sweetness, freshness, weightiness*? The current research presented significant findings which answer these questions. A1: Visual knowledge is more solid and influenceable than olfactory knowledge in unimodal conditions whereas olfactory knowledge is more solid and influenceable than visual knowledge in multimodal conditions. A2: *Liking* is a more clear and effectible value to verify the impression of the perceived stimuli. The worthiest finding from the results is that *liking* is relevant to experience. Figures 4,6 presents statistically significant evaluation trends for the evaluation of *liking* and *experience*. This tendency was observed in Figure 8 even though it did not present any significance.

Why is visual knowledge more solid and influenceable than olfactory knowledge in unimodal conditions whereas olfactory knowledge is more solid and influenceable than visual knowledge in multimodal conditions? Research by Rolls et al (1996) regarding the orbitofrontal cortex presented that, the rapid associative learning by the neurons in the orbitofrontal cortex which is associated with behaviours such as tasting is affected more by olfactory stimuli than visual stimuli [3]. Cho and Sai

(2018) studied the interaction effect of the spatial design elements and scent on the psychological mood state. They reported that the presence of olfaction helped reduce the negative mood of the participants and improved positive mood states in deficit spatial conditions such as narrow spaces with low ceiling heights [4]. These findings validate the postulation that olfactory knowledge is more affectable than visual in multimodal condition. These findings validate the postulation that olfactory knowledge is more affectable than visual in multimodal condition.

Why is *liking* influenced by the individual preference and not by stimulus characteristics? Berridge et al. (2003) have suggested *unconscious emotion* such as *unconscious liking* can elicit affective reactions subliminally while an individual is completely unaware of their affective reactions to a given scenario or stimulant [5]. Kihlstrom, John F., et al. (2000) suggested that emotions such as like/dislike can be unconscious expression of an individual's perception, memory or thoughts and can be expressed via the individual's behavioural and emotional response to things [6]. Therefore, it is safe to postulate that *liking* is an implicit *emotion* based on the individual's personal experience-driven value to influence clear and effectible on evaluations.

Why does sweet trigger the most various and complex bias excluding *sweetness* per se? Previous research works have demonstrated associations between taste/flavour attributes such as *sweetness* and external sensory stimuli. Blazhenkova & Kumar (2018) demonstrated that curved shapes were associated with sweet taste than angular shapes [7]. Another research by Wang et al. (2017) on the role of emotions in cross modal modulation of taste presented that sense of hearing could trigger on the sensory dimension of the tasting experience. The findings of the study suggested that positive emotions evoked by music enhanced the sweetness of different foods and drinks [8]. This leads to the assumption that *sweetness* is triggered not only by stimulants but also positive emotions. Therefore, it is reasonable to postulate that sweet triggers the most various and complex bias excluding sweetness per se.

The findings of this research are worthy as they provide an insight into the influence of structuring intuitive knowledge on subjective evaluations enhancing value-driven design factors to foster more valuable and creative experiences. The questions to be answered through the further research are as follow. Q1: Do structured knowledge affect perceived values? Q2: Does *liking* which contributes to the affective experience correlate with *sensitivity*? Q3: Do cognitive biases intervene in perception? Further study should clarify whether *liking* correlates with *sensitivity* in the structured sensory and if it leads the subjective evaluations to modify specific evaluation values.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI19K20619.

REFERENCES

[1] Kim S., Cho Y., Niki K. and Yamanaka T. The Influence of Holistic View Impression in Product Evaluation by an Approach in Kansei. In *Proceedings of the International Conference on Kansei Engineering and Emotion Research*, pp. 945-952, 2012.

[2] SuKyoung K. Designing User Experiences Focused on Multimodal Perception. *Linköping Electronic Conference Proceedings*, No. 146 (KEER 2018) pp.454-463, 2018.

[3] Rolls E. T., Critchley H. D., Mason R. and Wakeman E. A. Orbitofrontal Cortex Neurons: Role in Olfactory and Visual Association Learning. *Journal of Neurophysiology*, Vol. 75, No. 5, pp. 1970-1981, 1996.

[4] Cho Y. and Gopal S. An Evaluation Model of the Sense of the Presence in Virtual Reality Environment, *In the 13th International Conference on Design Principles and Practices*, Saint Petersburg, Russia, 1st to 3rd March 2019.

[5] Berridge K.C. and Winkielman P. What is an Unconscious Emotion? *Cognition and Emotion*, Vol. 17, No. 2, pp. 181-211, 2003.

[6] Kihlstrom J. F., Mulvaney S., Tobias B. A. and Tobis I. P. The Emotional Unconscious. In E. Eich (Ed.), *Cognition and Emotion*. New York: Oxford University Press. 2000.

[7] Blazhenkova O. and Kumar M. M. Angular versus curved shapes: Correspondences and emotional processing. *Perception* 47.1 (2018): 67-89.

[8] Wang Q. and Spence C. A. Sweet smile: the Modulatory Role of Emotion in Howextrinsic Factors Influence Taste Evaluation. *Cognition and Emotion*, Vol. 32, pp. 1052-1061, 2018.

TOWARDS A NEW STANDARD FOR FEA METHODOLOGY AND PRESENTATION IN PRODUCT DESIGN PORTFOLIOS

Ross MACLACHLAN
University of Strathclyde, Glasgow, United Kingdom

ABSTRACT
This paper presents the outputs from a taxonomy of senior year Product Design student projects uncovering common trends in the application of computer-based simulation, primarily Finite Element Analysis (FEA) in the delivery of creative product solutions. The 2 cohorts within the analysis develop their own product design briefs and are challenged to integrate their previous knowledge with new project-based learning. Where FEA is a relatively small component of the design curriculum, but one of the most likely forms of analysis within product design engineering work, the successes, mistakes, missed opportunities and shear variety of analysis opportunities can inform developments within FEA pedagogy in design centred engineering. Often students must make considerable leaps to move from familiar textbook problems to their own project work, and it can be difficult for multidisciplinary teaching staff to support the integration of FEA into project work. The paper presents our evolved curriculum thread, and aspects of pedagogy, aiming to link analytical classes with project modules in the middle years, and support senior project students applying FEA techniques to their own design concepts. The paper concludes by summarising future priorities towards consistent excellence and attainment for product design centred FEA methodology and its presentation within the design portfolio.

Keywords: FEA, finite element, design analysis, product design folio

1 INTRODUCTION
The work outlined in this paper was initiated through reflections on 15 years' experience of teaching engineering design (design analysis and machine element design) to Product Design Engineering students at the centre of their undergraduate degree; the Engineering Design module in year 3 (see Figure 1). When first involved in teaching this subject, all design analysis was based on hand calculations and paper based graphical methods; it has evolved to integrate computer-based analysis. The module is the most substantial teaching and assessment of FEA in the curriculum. Upstream assessment criteria for final projects are not explicit on analysis type, but the majority of students include FEA. This work is a reflection on qualitative attainment within our curriculum and final project deliverables, and on experience of integrating FEA as a personal skillset and teaching specialism. The overarching aim is to explore integration of curriculum learning in FEA into design project methodology, how it develops in project based learning and to identify priorities for future intervention.
Computer analysis in product design discipline will be discussed before presenting our curriculum. Cohorts of Product Design Engineering student folios are analysed to create an outline taxonomy of FEA in project work. It is hoped that the analysis will be of interest to students, supervisors and assessors considering FEA and other curriculum design tools/methods pivotal to project success. Similarly, curriculum designers/maintainers may be interested in the fuller curriculum.

2 FEA IN DESIGN EDUCATION
Whilst Finite Element Method and the Analysis technique based upon it, FEA, have been increasingly used in industry and academia since the 1950s, it has been computer developments in recent decades that have seen tools move from mechanical expert domains, to being integrated and increasingly useable CAD tools for the competent technical product designer.

There is a challenge in design education around the ambiguity in the gap between the traditional FEA specialist and the multidisciplinary product designer [1]. There are texts aiming to define the designer

as a pragmatic FEA user [2-4] but it can still be difficult for both educators and students to pinpoint the correct level of "rigor" in product design FEA studies. None the less, the creative design engineer demonstrably capable in CAD based analysis is a highly desirable and valued profile in industry.
Engineering educators at Wentworth Institute of Technology [5] and others of the ASEE [6] have regularly written of teaching philosophies and case studies around strategic use of FEA in mechanical design. In this conference series we have considered the integration of engineering fundamentals in design projects [7], innovation in machine elements [8], and specific simulation types such as topology [9]. There has been relatively little explicit discussion of the teaching, learning and overall impact of computer-based analysis within Product Design projects. An explicit account is attempted here.

3 CURRENT APPROACH

Figure 1 shows 3 key themes of the Product Design Engineering curriculum instrumental to integrating mechanical design analysis with product design project methodology. Module size indicates relative contribution in terms of credit weighting. EE, fluids, maths, mechatronics, Industrial Design, production techniques and management are other compulsory themes not shown here.
Locally, the author has a relatively unique vantage point to evaluate engineering design and FEA teaching and learning through holding organising roles in Integrating Project 2 and Engineering Design, as well as tutoring analytical aspects of Design 2 and Integrating Project 3. All teaching staff supervise and assess individual projects and can observe how their curricular contributions may manifest within.

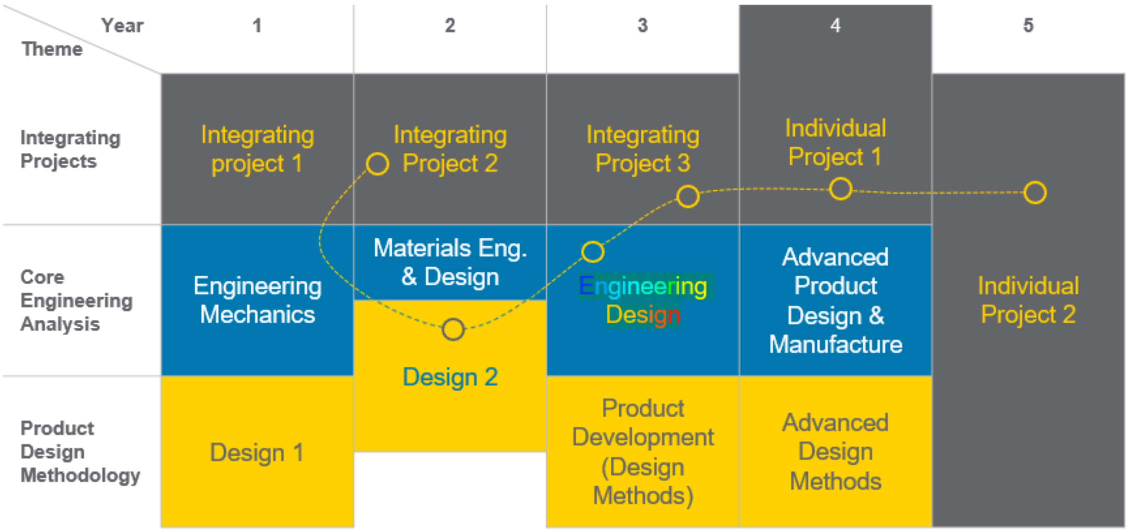


Figure 1. Partial PDE Curriculum showing relative module contributions directly relevant to FEA evidenced in Individual Projects 1 and 2. The author's involvement superimposed on the figure

3.1 Integrating projects and design methodology

Integrating projects 1 and 2 focus on CAD/CAM (including professional certification) and practical product build skills. Design 2 continues design methodology themes from Design 1 but with 25% of the module focused on integrating the engineer's bending formula and graphical force analysis techniques to analyse a product conceptualised by students. It is building upon year 1 Engineering Mechanics and introducing a pragmatic "designer" approach to analysis in a real product context. The project aims for a sense of iteration in analysis and Factors of Safety (FoS) to select section sizes and materials.

3.2 Engineering Design class and integrating project 3

Engineering Design in year 3 begins by revising product failure through bending, but quickly expands to reveal further failure modes – deflection, von mises stress, fatigue, buckling, stress concentration, motion loads and contextualized in machine element design for product design. Computer analysis techniques are introduced immediately for beam bending and sustained throughout the syllabus. To create a bending moment diagram in the CAD package requires students to learn the same steps for 3D FEA analysis – apply fixtures, apply loads, mesh and solve. Using a single software tool to bridge between simple 2D beam solutions and analysis of 3D multi plane stress parts leads to very smooth transition into the FEA topics and assessment. Students are tested every 3 weeks and are encouraged to use the software in the tests to check answers for simple and multi-plane bending/torque problems. The final test is a specific FEA assessment which advances the basic approach into analysis requiring advanced mesh control, split lines and more detailed fixture application to more complex geometry solid models. In parallel, the students are undertaking an embodiment product design project in "Integrating Project 3"; the author is involved in both modules highlighting linkages between the syllabi, introducing further CAD analysis such as topology study, virtual drop testing and strategies for converting 3D 'design models' to 'FEA models'.

3.3 Year 4

Advanced Product Design and Manufacture and advanced Design Methods in year 4 go into depth on other computer design support tools; DFMA and material selection, but do not currently expand on FEA. Some students may cover further FEA topics through optional module choices, and all are required to demonstrate "engineering analysis" in their "individual project 1" (worth 33% of year 4) and Individual Project 2 (worth 50% of their final year). In the projects students develop their own product briefs and are challenged to integrate previous knowledge with new project-based learning; it is difficult to balance new, exciting briefs with specific engineering opportunities. The majority do choose to utilise FEA.

4 FEA IN THE DESIGN PROJECT FOLIO

FEA is increasingly assumed essential to evidence analysis in projects. This is not necessarily problematic, but purpose in analysis is not always well articulated. Raw screenshots of an FEA analysis of the students' own design work can create an immediate impression of "rigor" in embodiment design, but that should only be concluded when more subtle quality indicators in FEA process are evidenced.

These projects cover so much ground – technical/market/user research, electrical/mechanical, prototyping, project management, systematic creativity, commercial aspects etc. Although not central, when scrutinised, FEA can also reveal significant insights into students' understanding. A light touch in analytical work more generally; a lack of iteration and optimisation of the design. Where simulation results are presented without discussion of setup and reflection on the implication of results on the design (see figure 5a.), the inclusion of FEA can undermine the project rather than bolster it. The decision of "great, some analysis is included" ☑ or "there is a lack of understanding of key principles of analysis" will come down to the other analytical strengths of the project.

5 STUDY APPROACH

Table 1 sets out parameters of the study. 'Individual Project 2' folios of 2 cohorts of students were analysed. Both cohorts have followed the curriculum path shown in Figure 1. Cohort 1 was chosen as an additional optional FEA "good practice" workshop was provided during embodiment design phases. The workshop included a tutorial/demonstration [4] and review of project folio examples and was attended by 10 students. Cohort 2 did not have this workshop opportunity.

Table 1. Study Sample Parameters

Cohort	Course	Samples	FEA Workshop	Lab access
1	Final Year MEng PDE	29	Optional (10)	Full
2	Final Year MEng PDE	29	No	Limited

Cohort 2 undertook their project without full access to prototyping facilities (COVID Pandemic restrictions) and therefore, interestingly, may have had higher reliance on virtual/simulation platforms. The author performed all analysis of the folios. An initial coding scheme was expanded/refined during the reviews. Table 2 provides an overview of criteria. All submission documents were reviewed where FEA results and discussion may by spread over report and folio documents.

Table 2. Study Criteria

Criteria	Explanations/Expectations	Quality Indicators
FEA relevance	Was it relevant and implemented?	Clear choice to include or not.
Study Types	See table 3 for range.	Discerning selection
Study Setup	Model simplification, fixtures, loads, mesh control, part vs assembly.	Highlighting decision making even when defaults are accepted.
Results and reflection	Reaction forces, stress, strain, displacement, Factor of Safety, clarity	Clear results extracted and some interpretation of results against

	of presentation.	design goals.
Validation	Cross referencing hand calcs or other data, check reactions.	Inclusion of some datum to validate that the numbers are realistic.
Impact	Was there clear intention?	Design revisions, clear decisions.

6 RESULTS

6.1 FEA relevance to project

24% (7) of cohort 1 did not complete FEA. These projects had either a bigger focus on electronic functionality (monitoring sport and sedentary behaviour) or struggled with complexity of surface models (2 x helmet designs) or water systems (irrigation kit). 2 students acknowledged that they would have ideally included CAD analysis. In cohort 2 17% (5) did not include FEA. In one case a highly detailed paper based analysis of tyre pressure control system was included. A student documented that FEA had failed in the time available, the 3 remaining did not provide alternative analysis.

6.2 FEA Study Types

Table 3. Distribution of FEA Study Types % (no. of Students)

	Static	Drop Test	Topology Study	Fluid Flow	Thermal	Fatigue	Mold flow analysis	Beam bending	Non-Linear
1	100 (22)	18 (4)	18 (4)	9 (2)	3 (1)	7 (2)	7 (2)	0	3 (1)
2	91 (24)	38 (9)	4 (1)	8 (2)	8 (2)	0	8 (2)	4 (1)	0

A potentially interesting difference is that some students in cohort 2 did only dynamic testing. It can be difficult to define use situations for some encased products, and the "drop test" offers eased dynamic impact testing. There were less topology studies in cohort 2, but topology was no less relevant to project models. Another student in cohort 2 generated bending moment diagrams in CAD finishing stress calculations by hand. As can be seen from the table many students undertook multiple study types, although none could be considered to have utilised multiphysics approaches.

6.3 Study setup

There was scope for better communication of the aim of studies and the explanation of the study setups. Figure 2 shows an example where the student provided a clear explanation of how the orthotic would be modelled and results utilised. Accompanying discussion provided rationale for these parameters, but many assume the reader can interpret from raw results alone (see Figure 3b). Figure 3 (a) shows an example of where the student was explicit in how the model fixtures and loads were applied, although not discussing how those were determined. Figure 3 (b) shows that a force has been applied to the whole face of a part when the use case of the product did not seem to warrant this.

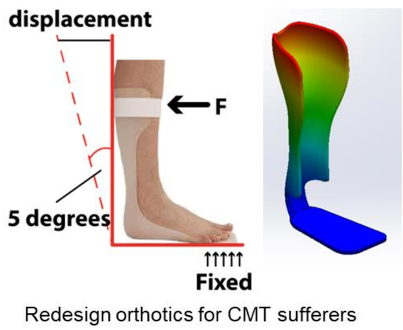


Figure 2. Clear setup example

In contrast, Figure 3 (c) shows a model prepared so that the force was strategically applied to match the use scenario. Only one project in cohort 1 and two projects in cohort 2 explicitly discussed mesh control. In one case mesh density had been increased to improve accuracy. In another (Figure 4a) this had been strategically done, in the way that had been promoted and assessed in year 3 class tutorials. In the majority of projects, the analysis is applied to a single part extracted from an assembly and therefore it is important to explain how the fixtures and forces reflect the assembly relationships. 38% and 36% of the cohorts analysed full assemblies, but only one student actually discussed how they had dealt with component interactions and contacts (Figure 4b.).

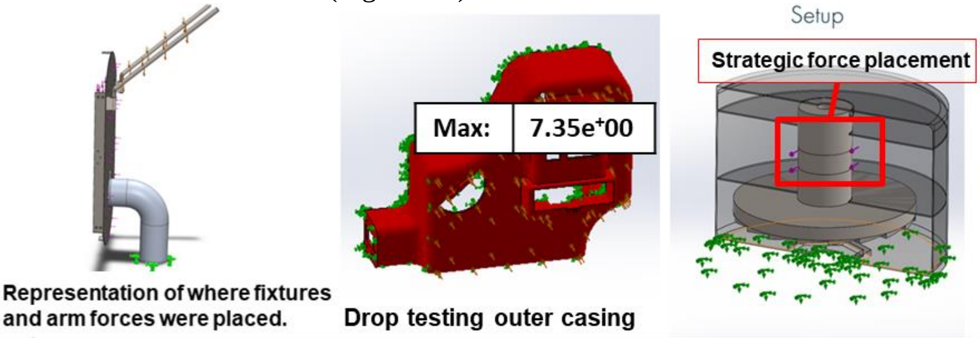


Figure 3. (a) EV fuelling station (b) unit casing; (c) urban air filter unit

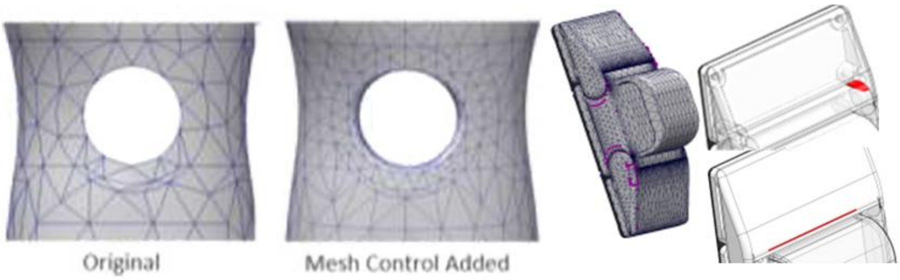


Figure 4. (a) interdental cleaning product mesh; (b) multi-part assembly

6.4 Validating and using FEA results for design impact

In the year 3 Engineering Design module students first learn to execute FEA to solve familiar 2D beam bending problems. Each problem is solved using formula alongside FEA, aiming to build confidence and emphasise a practice of checking and validating computer studies. This practice has been somewhat lost 2 years later with only 27% (6) of cohort 1 and 38% (9) of cohort 2 showing validating calculations in project work. Factors of Safety (FoS) derived from stress results are typically the most practical quantities for design and 50% and 65% of each cohort utilised FoS correctly. The best examples discussed results clearly in reports, highlighting key values (Figure 5b) and maximum stress locations (Figure 5c) in figures. However, there was a tendency for many to leave results as screenshots, too small to read (Figure 5a), with no design changes and 30% (6-7) of each cohort highlighted less useful strain results without any interpretation. In contrast figure 6 shows real design changes from iterative analysis.

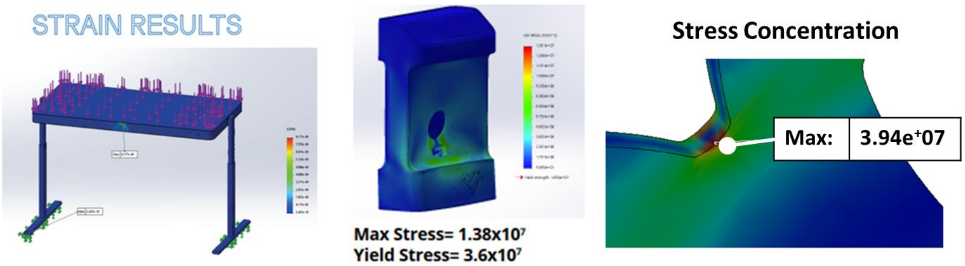


Figure 5.(a) home working desk; (b) defibrillator casing; (c) carry system for mountain bikes

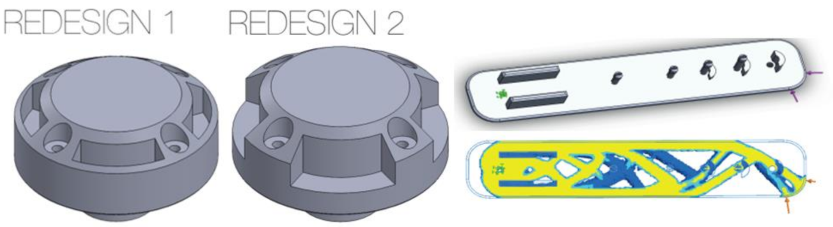


Figure 6. (a) lawn mower safety device (b) home daphnia cultivation device

7 DISCUSSION, LIMITATIONS AND CONCLUSIONS

The overall profile of the cohorts does not suggest that the FEA “good practice” workshop made a significant impact in the project work of cohort 1. Where a high proportion of cohort 1 included FEA, it is difficult to conclude that the slightly higher uptake in cohort 2 was due to the limited access to the university labs (often physical prototyping was achieved too despite this).

The growth in use of the “drop test” is not linked to any new timetabled initiative, but it was presented in the Integrating Project 3 for both cohorts. This may be one outcome of students’ looking for virtual testing options following restricted access to the workshops.

Topology studies appear to have wide application. There is a significant opportunity for promoting the use of CAD analysis for real design changes and therefore it seems reasonable to prioritise topology study for future syllabus and curriculum development work.

The relevance of fluid, thermal and fatigue studies will be project dependent. There were a number of more projects that could have utilised these e.g., a rowing machine was analysed for bending failure, but did not consider the repeated cyclic impact on some components. Buckling is relatively straight forward and often more relevant than bending, but not used. It is interesting that the software’s ability to analyse parts for their ease of injection moulding has not been explicitly taught, but students are making use of this feature in considering the manufacturability of their product. Like topology study, this appears a priority for embedding in the future. Where many students are undertaking multiple study types on the same part, multiphysics approaches should also be considered in the future.

Study limitations include that analysis was completed by the author alone and excluded year 4 project submissions and a project cohort who did not take the Engineering Design class but often undertake FEA. There have also been recent developments of the content and approach to delivering FEA which has not been captured in this up stream analysis; live and video demonstrations of FEA concepts and opportunities to be certified as an ‘FEA associate’.

The insights gained are discussed with focus on implications for future development of FEA teaching throughout the curriculum, with an overall aim for it to be used more often to push embodiment and detail design project phases forward and less often as an item on an assessment check list.

REFERENCES

[1] Meadwell J., Terris D. and Ford P. A little knowledge is a dangerous thing? Do BSc Product Design courses discourage collaboration?. *DS 83: Proceedings of the 18th International Conference on Engineering and Product Design Education (E&PDE16), Design Education: Collaboration and Cross-Disciplinarity, Aalborg, Denmark, 8th-9th September 2016*.

[2] Adams V. and Askenazi . *Building better products with finite element analysis*, 1999 (OnWord Press, Santa Fe)

[3] Kurowski P. *Finite Element Analysis for Design Engineers. 2nd ed*. 2016 (Warrendale: SAE International, Web).

[4] Akin, J. E. *Finite element analysis concepts: via SolidWorks*, 2010 (World Scientific, Singapore)

[5] Le, X., Duva A. W. and Jackson M. The Balance of Theory, Simulation, and Projects for Mechanical Component Design Course. In *2014 ASEE Annual Conference & Exposition*, Indianapolis, Indiana, June 2014, pp. 24-1189.

[6] Reffeor W. S. Using FEA as a Pedagogical Tool for Teaching Machine Component Design. In *2018 ASEE Annual Conference & Exposition*. Salt Lake City, June 2018.

[7] Bingham G., Southee D. and Page T. An integrated approach for the teaching of mechanics and electronics in a design context. In *DS 76: Proceedings of E&PDE 2013, the 15th International Conference on Engineering and Product Design Education, Dublin, Ireland, September 2013*

[8] Clavijo A., Boccardo R. and Angel R. Model Building in Machine Element Education. *DS 46: Proceedings of E&PDE 2008, the 10th International Conference on Engineering and Product Design Education, Barcelona, Spain, September 2008*, pp.

[9] Beger, A.-L., Brezing A. and Feldhusen J. "The potential of low-cost topology optimization." DS 76: *Proceedings of E&PDE 2013, the 15th International Conference on Engineering and Product Design Education*, Dublin, Ireland, September 2013.

DESIGN AND ENGINEERING AS AGENTS OF CHANGE: A CAPABILITIES FRAMEWORK

Ingrid MULDER and Alberto MAGNI
Delft University of Technology, The Netherlands

ABSTRACT
Design is generally accepted to provide valuable contributions to addressing complex societal challenges. Even though design and engineering professionals show increasingly capable of making societal impact, it is not straightforward why some creative practices are more impactful in fostering systemic change, let alone what additional capabilities they pursue to be distinctive. The current study introduces a capabilities framework highlighting a set of advanced design capabilities expanding the conventional skillset of designers and engineers towards enabling the adoption of local innovation at a systemic scale. Afterwards, the developed capabilities framework is used as a pedagogical framework to design a learning environment to prepare the next generation of design and engineering students to respond to today's societal challenges. We close with a discussion on the professional and pedagogic role of design and engineering as agents of change.

Keywords: Design capabilities, disruption, reflection, societal challenges, hyper-local transformation

1 INTRODUCTION
The UN Sustainable Development Goals (SDGs) call for new approaches to design addressing complex societal challenges because existing solutions to climate change, mobility, or urban inequalities are often not powerful enough to trigger structural social change [1]. For instance, the Oslo manifesto [2] promotes universal adoption of the SDGs as a design brief for the 21st century, while others stress the need to completely reinvent our socio-technical systems if we are to meet the SDGs [3]. In fact, such a move towards more socially and ecologically sustainable futures represents a collective societal design challenge and asks us to rethink design thinking and the design profession [3]. The current work responds to the call for new design approaches and aims to contribute to the current debate on the next professional and pedagogical role of design in bringing forward societal change. Over the past years, there is a growing interest in the role of design in addressing societal challenges [4-6]; expert designers are leaving their studios to generate solutions for global challenges at a local level. In their pursuit to help address the societal challenges they oftentimes collaborate with a diverse mix of local innovators, such as citizens, local authorities, academia, as well as private and public organisations. Although these coalitions differ in nature, they do share an interest in proposing positive change [7]. Interestingly, a growing number of such local coalitions that use design methods and processes beyond the conventional design domain are capable of leveraging the resourceful and interconnected nature of cities to foster hyper-local transformations. However, we lack empirical understanding of what makes some of these creative practices more impactful than others. It is, therefore, timely to consider the professional and pedagogical role of design and engineering as agents of change who tackling societal challenges; not only their diverse backgrounds and perspectives but also the scale and complexity of societal challenges force them to constantly adapt and learn, acquiring new capabilities to advance their initiatives towards systemic change.

1.1 Context of study
The context of study is a European research programme that aims to foster the uptake and scaling of radical and transformative innovation across European cities. The programme deliberately focuses on the urban context, as complex societal challenges manifest within cities and become more evident when they are directly affecting the lives of citizens. Through three open calls, local coalitions are invited to propose design solutions to address the SDGs. In total, a hundred design-enabled innovation projects across Europe are financially supported in different stages of innovation maturity, respectively

feasibility studies (1st call), prototypes embedded in an urban context (2nd call), and finally, pilots scaling their innovation across cities (3rd call); see [8] for details. The application platform guided the strategic articulation of design methods used and whether and how the projects responded to complex societal and environmental issues connected to the SDGs. Consequently, the awarded projects can be seen as exemplary agents of change demonstrating the value of design in hyper-local transformations that address global challenges. Next to funding and guidance to design methods and tools, the programme provided a capacity-building programme that, on the one hand, can be seen as a collaborative space for learning and reflection, and on the other hand, a community of learners [9]. Therefore, the objective of the research was to understand which capabilities are key to fostering change, embedding innovation locally, and scaling disruptive urban transformations, and next, how to train such capabilities to further infrastructure a learning community of change agents to diffuse disruptive innovation practices even beyond the programme itself. The resulting capabilities framework highlighting a set of advanced design competencies enlarging the skillset of designers and engineers necessary for local embedment and adoption of innovation at a systemic scale has informed the content creation of the training activities and guided the further development of learning community into the overall capacity building programme.

The current work introduces the developed capabilities framework as a pedagogical framework to prepare the next generation of design and engineering students to respond to societal challenges. The next section describes the method for our study. Afterwards, we introduce the identified capabilities key to embedding innovation processes locally and motivate how the use of such a capabilities framework can help bachelor and master students to reflect upon their designerly skillset. We conclude by elaborating on the value of the capabilities framework to discuss the professional and pedagogical role of design and engineering contributing to today's societal challenges.

2 METHOD

In order to understand what kind of competencies are needed to leverage designers' capacity to design for systemic change at a societal level, we have investigated pioneering creative practitioners to understand the professional role and then studied the pedagogical role in an educational context. Part of the setup of the programme, a literature review was conducted analysing existing studies on design expertise, capacity and capabilities, innovation capabilities and other expertise meaningful for innovation in the urban space, resulting in a draft list of capabilities that was used to inform the setup of a series of semi-structured interviews with selected pilots in the above-mentioned European project. Ten representative members of pilot projects were interviewed to understand what kind of skills and expertise were used to stretch their impact during the setup and development of their design projects. Interviews were conducted via the online communication tool Zoom and were audio-recorded for data collection. Afterwards, transcripts were analysed and loosely coded for recurring themes, skills, and abilities that were mentioned by innovators during the interviews. In an expert session, these clusters were contrasted with finding from literature review and synthesized in a capabilities framework highlighting the advancing role of design and engineering as agents of transformation in the public realm. The resulting visual overview has been used as a pedagogical framework for building capacity in these new professional roles (see Section 3, Figure 1 and Table 1). The framework not only guided the setup of a series of training for design practitioners active in social and urban innovation within the introduced capacity building programme but also the successful development of a learning community. The current study aims to further contribute to the debate on the professional and pedagogical role of designers and engineers as agents of change who aim at tackling societal issues. Hereto, the same framework has been utilised to set up a learning environment for design and engineering students with the aim to explore whether the newly identified capabilities fit their needs and bring opportunities for expanding current design and engineering education curricula. Two courses at the Faculty of Industrial Design Engineering were selected that fit within the scope of supporting design and engineering students in investigating the use of design for urban transformations and social innovation in urban environments. The first course, Design & the City, is a Master elective challenging design students to map, reflect, and elaborate propositions on the value that design plays within urban transformation processes, examine different roles of design and corresponding design capabilities, and explore what could be the next role of designers in supporting such enabling design processes at a systemic level in an urban context (n=158). The second course, People in Transit, is a Bachelor Minor attracting among others, students of Industrial Design Engineering, Mechanical Engineering, Aerospace Engineering, and aims to train students to develop complex mobility systems changing the fruition of the urban environment, therefore involving the creation of systemically embedded innovation at the urban level (n=59). In order to facilitate a learning environment with students and enable reflection on the needed capabilities to act as agents of disruptive urban transformations, the framework was used as a placeholder to help students reflect on the complex and interrelated tasks. Accompanying the framework, canvases and templates were designed to guide students in collaborative reflections on their projects as well as on initiatives of urban innovation, helping them articulate their thoughts on their roles as agents of change, and help them by scaffolding which capabilities they found most relevant to learn as innovation professionals for their current and future projects. Next to the students' reflections part of their assignment, data for our study was collected by observing whether and how the students referred to the capabilities elaborated in the framework and taking notes of their reflections during collaborative activities in class.

3 CAPABILITIES FRAMEWORK

Figure 1 shows the resulting three-layered visual overview motivating a set of professional capabilities needed for igniting urban transformations and refers to ten training models co-developed with the participating pilots answering their learning needs.

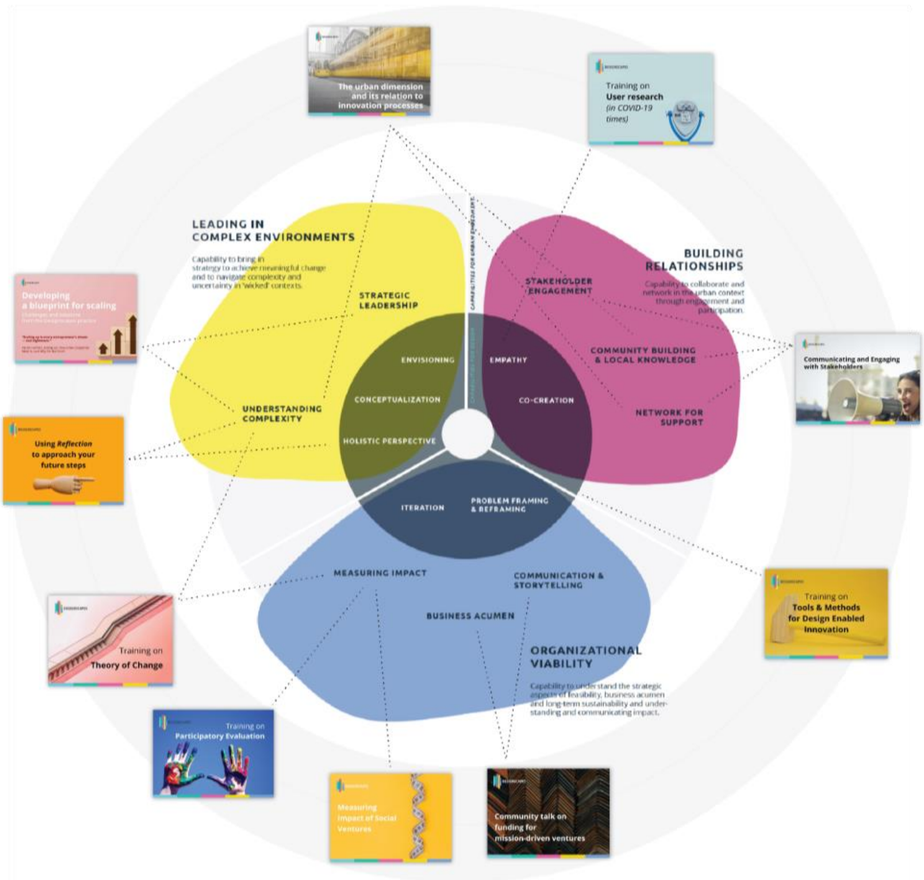


Figure 1. Framework of design capabilities for social innovation and urban transformations and corresponding training modules addressing key learning needs

3.1 Attitudes as pillars for change

The first, inner, layer of the capabilities framework shows what emerged as pillars for urban innovation, namely the main attitudes recognized as key for leading disruptive urban transformations. Key attitudes refer to important personal competencies that are necessary in order to sustain the right mindset when working on complex innovation processes aiming at bringing urban transformations.

3.2 Design capabilities for urban innovation

The second layer of the framework illustrates what has been recognized as specific design capabilities and skills that show precious in initiating and conducting innovation processes aimed at disruptive urban innovation. These include, among others, more conventional expert design skills such as problem reframing, the ability to conduct co-creation processes with stakeholders, conceptualizing abstract ideas.

3.3 Capabilities for embedding urban transformations

Finally, the third, outer, layer of the framework clusters that have emerged as additional competencies key to developing and embedding disruptive innovation processes within urban contexts. Such capabilities are clustered in three main areas of expertise and action that innovators should be capable of dealing with to succeed in their urban innovation processes, namely *working together*, intended as the ability and know-how for collaborating and networking (building relationships) in the urban context; *viability*, understanding of feasibility, business acumen and long-term sustainability; and *leading change*, the ability to create meaningful change by leading and creating the conditions that allow innovation (e.g., culture change, mindset). Table 1 shows the final list of competencies.

Table 1. List of competencies clustered in overarching capabilities and themes

1 - Personal Competencies		
Key attitudes	Passion and drive	
	Willingness to share and be open	
	Commitment and follow-through	
	Persistence	
2 - Design		
Design capabilities	Problem Framing & Reframing	Identify a problem or need, Explore different approaches and opportunities within the problem
	Conceptualization	Comfort with ambiguity and the abstract, Ability to visualize a concept or give 'shape' to it
	Envisioning	Conceptualizing an idea for the purpose of shared understanding and dialogue, Engaging stakeholders by using visualization to create a shared language
	Co-creation	Facilitation of creative skills in others
	Holistic Perspective	Understand the connection between details and the whole picture, Zooming in and out
	Empathy	Understand or share feelings of a user or stakeholder, Ability to conduct and apply user research for this purpose
	Iteration	Structuring loops or cycles of doing/testing and reflecting in order to come to the right solution
3 - Urban embedment		
Working Together	Stakeholder Engagement & Management	Stakeholder Mapping, Negotiation, Building consensus, Co-ownership models, Leadership skills, Building Trust & Transparency, Facilitation
	Community Building & Local Know-How	Building & mobilizing an on the ground network, Building trust & Transparency, Being accessible to the community, Being an Ally (e.g., Social Inclusion, Anti-Oppression Training, Understanding other), Embedding in the local urban context, Understanding the current context
	Network for Support and Connections	Peer support, Mentorship, Inspiration from others, Network or contacts in the field, Attending conferences, Connection to an established urban leader or institution in the field (legitimacy)

Leading Change	Strategic Leadership	Theory of Change, Strategy, Organizational Management, Stakeholder Management, Time and Project management
	Systems Thinking & Understanding Complexity	Systems mapping, Landscape mapping, Systems thinking
Viability	Business Acumen	Co-ownership models, Business model innovation, Sustainable value models (e.g., public or non-profit), Financing and investment (how to attract funding), Financial understanding, Validating an idea, Conducting a feasibility study
	Communication & Storytelling	Narratives & storytelling, Pitching
	Measuring Impact	Social Return on Investment, Demonstrating Value

3.4 Towards a pedagogical framework

The resulting framework was used to scaffold a guided reflection with students in two selected courses. The confirmed list of capabilities collected in our study, organized in layers explicitly exceeding the conventional design domain, facilitated students in acknowledging the expanded role of design practice when tackling urban transformations, allowing them to (indirectly) learn with and from design and engineering professionals' projects as concrete examples of disruptive urban transformations. Providing a lens to translate interconnected tasks into concrete competencies students could relate to, the framework facilitated students to compare their own projects with those of the selected design innovators who were seen as role models and enabled them to reflect on and articulate upon similarities and differences that would stretch their current design practice into agents of change.

4 DISCUSSION AND CONCLUSIONS

In the current section, we reflect on the proposed capabilities framework and discuss its value in stretching the current design and engineering curriculum and training future generations of urban innovators as agents of change in response to today's societal challenges. It can be concluded that the framework provides empirical evidence of key capabilities required by professional agents of change to successfully conduct social innovation and urban transformations. By elaborating upon three key areas of expertise fundamental for the embedment of disruptive innovation, the framework provides directions on how skills currently trained within design and engineering education could be expanded to build capacity of designer and engineers in establishing stronger "co-creative partnerships" [10] for innovation (working together), conceiving long-term sustainable innovation (viability), and facilitating the infrastructures and ecosystems [11] for social innovation (leading change). Furthermore, by employing the elaborated capabilities framework with university students we observed its value in use as a pedagogical framework supporting design and engineering students to increasingly become agents of change. Students showed to become more aware of the interconnectedness of tasks involved in urban transformations, and where and how different capabilities could be key for conducting such processes. Assessing the value and limitations of their current design and engineering expertise in accelerating urban change, also helped them to articulate how to expand their skillset as agents of change, particularly in the context of mission-driven innovation as well as facilitating local change, and urban transformation [12]. The following quote illustrates how bachelor students recognized the establishment of stronger relations with stakeholders at different levels as a key learning need for their team to conduct their mobility project in the city of Rotterdam.

"It would be nice to have the capabilities from Theme 3.1 (working together) more implemented in the team, since we then have more valuable connections to relevant parties", "I think it would be interesting to improve the ground network and maybe learn some techniques about interviewing or observing people in the urban context"

Interestingly, the framework also showed value as a scaffolding model to allow students to monitor their growth over time, towards becoming professional agents of transformation.

“It could be very nice to have one of those discussion sessions in the first week, to get a broad understanding of everything that is still needed, and one in the second or third week, to see how much progress has been made”

We particularly noticed how Master students transformed in their design practice after taking the course. Students embraced more complexity in their design projects and were able to identify multiple layers of design activity, for example, articulating strategic actions for ecosystems infrastructuring [11] next to conventional value creation activities:

“I really liked that I could (in the same project) zoom in to create immediate value, but also step back and look at the broader picture trying to create this network and infrastructure”

It can be concluded that the developed capabilities framework not only enabled students to become more aware of a new role that designers and engineers should take in order to accelerate urban transformations, but they also became more ambitious in their design projects (inclusion of multiple stakeholders, dealing with power literacy). In particular, the framework showed valuable in stimulating the engagement of students towards acquiring new competencies, activating students’ receptiveness and eagerness to acquire and cultivate a larger skill set of capabilities, ultimately showing promise to guide them in developing their skills over time towards becoming increasingly capable agents of disruption and transformation in cities. Last but not least, several students even managed to articulate their pioneering role in job interviews and got hired as change agents within systemic service design agencies and/or leading tech consultancy firms.

ACKNOWLEDGEMENTS

The current work is part of DESIGNSCAPES (Building Capacity for Design enabled Innovation in Urban Environments) funded by the Horizon2020 call CO-CREATION-02-2016 - User-driven innovation: value creation through design-enabled innovation, under Grant Agreement No. 763784. Special thanks go to the students participating in the Master elective Design & the City and the Minor People in Transit as well as to Alicia Calderón González, Kirsten van Dam and Maya Goodwill for their support in interviewing the participating pilot projects. The support of and fruitful discussions with of Elmer van Grondelle and the partners of the DESIGNSCAPES consortium are gratefully acknowledged.

REFERENCES

[1] United Nations Sustainable Development Goals. Available online: https://sdgs.un.org/goals

[2] Oslo Manifesto (2015). The SDGs are a Design Brief for the 21st Century. Available online: https://www.oslomanifesto.com

[3] Mulder I. and Loorbach D. (2018). Rethinking Design: A critical perspective to embrace societal challenges. In: Kossoff, G. and Potts, R. (Ed). *Can Design Catalyse the Great Transition: Papers from the Transition Design Symposium 2016*, Dartington, UK, pp. 16-24.

[4] Buchanan R. (1992). Wicked problems in design thinking. *Design Issues*, 8(2), pp. 5-21.

[5] Margolin V. and Margolin S. (2002). A “social model” of design: Issues of practice and research, *Design Issues*, 18(4), pp. 24-30.

[6] Manzini E. (2016). Design culture and dialogic design, *Design Issues*, 32(1), pp. 52-59.

[7] de Koning J., Puerari E., Mulder I. and Loorbach D. (2019). Landscape of participatory city makers: A distinct understanding through different lenses. FormAkademisk - Research Journal of Design and Design Education, 12(2), pp. 1-15.

[8] Designscapes.eu: Funded Initiatives. Available online: https://designscapes.eu/funded-initiatives/

[9] Designscapes.eu: Design-enabled Innovation Training Modules. Available online: https://designscapes.eu/dei-training-modules/

[10] Mulder I. (2018). Co-creative partnerships as catalysts for social change, *Strategic Design Research Journal*, 11(3), pp. 178-185.

[11] Morelli N., Aguilar M., Concilio G., De Götzen A., Mulder I., Pedersen J. and Torntoft L.K. (2017). Framing Design to support Social Innovation, *The Design Journal*, 20:sup1, S3171-S3184.

[12] Mazzucato M. (2018). Mission-oriented research & innovation in the European Union. European Commission.

ENDING UP AT THE BEGINNING – TEACHING MATERIAL DRIVEN DESIGN TO ENGINEERING STUDENTS

Fredrik HENRIKSSON
Linköping University, Sweden

ABSTRACT
Material Driven Design, or MDD, is a new way of realizing products starting in the understanding of the material rather than the need-driven approach that can be used to describe classic product development methodology. While new, MDD has potential to encourage more sustainable products being developed and is a useful tool for new designers and engineers to learn. In this paper, the author presents some lessons learned from teaching MDD to students in design and product development at a Swedish university. These students have experience from design and product development projects but have not done material-driven projects before. In general, the author concludes that the students are remarkably well-prepared in terms of tools and knowledge to do MDD, but that course coordination can make the projects less efficient if this is not solved early on. In master thesis projects or courses with few in-process deliverables, the implementation seems easier and can give students another path to solve problems in industry.

Keywords: Material driven design, design education, NPD, engineering education

1 INTRODUCTION
The product development process has been described in multiple different ways, but in general it comes down to the process of transitioning from some kind of market opportunity into a physical product, sold and delivered to customers [1]. A part of this is the definition of the product itself [2], and physical products can be defined by their material, geometry, and the processes used to manufacture them [2]. In a typical curriculum for mechanical or design engineering students, all these three parts of the definition will be addressed to some extent, with different emphasis depending on specialization, traditions and other factors affecting course composition at a certain university. In this paper, the emphasis will be on the teaching of materials in products and specifically how decisions regarding materials in products can be made.
There are multiple perspectives that can be taken on material selection [3], and is something that is taught to engineering students. But can classical methods for material selection, or even classical product development processes, cover all types of projects that engineers will face? Given the vast number of development projects being conducted in industry at any given time, it is unlikely that all of them would fall neatly into one specific process description. While classical product development methodology is based on problem-driven challenges, there could be other reasons for starting a product development project, perhaps some sort of technology-push variant rather than the more classical market pull process. And even within the problem-driven approach, ideas like agile development can be argued to alter the way a product development project is done. Agile development originates from software development [4] but has been adapted to the development of physical products as well [5, 6]. There is a need for teaching engineering students more than the classical approach to product development, and one of the interesting newer methods is Material Driven Design [7]. But what happens when Material Driven Design is included in an educational programme still centred around problem-driven development approaches? Can it be introduced without rewriting the whole curriculum, and can material-driven projects be run alongside traditional, problem-driven, projects?

2 MATERIAL DRIVEN DESIGN

Material Driven Design [7], (MDD), is a method for designing new products. While other, more traditional, methods for product development are based on a problem for a customer [8], MDD derives its name from the fact that the material to develop a product in is the first input into the process. Karana et al [7] describes four stages of the method: Understanding the material; Creating materials experience vision; Manifesting materials experience patterns; Designing material/product concepts, as can be seen in Figure 1. With regards to workload, stage 1 and 4 are more time-consuming where stage 4 contains much of what would be described in a traditional product development methodology model.

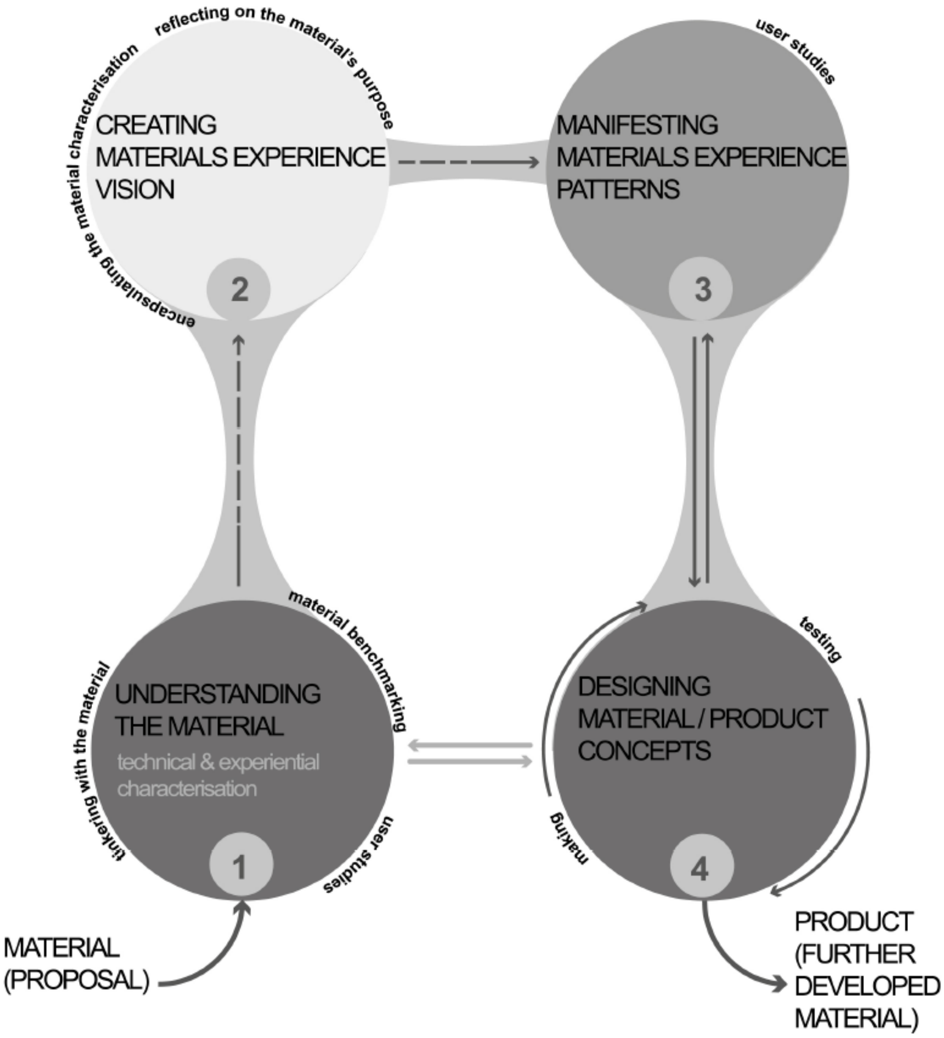


Figure 1. The MDD Method, figure from Karana et al. [7]

While a problem-driven product development process like Ulrich and Eppinger [8] or Pahl et al [9] would implement something similar to Ashby's material selection method [10] for selecting materials in a detail design stage, MDD both starts with a material and centres around the material properties rather than the product requirements [7]. It can be argued that these methods are not made for the same kinds of products, but even if replacing Ashby with something more focused on material experience, like Karana et al presented in their tool for meaning-driven material selection [11], this still assumes that some design work has been done before the material selection is done and that there are product requirements (or sought-after experiences) that can be fulfilled by selecting the appropriate material. MDD turns this around by finding the correct product for the material used in the project [7]. MDD thus should be viewed as a method for setting up the whole development process, and not a tool to select a material.

3 STUDY SETTING

This paper covers experience from the teaching of Design and Product Development students at Linköping University. Material Driven Design was introduced in the curriculum on the third year of a combined bachelor's and master's degree programme in 2017. Since then, the topic has been covered as a part of a general course on materials and their role in design, as well as in bachelor thesis projects, project courses in later years and master thesis projects.

In general, the Design and Product Development programme curriculum emphasizes on a combination of classical engineering skills and holistic design knowledge, and the capability to both analyse and create services and products [12]. Looking at the general course on materials and their role in design in particular, the emphasis is on understanding how material structure affect material properties, and how these material properties affect product properties [13].

While both the general course on materials and their role in design and the master thesis projects are unstructured in terms of fixed dates for deliverables, the bachelor thesis project and later year project courses utilize some form of simplified stage-gate model inspired by Cooper's description [14], intended for course coordination. This means that the students have fixed dates for delivering planning documents, pre-studies, concepts, and developed solutions. These courses do not have clearly defined definitions of what pre-studies, concepts or developed solutions could entail, especially not for material-driven projects, but rather guidelines that can be adjusted somewhat to fit a specific project.

In total, approximately 10 projects are studied, totalling 50 students. Of these, five projects are directly material-driven (defined as the main goal in the brief) and the other 5 are projects from courses where students are free to choose between problem-driven and material-driven project approaches and (as approximately 10% of the total course class) have included material-driven design approaches to some extent, sometimes in a hybrid fashion with traditional product development approaches and sometimes as including "MDD workshops" as an ideation tool. These projects have covered established wood-based materials as solid pine as well as novel, high-technology materials as flexible solar panels and graphene. In all the studied courses, problem-driven and material-driven projects are mixed so that both types of projects are done within the same course (but not by the same students).

4 OUTCOMES

The outcome will be divided into three parts; preparing the project (focusing on outcomes from writing the brief etc.), supervising the project (focusing on the execution of the project itself, and how supervision can be done), and analysing the outcome of the project (where the course coordination and grading of the project will be discussed). This section mainly covers aspects that can guide planning and implementation of material-driven projects in similar settings.

4.1 Preparing the project

Before the project is started, resource-allocation can differ somewhat from other projects since the students may require more time for experimenting with and experiencing the material early in the process. While experimenting is common in all design processes, the physical experimentation with materials can require more in terms of equipment, time and availability from experts.

For the preparation the project, the only main difference when writing a project brief for a problem-driven and material-driven project seems to be that the material-driven brief does need to be more clearly defined; the students will accept some higher level of uncertainty in the problem-driven brief than in the material-driven. This could certainly be due to experience with problem-driven briefs vs. inexperience with material-driven briefs, but other's experience would be much welcome to further analyse this.

When looking outside of preparing the brief for the students, some extra time needs to be spent on explaining the concepts of MDD and what it can mean in terms of in-course deliverables to other involved teachers, since they can differ significantly from what they are used to from problem-driven development projects. This also applies to support infrastructure such as workshop access or laboratory environment; both timing and tasks can be differing from previous experience which can sometimes raise questions from support infrastructure personnel.

4.2 Supervising the project

During the execution of these projects, the supervision is not significantly different from supervising other projects for similar students. The overall work is very similar, as well as the distribution between problem-solving, motivational work, and enforcing the requirements set for the course, but the distribution in time could differ somewhat from problem-driven projects since the crunch-points differ between the two types of processes.

In the early stages of the project, some encouragement to test can be needed. From our experience, the students can be hesitant to perform “simple” tests or tinker since it can be perceived as non-value-adding. This can usually be resolved with encouragement, but without some intervention the process can slow down while students try to design experiments “worthy” of the time spent instead of building experience and knowledge gradually.

At a certain point in the project, usually around the initiation of stage four in the MDD process, there seems to be a small “slump” where the students can express some sense of dejection when they realize that this is approximately where a problem-driven project starts; they feel that they have spent a large portion of the time available in the project only to ending up at the beginning of a project. The supervision usually must focus on motivating the students here, and after having pushed through the students often express surprise over how easy the decisions were in the later stages of the process since they already have worked through the ideas and formulated a clear vision and goal for the end product.

During the supervision, it can be beneficial to remind students of the different tools that they have learned in previous courses and discuss how these can be applied in a material-driven project. The author’s experience is that the students have multiple suitable tools available, but that they can need some help to understand that they can apply them in a different type of development process as well. After the first two or three tools implemented in the project, this is usually solved.

4.3 Analysing the outcome of the project

On a general level, the outcome from these projects does not differ significantly from problem-based development project. The quality of the final products is similar, and the level of innovation is also similar: some projects have innovative potential, while others less so. This is while the starting point of the project types are vastly different, which at least indicates that the students can manage using MDD as well as traditional product development methodology as a tool to generate product concepts. MDD can also be said to fulfil the basic description of product development as described by Krishnan and Ulrich [1], so this outcome is not unreasonable from a theoretical standpoint.

No real conclusions could be drawn regarding student long-term learning from this study, but the students working in these projects does not seem to have any more issues fulfilling the course requirements in comparison to their counterparts in problem-based development projects. It can also be argued that including MDD should give the students another way of setting up a design project, which should help understanding the complexities of design and product development further.

One identified challenge is the course coordination and check-up throughout the course. Especially mid-way through the projects, the gate meetings and deliverables are complicated for both teachers and students to navigate. These gate meetings are reasonably-well-fitting to classical product development processes, and the deliverables are more clearly defined when the classical, problem-driven process is synced with the gates. Especially if there are multiple projects in a course and there is a mix of material-driven and problem-driven projects, this can create uncertainty among students and teachers that can affect the progression of the project. One example is the use of a concept gate, where clearly defined concept ideas were presented. In the material-driven projects, the definition of the concept was unclear and complex to translate to a point in the MDD process. This created some uncertainty among both teachers and students, that affected early projects in a negative manner.

When the project is finalized, the difference between a material-driven and a problem-driven project diminishes, so grading and evaluating the project is not usually a problem if the students have managed to design a product and going through all four stages in the MDD method. The author cannot vouch for the ease of grading if the project is not as finished, since this could become more like the mid-way deliverables that are described in the previous paragraph.

5 CONCLUDING REMARKS

From this work, we can see that industrial design engineering students can produce innovative solutions with a high level of quality while using MDD for product development. The students themselves are also remarkably well-prepared for using the method, since most traditional tools, methods and activities used in design engineering can be used in an MDD process; the students already have a functioning “toolbox” for realizing products in this manner. What becomes the issue with this working process, instead, is to fit a material-driven project into a classic stage-gate model used for course coordination.

If suitable steps can be made in the course coordination to accommodate for the specific progress of an MDD project, the students seem to both enjoy the process and broaden their ability to tackle different types of industrial problems without having to relearn all new tools. This means that teaching MDD can be a resource-effective way to provide engineering and design students with another path to solving problems.

The author will continue to teach and use MDD as a tool in design and engineering education as of now, since there are industrial application of material driven design and since the students already have much of the knowledge needed to master the process. Thus, including MDD in the education seems like a small effort for possibly significant gains for the students.

For future work, the author sees the benefits of making a more structured implementation analysis, as well as studying the long-term learning outcomes from implementing MDD as a complementary method to classical product development work in teaching. After this has been done, the plan to continue teaching MDD mentioned in the previous paragraph will be re-examined.

REFERENCES

[1] Krishnan V. and Ulrich K. T. Product Development Decisions: A Review of the Literature, *Management Science*, vol. 47, no. 1, pp. 1-21, 2001.

[2] Ullman D. *The Mechanical Design Process*, Fourth Edition ed., New York, USA: McGraw-Hill, 2010.

[3] Henriksson F. *On Material Selection and Its Consequences in Product Development*, Linköping: Linköping University, 2021.

[4] Beck K., Beedle M., van Bennekum A., Cockburn A., Cunningham W., Fowler M., Grenning J., Highsmith J., Hunt A., Jeffries R., Kern J., Marick B., Martin R. C., Mellor S., Schwaber K., Sutherland J. and Thomas D., Principles behind the Agile Manifesto, [Online]. Available: *https://agilemanifesto.org/principles.html.* [Accessed 18 03 2022].

[5] Cooper R. G. and Sommer A. F. From Experience: The Agile-Stage-Gate Hybrid Model: A Promising New Approach and a New Research Opportunity, *Journal of Product Innovation Management*, vol. 33, no. 5, pp. 513-526, 2016.

[6] Scaled Agile, "SAFe 5," [Online]. Available: *https://www.scaledagileframework.com/.* [Accessed 18 03 2022].

[7] Karana E., Barati B., Rognoli V. and van der Laan A. Material Driven Design (MDD): A Method to Design for Material Experiences, *International Journal of Design*, vol. 9, no. 2, pp. 35-54, 2015.

[8] Ulrich K. T. and Eppinger S. D. *Product Design and Development*, New York: McGraw-Hill/Irwin, 2011.

[9] Pahl G., Beitz W., Feldhusen J. and Grote K. *Engineering Design - A Systematic Approach*, Third ed., London: Springer, 2007.

[10] Ashby M. F. *Materials Selection in Mechanical Design*, Italy: Butterworth-Heinemann, 2005.

[11] Karana E., Hekkert P. and Kandachar P. A Tool for Meaning Driven Materials Selection, *Materials and Design*, vol. 31, no. 6, 2010.

[12] Linköping University, "Civilingenjörsprogramme i design och produktutveckling, 300 hp - Utbildningsplan," [Online]. Available: *https://studieinfo.liu.se/program/6cdpu/.* [Accessed 18 03 2022].

[13] Linköping University, TMKM11 Material för design - Kursplan, [Online]. Available: *https://studieinfo.liu.se/kurs/TMKM11*. [Accessed 18 03 2022].

[14] Cooper R. G. Stage-Gate Systems: A New Tool for Managing New Products, *Business Horizons*, Vols. May-June, pp. 44-54, 1990.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

USE OF DESIGN OF EXPERIMENTS, DESIGN THINKING, AND DATA SCIENCE IN PRECISION AGRICULTURE

Verónica SAAVEDRA, Carlos GONZALEZ-ALMAGUER, Arturo BARRON, Claudia ZUBIETA, Eduardo CABALLERO, Hugo PEREZ and Lourdes MUCIÑO
Tecnologico de Monterrey, Mexico

ABSTRACT
Precision agriculture was born with the massive introduction of GPS at the beginning of this century and consists of the use of technology to obtain data, its statistical treatment, and decision-making.
At the Tecnologico de Monterrey experimental agriculture centre, precision agriculture has been implemented to obtain better sowing techniques and to optimise resources; this information has served the farmers of the Bajío region to improve their harvests.
The use of satellites to obtain sensitive information, in addition with technological innovation such as the use of sensors and drones, provides a large amount of information that requires the implementation of design techniques. First, it is necessary to build databases and later, through the design of experiments and design thinking, to elaborate the statistical experiments in which the appropriate parameters will be obtained to maximise the production of agricultural products with the highest nutritional value and quality.
Nowadays, supported with data science, design of experiments, and precision agriculture the present research is the base for future works applying these concepts in order to contribute to the development of Mexican agriculture. This has led during the last year that the department of industrial engineering of the School of Engineering and Sciences of Tecnológico de Monterrey the need of the design of databases to take advantage of the information obtained in the experimental field and using dynamic factor factorial design techniques and machine learning, they were capable to obtain information for decision-making.

Keywords: Design of experiments, innovative education, data science, precision agriculture, higher education

1 INTRODUCTION
This paper shows the results obtained from the design of a methodology that fuses the Design of Experiments, Design Thinking to Data Science, as well as its implementation for the subject of Analysis of Design of Experiments, and the end-of-course projects were made at the Centro Agrícola Experimental del Tecnologico de Monterrey (CAETEC) focused on the search for the appropriate parameters to maximise the level of nitrogen in corn, which is part of the diet of cattle in milk production. Likewise, CAETEC is a living laboratory focused on the practice of techniques and theory seen in class to maximise the experiential learning of students according to the TEC 21 Model of the Tecnologico de Monterrey (challenge-based learning).
In 1564, Vasco de Quiroga began technical agriculture in the new world by comparing climates and soil characteristics in Spain to introduce new crops in the Purépecha region today known as Michoacán, with which he took advantage of natural conditions to generate poles of development through agriculture. Sir Ronald Aylmer Fisher was a statistician and biologist. In 1919 he began working at Rothamsted Research, an agricultural experiment station, where he developed the analysis of variance to analyse his vast data on crops grown since the 1840s, which gave rise to the design of experiments.
The design of experiments refers to the process of designing and conducting experiments in such a way that adequate data are collected that can be analysed with statistical methods to obtain valid and objective conclusions. (Montgomery, D.) [1] A natural starting point for the design of experiments in agriculture

is the excellent review by Verdooren (Verdooren, LR) [2] who tracks development from ancient times through to the advent of Sir RA Fisher in 1926, which represents the start of modern statistical design. The design of experiments can be used as a statistical simulation tool, in which the parameters can be changed, and different results observed; in agriculture it allows us to approach the ideal parameters without having to wait for the sowing - harvest cycle to end to analyse the results, this allows us to dramatically reduce research and development time (Almaguer, C. et al) [3]. Figure 1 shows the precision agriculture timeline.

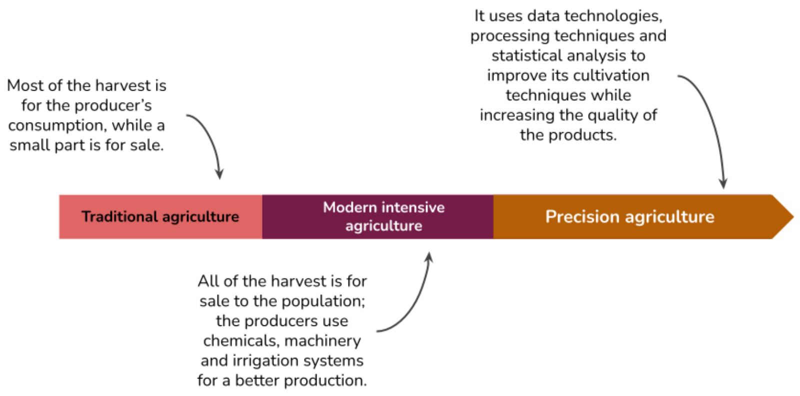


Figure 1. Timeline of precision agriculture

For students, the most difficult part in the design of experiments process is the definition of the problem, abstracting reality into a model where the variables and interactions of the system can be reflected is not very simple, to correct this weakness in 2009, González and Lloveras [4] proposed to introduce the engineering of thought that is based on the algebra of sets to focus the investigation only on the area of interest. This methodology was enriched with the introduction of design thinking and in this way, we proposed a methodology that fuses this technique with the design of experiments primarily to generate learning activities but has led to the design of new products or processes. Figure 2 shows the relationship between Design Thinking, Design of Experiments, and Data Science.

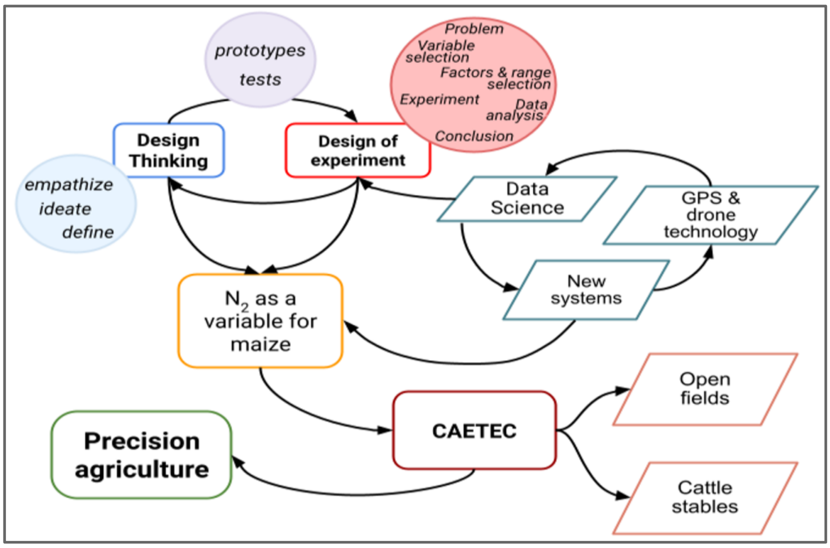


Figure 2. Relationship among design thinking, design of experiments and data science Self-elaborated

Design thinking has been used to educate in medical schools with two primary functions: the first, to develop a specific new product and the second, to develop in the students a problem-oriented way of thinking about the development of a new product. Regarding the last, Hernández [5]. Sanders J. and Goh P. [6] illustrate design thinking among second-year students to develop a new community service, highlighting as challenging the stakeholders' diverse perspectives and the introduction of extra activities

to the medical students' curriculum. Design thinking has also benefited the business administration program at the University of Amazonia, where students generate experiences corresponding to their reality as citizens. By applying DT principles, they can promote the learning of social thinking skills in other people. (González-Almaguer, C., et al)[7].
The term Data Science (DS) refers to an interdisciplinary field that involves a series of methods, processes, and systems, with the aim of extracting knowledge from data. DS, which is a discipline very related to Computing, has proved to be of great application in very different domains, particularly Education (Klašnja-Milićević et al., 2017) [8].
The application of DS in the field of Education may result in great interest for involved stakeholders (students, instructors, institutions, etc.) since the extracted knowledge from educational data would be useful to deal with educational problems such as students' performance improvement, high churning rates in educational institutions, learning delays, and so on. There are a series of disciplines related to Educational Data Science, such as Educational Data Mining and Learning Analytics (Romero & Ventura, 2020), [9], and all of them are of importance for this special issue.

2 DOE IN PRECISION AGRICULTURE

CAETEC is an educational laboratory for the students of the Tecnologico de Monterrey, and it is the place where they are expected to learn about the different types of fertilisers, the types of soil, and the type of irrigation used and put into practice the concepts acquired to the experimental design; therefore, the implementation of precision agriculture can be a success factor in practice. 'Precision agriculture is a management strategy that gathers, processes, and analyses temporal, spatial, and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.'(International Society Precision Agriculture) [10]. For academic purposes, the study of this branch of knowledge is integrated as an enterprise resource planning system (ERP) and the generation of the data is the raw material for the design of experiments, as well as the data science. Integrated information is the source for precision agriculture, and it helps researchers and students to develop a prospective thinking.
To maximise milk production, the significant variable is the level of nitrogen in corn [11], which is an essential component in the diet of cows, being the main factor for milk production. The cycle begins with a corn seed and ends with the production of milk.
To achieve these conditions, it is necessary to experiment with different planting methods to obtain corn, which in turn will be the primary food for the cows. CAETEC has a cattle herd focused on milk production. For this reason, it is intended to carry out the design for precision agriculture with which it is sought to maximise the level of nitrogen in corn. For this analysis, a design of experiments of three factors was proposed: Fertiliser, Type of irrigation, and Type of soil. These factors are considered by CAETEC as fundamental in the percentage of nitrogen in corn. With the approach of the design of experiments, it is intended to validate this argument.
In this way, students will not only learn the different types of fertilisers, type of soil, and type of irrigation, but they will also put into practice the concepts acquired in the experimental design. The following figure shows the relationship between the three factors to be analysed and their interactions.

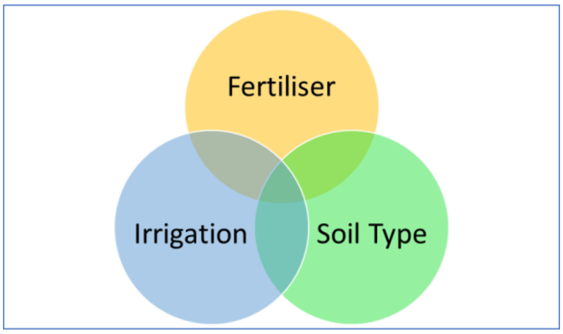


Figure 3. Example of Three factor Factorial Design. Self-elaborated.

2.1 Proposal for design of experiments

Halamchi, et al. [12] proposed Regression Analysis for predicting dry matter intake (DMI) in cows, this affects directly in the production of milk. The nature of the data in CAETEC does not allow the use of regression analysis and hence Design of experiments was proposed.

According to Montgomery [1] the guidelines for Designing and Experiment is given by:

1. Recognition of and statement of the problem Pre-experimental
2. Selection of the response variable
3. Choice of factors, levels, and ranges
4. Choice of experimental design
5. Performing the experiment
6. Statistical analysis of the data
7. Conclusions and recommendations

The purpose of this article is to design jointly with CAETEC and the School of Engineering and Sciences of the Tecnologico de Monterrey until step 4, that is, until the selection of the experimental design.

2.2 Three-factor factorial design

The first proposal for CAETEC consisted of using three factor factorial design which involves three factors or sets of treatments. Factor A was going to be the soil type, Factor B was going to be the fertiliser, and Factor C was going to be the irrigation method, these are arranged in a factorial design; that is, each replicate of the experiment contains all treatment combinations. For this type of design, it is necessary to have at least two replicates of the treatments. The order in which the observations are going to be taken will be at random so that this design will be a completely randomised design.

Factor A (Soil type)
Factor B (Fertiliser)
Factor C (Irrigation method)
The effect model i was given by:

$$y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \epsilon_{ijkl} \qquad (1)$$

where:
□ is an overall mean effect,
τ_i is the effect of the ith level of the row factor A,
β_j is the effect of the jth level of column factor B,
γ_k is the effect of the jth level of the row Factor C,
$(\tau\beta)_{ij}$ is the effect of the interaction between i and j
$(\tau\gamma)_{ik}$ is the effect of the interaction between i and k
$(\beta\gamma)_{jk}$ is the effect of the interaction between j and k
$(\tau\beta\gamma)_{ijk}$ is the effect of the interaction among i, j, and k
ϵ_{ijkl} is the random error, Normal(0,□^{2})

All the factors are assumed to be fixed. The treatment effects are defined as deviations from the overall mean and the effects of the interactions are fixed and also add up to zero.

3 A NEW MODEL TO OPTIMISE THE RESPONSE VARIABLE

Traditionally we conceptualise the factors, as referred to in figure 2, and we look for their relationships, in a said model that reflects traditional agriculture we have 3 factors that, in turn, represent 7 hypotheses of interest, being the dominant one or, the one that explains the response variable is the intersection of the three, and for this, we must determine the levels until we find the perfect combination. There is also a need to analyse new factors such as the type of seed and the nutrition of the crop. In the CAETEC the students and experts, thanks to design thinking, noted that this kind of model was insufficient to predict the response variable, hence a new methodology was proposed.

Design is everything. New technologies and the exponential growth of data science challenge researchers in new ways to conceptualise factor selection and levels to maximise response variable, and the paradigm shift is to migrate from static design of experiment models to dynamic experiment models through data science, specifically with the use of machine learning algorithms that instantly generate the necessary levels to generate a design of experiments and maximise the response variable at a point in time.

The use of state-of-the-art technology to obtain information such as drones, sensors on tractors, and satellites, allows us to obtain data in real time, which, when used in correct models, allows us to make the correct combination of levels in the factors that give as a result, the optimization of the NDVI level. The NDVI is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green on an area of land (Weier and Herring, 2000) [11], which in the end we can translate as the nitrogen level.

In this new model, we conceptualise all this information to obtain the levels, we must change towards a view of decision trees in a timeline, that is, each factor is, in turn, made up of multiple variables that are derived, in turn, in multiple experiments. For example, to form the favoured level, we require information from the soil, and this is formed by the depth, length, and density, the information obtained by the satellites together with the combination of the sensors in the tractors allows us to have relevant data on the mineralization of the land, combined with the time variable, and the region or cell studied (a cell studied is the coordinate obtained in a crop field) generates its levels.

The design of machine learning algorithms will allow us to generate and process this information to predict the correct factors and levels for the factorial design. This process will be replicated for all the necessary factors in order to maximise the nitrogen in the corn.

The use of statistical quality control tools, such as the Pareto diagram, will allow us to define which factors are the most decisive to be analysed and simplify their application in the agricultural field. A dynamic design of experiments will allow us to make corrections in the timeline of the sowing-harvesting process, as well as to do preventive measures when the machine learning algorithms give us warnings about external factors that affect our production system, such as the climate and pathogens, and will allow us to prevent these variables from affecting the result. Figure 4 shows us the proposed methodology.

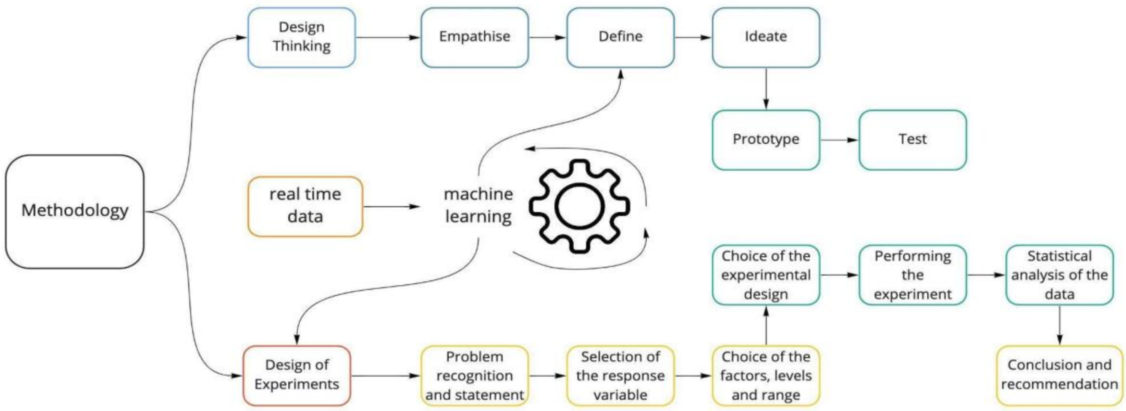


Figure 4. Proposal of Methodology. Self-elaborated.

The design of the layout for the databases is decisive, this will optimise the data mining process, facilitating the selection of quality data and thus avoid contamination of information by useless data; in this part, statistics play a fundamental role.

4 CONCLUSIONS

In the present research, we worked on the design and definition of the variables of interest to improve the corn crop, that is, up to the approach of the problem and the suggested methodology for the analysis of the information to be able to carry out the CAETEC data science. It is necessary to work with algorithms that allow us to find the levels of the factors in the proposed design of experiments. Once the data is collected, the DS will be crucial in the analysis of the information. DS added to the design of experiments will give to CAETEC a powerful tool to making decisions to maximise the nitrogen in corn to feed the cows. The Bajío Region in Mexico will also be benefited with this analysis.

Due to the sowing time and the different iterations or improvements of the parameters of the critical factors. Final results that impact until the maximisation of milk production will be presented in future research.

ACKNOWLEDGEMENT

The authors acknowledge the technical and financial support of the Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

REFERENCES

[1] Montgomery D. *Diseño y análisis de experimentos*, 2011 (Limusa Wiley, México).

[2] Verdooren L. R. History of the Statistical Design of Agricultural Experiments. *Journal of Agricultural, Biological, and Environmental Statistics*, 2020, 10.1007/s13253-020-00394-3.

[3] Almaguer C., Montejano G., VázquezFeijoo H. and Nieto Barrera J. Proyectos de Desarrollo Rural en Zonas Marginadas de Mexico Usando Ingenieria concurrente. *Congreso Iberoamericano de Ingeniería de Proyectos*, CIIP'03, Mar de Plata, Noviembre 2012.

[4] González C. and Lloveras J. Proyectos de Desarrollo, Diseño de Nuevos Productos e Innovacion para Agroindustrias en Zonas Marginadas de Mexico. *In International Congress on Project Management and Engineering*, AEIPRO'08, Badajoz, Julio 2009.

[5] Hernández-Gil C. and Núñez-López J. A. Design thinking aplicado al mejoramiento de las competencias ciudadanas en universitarios: voto popular. Revista de Investigación Desarrollo e Innovación, 2020, 11(1), 85-98. *https://doi.org/10.19053/20278306.v11.n1.2020.1168*.

[6] Sandars J. and Goh P. S. Design Thinking in Medical Education: The Key Features and Practical Application. *Journal of Medical Education & Curricular Development*, 2020, 7, 1-5.

[7] González-Almaguer C., Saavedra V., Caballero E., Acuña A., Zubieta C., Barbosa E. and Lule M. Design Thinking and Design Experiments: The Fusion of the School of Design and Industrial Engineering to Create Learning Experiences in The Tec21 Educational Model. In *International Conference on Engineering and Product Design Education*, EPDE 2021, Herning, September 2021.

[8] Klašnja-Milićević A., Ivanović M. and Budimac Z. Data science in education: Big data and learning analytics. *Computer Applications in Engineering Education,* 2017, 25, 1066–1078. https://doi.org/10.1002/cae.21844

[9] Romero C. and Ventura S. Educational data mining and learning analytics: An updated survey. *Wires Data Mining and Knowledge Discovery*, 2020, 10, e1355, https://doi.org/10.1002/widm.1355

[10] International Society Precision Agriculture. Precision Ag Definition. Available: *https://www.ispag.org/about/definition* [Accessed on 2022, 04 March] (2019).

[11] ElMaraghy W., ElMaraghy H., Tomiyama T. and Monostori L. Complexity in engineering design and manufacturing. *CIRP Annals-Manufacturing Technology*. 2012. ;61(2):793-814.

[12] Halachmi I., Edan Y., Moallem U. and Maltz E. (2004). Predicting feed intake of the individual dairy cow. *Journal of Dairy Science*, *87*(7), 2254-2267.

DESIGN PROCESS OF A VIRTUAL LEARNING ENVIRONMENT FOR IMMERSIVE TEACHING OF THE OPERATION OF HIGH-RISK EQUIPMENT IN ARCHITECTURE AND INDUSTRIAL DESIGN WORKSHOPS

Alejandro ACUÑA[1] **and Maria Elena MELÓN**[2]
[1]Architecture, Art and Design School, Institute for the Future of Education, Tecnologico de Monterrey
[2]Architecture, Art and Design School, Tecnologico de Monterrey

ABSTRACT
This document explains the objectives, characteristics, and design process of a virtual learning environment for the immersive teaching of high-risk equipment operation in Design and Architecture workshops. This proposal aims, through a tutorial and assessment mode, to substantially improve the training processes in cutting machinery in the Design and Architecture workshops for students enrolled in Creative Studies. The project has a special emphasis on safety and equipment operation aspects, with the possibility to register and document the training process of each student. At this moment, the educational innovation project shows an 80% progress, expecting to have the first implementation tests in March 2022. The main aspects of the research methodology to be carried out during 2022, once the virtual environment is finished, are explained in the document. This project has the support of the Novus Fund for Educational Innovation, Institute for the Future of Education, Tecnologico de Monterrey, Mexico.

Keywords: Virtual reality, interactive learning environments, higher education, simulation, educational innovation

1 INTRODUCTION
Training in the use of machinery for wood and metal (cutting, roughing, drilling, and sanding) is essential in Industrial Design and Architecture careers since students build models and prototypes using these machines. Because this equipment is of medium and high danger, training in its use is of the utmost importance and relevance, especially to maintain the physical integrity of the students.
To avoid accidents, general regulations have been published for each workshop and safety certificates have been placed on each machine. The training for first-semester students has always been carried out in person and with the support of a supervisor. The person in charge of the training gives the explanation of each machine and manipulates it, while the students limit themselves to listening and observing.
The proposed innovation, applying virtual reality technologies for training, implies a radical change in the way in which this first approach to machinery is carried out, given that each student will be able to interact with the virtual machines as many times as necessary without any risk while learning the procedures and safety measures of each piece of equipment.

2 METHODOLOGIES

2.1 Theoretical framework
In the Oxford Dictionary the term "virtual reality" is defined as "A set of computer techniques that allow the creation of simulated images and spaces in which a person, through a visual device, has the sensation of being and being able to function within them" [1]. Three essential concepts linked to virtual reality emerge from this definition: immersion, interaction, and feedback. The concept of immersion refers to the perception of being physically present in a world that is not physical and occurs when the user feels

that the simulated environment and objects are perceptually convincing, authentic, or real [2]. In these spaces, users can interact with objects using different physical interfaces and obtain responses to this interaction. Thanks to these characteristics, virtual reality has been used extensively for specific educational or training purposes and can be considered as one of the natural evolutions of computer-based training [3].

Virtual reality allows, among other things, to increase learning through the manipulation of objects on a real scale. This physical exploration of objects helps students to understand and memorize them better, allowing teaching under the approach of learning by doing, especially when there are restrictions that prevent the use of objects or the real environment [2]. Students can experiment under a constructivist learning scheme, resulting in an experience that improves learning [4].

Active interaction and participation is naturally promoted if the user sees and hears the result of his actions immediately [3]. Through devices such as viewers, headphones and controls, the user can obtain feedback that, in the field of education, is vital. Additionally, information that is not available in the real world can be provided improving the learning of a task [5]. In many cases, there are multiple opportunities to access resources and a greater amount of time to complete specific activities, allowing for repetition and modification, fostering deeper learning [6].

Regarding the perception that students have about virtual reality, two decades ago [7] stated that students had a favourable attitude towards virtual reality in the educational process. Ten years later, Pantelidis reaffirmed that students find it exciting and challenging to walk through a three-dimensional environment and interact with it [3]. Jensen reviewed 21 research papers published from 2013 to 2017 that describe experimental studies of the use of HMDs (Head Mounted Displays) [8]. In these studies, he found again that virtual experiences are perceived as useful and interesting. According to Martin-Gutierrez virtual technologies increase student motivation to a certain extent because they feel like protagonists while they live immersive experiences [4].

It is not only about the attitude and perception of the students, simulations, games, and virtual environments have been found to have a significant positive impact on learning outcomes [9], [10], [11]. In a review of 56 papers (post 2005) related to empirical research, the findings suggest that the levels of learning achieved are the same or better in non-traditional laboratories (virtual and remote), compared to traditional laboratories in all levels of learning: knowledge and understanding, practical, analytical and research skills, as well as social and scientific communication [12]. Jensen identifies several situations where HMDs are useful for skill acquisition [7]. This includes cognitive skills related to information retention and comprehension, spatial and visual knowledge, as well as psychomotor skills related to head movement.

Among the motivations for using virtual environments, the one that stands out is the fact that they provide the opportunity for training in safe environments, avoiding potential real risks [2] [9]. Pantelidis suggests using virtual reality when real training is dangerous or when mistakes made by the student using the real object can be devastating or harmful to both the student and the equipment [3].

In the specific case of virtual laboratories, savings, flexibility, multiple access, the possibility of changing configurations and resistance to damage are also important motivations, according to Potkonjak [13].

It has been widely accepted that these types of systems are the desirable initial step in teaching science, technology, engineering, and design, recognizing that more advanced students still require hands-on experience with real equipment. However, with the fast advancement of technology, the gap between what can be done in the real world and what can be done in a virtual world is shrinking [13]. Today virtual reality is recognized as a strategic and well-defined tool in education [14].

2.2 Description of the innovation

The innovation that is presented in this paper consists of designing and implementing a multi-modal and interactive virtual reality platform that provides knowledge and active training in the use of the main wood and metal cutting machines in design workshops. The platform has a main menu where you can choose the machine you want to train on, two modes of use: tutorial and assessment, and a progress record per student.

In the tutorial mode there is a guide that provides information on the general safety equipment that must be worn, the additional safety measures to be considered, the type of materials that can be used and the steps to follow to operate the selected machine. According to the meta-analysis carried out by Lee [14], students perform better if some type of guide is provided and if the sequence of activities is controlled

by the computer [10], [11]. For this reason, the assistant designed for this environment guides the student at each step and provides the necessary visual and auditory feedback to promote understanding and retention of information.
In the assessment mode students must complete certain tasks following specific instructions. They are told what to do, but not how to do it. If all steps are completed successfully, training on that specific machine is passed. Virtual reality has great potential as an assessment tool since it allows accurate monitoring of student's activity within the virtual environment [16].
The environment is flexible because it allows students to enter when they have any free time, stay if they want to and repeat the guided training and assessment sessions as many times as needed.
This virtual learning environment will be installed in the space known as the VR Zone, which has virtual reality capable machines and headsets. All students on campus have access to this area.

2.3 Innovation implementation process

2.3.1 Platform design process

The platform design process has consisted of several stages:

Stage 1 - Visit to the Design and Architecture workshops

At the beginning of the project, several visits were made to the Design and Architecture workshops to learn about the security measures and the steps to follow in the operation of the different machines. Figure 1 shows Camerino Ávila, coordinator of the DICI workshops, explaining the operation of one of the machines.

Figure 1. Visit to the Design and Architecture Workshop

Stage 2 - Selection of machines

After these visits, five of the most dangerous and commonly used wood and metal cutting machines were selected: band saw, circular table saw, mitre saw, bench jig saw, and metal cutter, because these are the machines that students frequently use to complete their design or architecture projects and the ones that can cause accidents. In the same way, the main use cases of each of the machines were selected: common or straight cut, narrow and angled cut.

Stage 3 - Preparation of the script, flow, and state diagrams

For each of the machines and use cases, flow and state diagrams were prepared to clearly show the order and conditions to be fulfilled in the operation of the equipment. The flow charts included the scripts that were professionally recorded for the tutorial mode. Figure 2 shows the states through which the mitre saw passes when performing a straight cut.

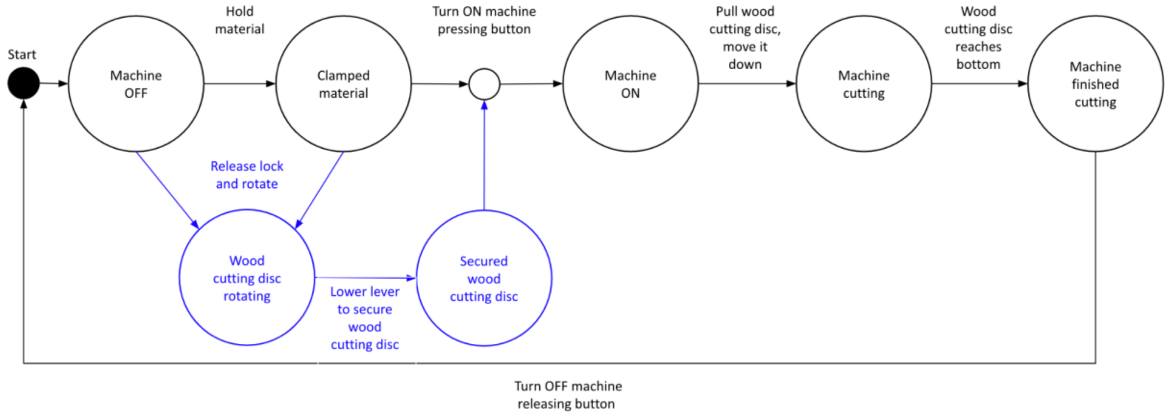


Figure 2. State diagram of the mitre saw

Stage 4 - Implementation of the tutorial and assessment mode
Once the flow diagrams were ready, the five machines and the space that simulates the workshop where the equipment is physically located, were modelled and textured in 3D, see Figure 3. Subsequently, the sequence of actions, operation and interaction with the virtual machines were programmed in a modular way, first in the tutorial mode and then in the assessment mode. For flexibility and to reduce the complexity of the system, a series of modules were created (security, material selection, common cut, narrow cut, angled cut modules). Some modules are dependent on others, while some are independent. All of them can be repeated as many times as needed to practice and pass the training.

Figure 3. Jigsaw and Table Saw 3D Models

Stage 5 - Preparation of questionnaires
Parallel to the implementation of the virtual environment, the questionnaires that will be applied to the students before and after the training (whether traditional or virtual) were developed. The objective of these questionnaires is to evaluate the experience of the students in the use of the virtual machines, knowledge about their operation and, above all, knowledge about the safety measures that must be taken in general to enter the design workshop.

2.3.2 Implementation plans
This innovation is planned to be implemented at the Tecnologico de Monterrey campus Querétaro during the February-June 2022 semester. The courses in which the virtual environment will be tested are *Specification of Products and Services*, a course offered during the first semester of the Creative Studies entry, and *Specification of Products and Services*, offered during the fourth semester of the Design programme.
It is expected to have a sample with 24 students from the Digital Art, Design and Architecture programmes with no experience in the use of cutting machines, and 40 students from the Design programme with some experience in this area.
A quantitative approach will be used to research the level of learning of the safety measures and general operation of the machines, while qualitative methods and techniques will be used to explore the

experience of students while using the simulator and the real machines. The instruments that will be used for data collection are the automatic records of the virtual environment, questionnaires in which the level of knowledge about the safety measures and operation of the machines are evaluated, and finally, focus groups at the end of the semester.

2.4 Innovation design assessment

The first tests of the virtual environment were carried out with staff from the Design and Architecture workshops, to ensure that the correct terms and procedures were being used, as well as adequate interaction and feedback. Online sessions were also held to review and correct the tutorial and assessment mode scripts. Based on these tests and reviews, various adjustments and changes have been made related to the information provided by the platform and the correct order of the steps in the operation. Figure 4 shows two photographs of the tests carried out on January 29, 2020. Figure 5 shows three examples of user interaction with three different machines within the virtual environment.

Figure 4. Interaction tests

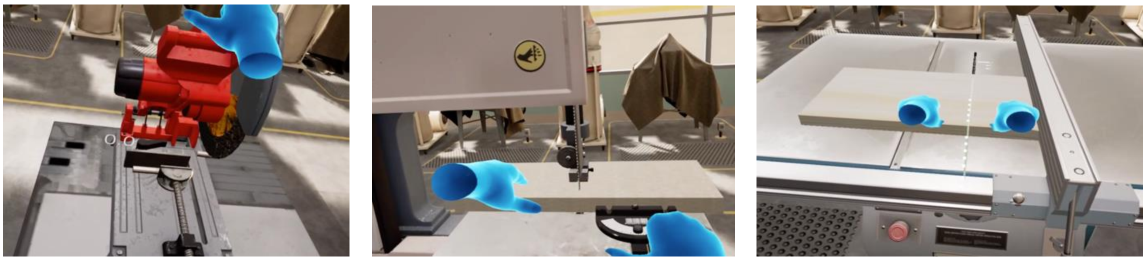


Figure 5. User interacting with the machines within the virtual environment

3 CONCLUSIONS

The development of the platform is complete, but, unfortunately, the confinement derived from the COVID19 pandemic has delayed the implementation of the innovation in the different courses. The tests with students imply the physical presence on campus, in addition to the use of the virtual reality headsets. Once face-to-face classes are restored, the platform will be used to substantially improve the understanding, retention and compliance with the safety measures and operation of the machines in the design workshops. It is also expected to increase the number of students trained in their use. The goal is to have all users of the Design and Architecture workshops pass the assessment mode of each machine within the virtual platform before they have the right to use the real machines.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support of Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work. Similarly, we thank Camerino Ávila and Hugo Cruz, Coordinator and Supervisor of the Design and Architecture workshops, for their contributions regarding the safety measures and procedures for the use of the machinery. Lastly, we would like to thank Grayscale Interactive, who has enthusiastically supported us to materialize this idea.

REFERENCES

[1] *Spanish Oxford Living Dictionaries*. Available: *https://es.oxforddictionaries.com/definicion/realidad_virtual* [Accessed on 2022, 10 February], (2019) June.

[2] Freina L. and Ott M. A Literature Review on Immersive Virtual Reality in Education: State of The Art and Perspectives, 2015, *eLearning & Software for Education*, (1).

[3] Pantelidis V. S. Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education*, 2010, 2(1-2), 59-70.

[4] Martín-Gutiérrez J., Mora C.E., Añorbe-Díaz B. and González-Marrero A. Virtual technologies trends in education. *EURASIA Journal of Mathematics Science and Technology Education*, 2017. 13(2), 469-486.

[5] Gavish N., Gutiérrez T., Webel S., Rodríguez J., Peveri M., Bockholt U. and Tecchia F. Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks. *Interactive Learning Environments*, 2015, 23(6), 778-798.

[6] Charuk K. Designing the online laboratory. In D. A. Cancilla and S.P. Albon (Eds.), *Moving the laboratory online: Situating the online laboratory learning experience for future success*, 2010, (pp. 283-291). Newburyport, MA, USA: The Sloan Consortium.

[7] Mikropoulos T.A., Chalkidis A., Katsikis A. and Emvalotis A. Students' attitudes towards educational virtual environments. *Education and Information Technologies*, 1998, 3(2), 137-148.

[8] Jensen L. and Konradsen F. A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 2018, 23(4), 1515-1529.

[9] Merchant Z., Goetz E. T., Cifuentes L., Keeney-Kennicutt W. and Davis T. J. Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education*, 2014, 70, 29-40.

[10] Vogel J. J., Greenwood-Ericksen A., Cannon-Bowers J. and Bowers C. A. Using virtual reality with and without gaming attributes for academic achievement. *Journal of Research on Technology in Education*, 2006, 39(1), 105-118.

[11] Sitzmann T. A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel psychology*, 2011, 64(2), 489-528.

[12] Brinson J. R. Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, 2015, 87,218-237.

[13] Potkonjak V., Gardner M., Callaghan V., Mattila P., Guetl C., Petrović V.M. and Jovanović K. Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, 2016, 95, 309-327.

[14] Berg L. P. and Vance J. M. Industry use of virtual reality in product design and manufacturing: a survey. *Virtual reality*, 2017, 21(1), 1-17.

[15] Lee J. Effectiveness of computer-based instructional simulation: a meta-analysis. *International journal of instructional media*, 1999, 26(1), 71.

[16] Mantovani F. *VR learning: Potential and challenges for the use of 3D environments in education and training. In G. Riva & C. Galimberti (Eds.), Towards cyberpsychology: Mind, cognitions, and society in the internet age*, 2001, pp. 207-226 (Amsterdam: IOS Press).

EXPANSION OF SERVICE DESIGN ACADEMICS IN BELGIUM: THE GROUNDWORK FOR A CURRICULUM BASED ON CONTEMPORARY INDUSTRY NEEDS

Domien LOOSEN, Thomas MARQUENIE, Lotte VERBOVEN and Ivo DEWIT
Department of Product Development, University of Antwerp, Belgium

ABSTRACT
The Belgian design scene is not unfamiliar with the concept of service design and has hosted some leading-edge companies throughout the years, pushing the field forward. The next step in the development of the field is the expansion of the academic aspect of service design within Belgium. The topic of service design is already addressed in existing design programmes, though it is yet to be a focus of study on its own. This paper helps to expand the range of study programmes at the University of Antwerp and contributes to shaping the service design landscape in Belgium.
The Department of Design Sciences at the University of Antwerp provides students with extended interdisciplinary skills and knowledge, leading them into the world of design. The department now seeks to create an additional master's programmes with a curriculum catered to service design providing graduates of this programme with all the necessary skills to be at the top of their game when they start their careers in service design. To ensure continuity between what the university delivers and what the job market expects and desires, the programmes will be developed from the ground up. The university, for this study, has worked in collaboration with current leaders in the field, providing their expertise and requirements for the future of service design. Insights were obtained by means of workshops and collaborative projects with students and experts in the service design scene, as well as building on existing literature and current educational programmes across the world.

Keywords: Service design, design education, curriculum of a master's programmes

1 INTRODUCTION
As our global economy experiences a shift in focus from product driven to services and product service-system driven [1], the field of Service Design (SD) has grown significantly. Design agencies are pivoting and specializing in the field to follow new expectations and standards. Design schools across the world are starting to provide SD specific course options to facilitate this change and support the increase in demand for designers fluent in service-dominant logic. In an attempt to provide relevant education in an ever-evolving world, the University of Antwerp would like to expand its design academics and add the option for a SD specific postgraduate course. To ensure this course accurately reflects the needs of the sector, this paper provides a first step towards creating the new curriculum by determining these wants and needs through a workshop with local service design agencies.
In current traditional design academics, service design is often still seen and taught as a subsection of classical (product) design. This follows an older perspective on service design, as described by Holmlid, S. (2007), "a human-centred approach and an outside-in perspective. It is concerned with systematically applying design methodology and principles to the design of services." [2]. Though still relevant, it treats service design simply as an area of implementation for established design methodologies, rather than requiring its own underlying foundation. More recent literature starts to describe SD as holistic [3], and a toolbox or management approach [4]. Acknowledging that SD is not just a step or function of design but a process of its own.
These definitions and implementations of SD are evolving fast, the academics however are currently lagging. This paper will cross reference with insights in the SD process as applied in the Belgian SD sector to aid in creating a curriculum that answers to industry needs and is future proof.

This includes SD having to take into consideration complex and overlapping service systems, therefore needing to more frequently involve system design [5]. Currently the university teaches these concepts through a strategic design module in the first master's and a project following the PSS (Product Service System) design toolkit by Ivo Dewit (2018) [6].
By creating a SD specific postgraduate course, the university will be the first in Belgium to provide such a course.

2 RESEARCH QUESTIONS

1. What are the key skills and characteristics required of a graduate of the curriculum by the current field of SD?
2. What valuable insights can the above give into realistic methods to educate students within the new curriculum?

Our goal for this paper is to formulate answers to the research questions stated above. By co-creating and discussing topics of interest in SD and how such a postgraduate degree should look. This with all involved stakeholders, during a set of workshops.

3 RESEARCH METHODS

Before getting started with the workshop we conducted some preliminary literature research regarding SD and different academic options. Additionally, we inquired with current design students at the university to poll their knowledge and interest in SD and an additional postgraduate option.
For the workshop, we invited members of the Service Design Network (SDN) Belgium from different agencies. These members were briefed beforehand and welcomed in a polyvalent space where the workshop took place with seven participants.
The workshop started off with two warm up activities. The first was the creation of a word cloud with key words defining SD. During the second, the participants were asked to each note down what the timeline of the service design journey looked like to them. These activities not only allowed to get the participants to start thinking about the topic, but it also allows us to gauge how uniform the perception of the field is across different members and compare this to existing literature.

Figure 1. Workshop with SD agencies

The actual workshop was divided into three parts. During the first the participants were asked to fill in a set of posters aiming to explore the current situation. One asking to describe what the current typical CV of an applicant looks like. Then moving on to what the profile of a new hire tends to look like. During the second phase, the participants were asked to describe "The Ideal Newbie" a hypothetical perfect candidate for hire. Discussing their background and studies, their hard and soft skills, as well as their personality. This is the profile of graduates the eventual curriculum should aim to produce. The last phase was a conversation and brainstorming session about what such a curriculum might entail, what should be taught and how it could most effectively be brought to the students. Additionally, the background of students that should be able to enrol in the programmes was discussed. This conversation was recorded for review later on.

4 RESULTS

A trend we noticed during the preliminary desk research, indicates that a consistent reliance on theoretical methods remains. This theory-based knowledge is used as background for more effective implementation of the functional, more practical skills. This might indicate a dichotomy between the ways of teaching and the implementation of the skill or knowledge.

During an initial survey to get a general idea of the interest towards this topic amongst students. Although the familiarity of SD was a bit disappointing, the curiosity and willingness to learn about it was surprisingly high. The survey ended up shaping a basic blueprint of what students expect from a new topic like this, how it's taught, by whom and what the requirements are.

The workshop involving the SD agencies was very interesting as it made it possible to further delve into the way we could bring this to a bigger audience. The typical journey laid out 8 key steps to follow:

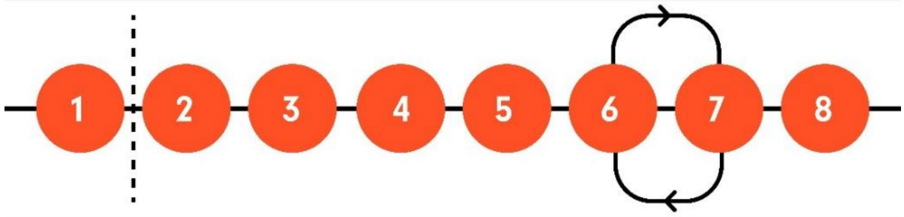


Figure 2. Common layout of the SD process

1. Estimation workability of the collaboration design agency & client
2. Defining design challenges and agreements
3. Research (desk research, stakeholders, context map)
4. Observation (interviews with experts & users)
5. Concept design (journey, vision, touchpoints)
6. Testing (prototype)
7. Refine
8. Elaboration & implementation

This design journey, based on different paths of different agencies, can give a good insight into the different touchpoints a service designer must cross. These steps can eventually be considered as a guide to follow when starting to create a new postgraduate course.

The journey illustrated by the design agencies above is noticeably similar to the one described in "This is service design doing" Stickdorn (2018) [4]. The minor differences are related to the global structure of the journey. Where observation is followed by concept design in our model, this is not the case in the illustrated journey in the book. There, observation, which includes a wide variety of analyses consisting of stakeholders, mind maps and journey maps, is followed by ideation planning and scope definition. Then brainstorming leads to the formulation of raw ideas and selection which is then followed by prototyping planning, diverging in explorative prototyping, and converging in evaluative prototyping. When comparing our findings to the SDN research framework [8] the achieved outcome is consistent. However, as opposed to our 8 phases, this paper only uses two (planning and execution). These two approaches are comparable.

Next, the attention went to discussing what the current situation is and the wants & needs of SD agencies. All parties described aspects such as 'skills to be taught', 'habits to unlearn' and 'most difficult to teach' as can be seen in the table below. There was a clear emphasis on presenting and facilitating. The "Designer's ego" was amongst the more popular answers in its category.

Table 1. Answers describing a typical new Hire to a Service Design agency

Skills to be Taught	Habits to Unlearn	Most difficult to teach
- Fitting tools to people / Context	- Dealing with uncertainty	- Eye for detail
- Prototyping (services)	- Doing, Not talking	- Organisation analysis
- Knowing how to build the perfect team for the job	- Over-aesthetics	- Critical thinking, but working towards solutions
- Client / Project management	- Keeping the level appropriate	- Seeing patterns in design research
- Advocate customer centricity	- Copy/Pasting	- Turning user insights into design principles and ideas

- To be a good Facilitator	- Designers' Ego	- Talking to management
- Thinking in opportunities	- Product dominant mindset	- People reading and managing in co-creation
- Distinguishing main goals from side problems (complexity)		- Cocreating with users, be honest: The solution will not come from you, the 'almighty designer
- Presenting		
- Design process		
- Self and Time management		

This all led to creating a hypothetical CV to illustrate clearly what the ideal newbie should look like in terms of academic career, skillset, and approach. Although these requirements are fluid, they give a guideline. In terms of studies proceeding a career in SD, topics such as psychology and communication management came out as the best preparational experiences in terms of understanding a client's needs, which is a soft skill. But things like visualization of complex systems, sketching and digital prototyping are mostly taught in studies such as product development, graphic design or digital design.

In general, being wide eyed towards the world and your environment is a key to success. Having the confidence to differentiate main goals from side problems and strategic management are also highly appreciated skills amongst the SD agencies. Undoubtedly, being comfortable working in a team and facilitating a group or co-creating, is necessary.

Besides hard skills such as prototyping and creativity, ways of teaching those skills were also discussed. Projects and cases were amongst the more popular methods. Big individual projects from A to Z make you bump into all kinds of real-life struggles. Including feedback sessions and alternating between short design sprints and longer ongoing projects, together with theoretical courses, are ways to delve into the SD world. Guest lectures by experts in the field, to give a realistic view on the economical aspect of SD, was also a highly requested suggestion. A strong consensus was reached that an internship does not belong in a postgraduate course, there are other ways to bring experts to the course such as masterclasses. Instead of an internship and a thesis, we must combine these two into one end-term project. The ideal situation of the application of the theory must be fluent and dynamic. There is no need to test the theoretical knowledge if we can apply it in real life scenarios. Creativity is the biggest challenge for people without a design background. This could become a part of the curriculum but should ultimately be integrated everywhere.

5 DISCUSSIONS

In general, people interested in the service design domain already have an open-minded, critical way of thinking and a proactive attitude. These soft skills must be used to develop further soft and hard skills.

The desired hard skills can be categorized into two main categories. The first involves maintaining situational overview and a general level of understanding. This consists of analysing the organizations and the services they provide - differentiating main goals from peripheral goals - defining the right design challenges, principles & drivers - cocreation with the user - and (self-)management. Each of these capabilities are highly sought after when entering a service design agency. The last three however were ones that could be considered as 'to be taught'. The second is quick hands-on creation, aiming for creativity, and especially clear communication. Particularly in the form of prototypes, experiments, research, and processes. Implementing co-creation where needed [9].

When it comes to the soft skills there were once again two distinguished core aspects that came up. On one hand there is mindset and an innate understanding of what a service really is and can be. It also addresses thinking in alternatives and being able to appropriately keep options open long enough to allow for well selected solutions. The mindset is closely related to design thinking. It is not an easy thing to teach because it is innate to the person. It is something the course would have to filter for and bring to the surface. On the other hand, they focus on successful stakeholder management and being able to facilitate in group settings to achieve this, the student is required to be able to use improvisation and intuition to adapt during these sessions quickly and creatively.

The conversation between the experts concludes that service design is much more than a process, that the mindset plays a key role in the innovation of new product & services [4]. A focus on soft skills that encourage a productive attitude and the ability to integrate room for new ways of thinking, are a key element for innovation. This aligns with research done by Katzan [10].

Participants agreed that classic courses like thesis and internship do not belong in the postgraduate course, especially not in their typical form. When it came to the trade-off between group-assignment or individual projects, the opinions were divided. The importance of the ability to act independently and the greater value of working in a team were played against each other. A solution for this dilemma, presented by some of the participants, could be in the form of a personal project with group-based feedback sessions, implementing the course taught concepts in an individual's own context. Theoretical courses were not exceedingly popular in their current state. The participants had great ideas of the application of these theories in a large project. Owning the skills, you were taught and being able to apply them is more important than knowing the theories they were based on.

Factors such as cultural differences, gender, and perception were not specifically mentioned during the workshop though can be considered under the term ‘Open mindednesses’. The importance of which was discussed when determining important characteristics. This type of open mindedness and inclusion will play a key role in the future of service design [11].

6 CONCLUSIONS

The first research question was analysed fully, with collaboration and input from experts in the field. A selection of clear requirements soon emerged, focusing on soft skills with hard skills to support them.

Given the importance of design thinking to succeed in the field of SD, this knowledge should be an initial requirement to continue with the rest of the curriculum. Due to this, it is possible the course might consist of multiple paths, depending on the level of design background of the student.

The information brought to the students should be conveyed in real-world contexts, allowing for realistic application. Following this logic, the eventual curriculum ought to be project heavy, with a focus on developing the individual and necessary skills. It is important to note that this is about requiring insights and skills and learning to implement them.

Reflecting realistic settings could also mean implementing creative sources of 'sabotage’ or 'struggles’ that would reflect those that could occur in the real world. The student should be able to face projects failing and moving on from that point. It is part of the design process that does not get reflected enough in current academics. The aim is to create a modular and evolutive programmes, keeping in mind the participating partners, students and contemporary environment.

Additional and more thorough research and development is needed since we were not able to fully define the methods and build-up of the curriculum within the scope of this study.

Understanding the current field of SD and its actual requirements is a key step in providing relevant and specific educational programmes to support and enhance the future of service design. The industry is increasingly asking for or at least needing expertise in services surrounding their products. This demand cannot be ignored. Service design and its importance is often overlooked in the design process and ought to be brought to the foreground and provided the necessary attention [12]. Starting in education.

This paper aims to aid in the creation of new design focused courses or the adaptation and improvement of existing ones.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the founders of SDN Belgium and the collaborating agencies who participated in the workshop for their time and providing valuable insights and a highly educational experience. We would also like to thank Juul Accou and Léa Syenave for their help getting this project initiated.

REFERENCES

[1] Maglio P. P., Vargo S. L., Caswell N. and Spohrer J. (2009). The service system is the basic abstraction of service science. Information Systems and E-Business Management, 7(4), 395–406. https://doi.org/10.1007/s10257-008-0105-1

[2] Holmlid S. (2007). Interaction Design and Service Design: Expanding a Comparison of Design Disciplines.

[3] Penin L. (2018). *An Introduction to Service Design: Designing the Invisible*. Bloomsbury Visual Arts.

[4] Stickdorn M., Hormess M., Lawrence A. and Schneider J. (2018a). *This Is Service Design Doing*. Van Duuren Media.
[5] Grimes J. and Mager B. (2021). Service Design and Systems Thinking. Touchpoint, *The Journal of Service Design*, 12(2).
[6] Dewit I., Van Ael C., De Roeck D., Baelus C., Van Ael K. and De Roeck D. (2018). *PSS Design and Strategic Rollout: tools for product-service systems*. University Press Antwerp (UPA).
[7] Sassoli D. M. and Zacarias A. P. (2021). Decision (EU) 2021/820 of the European Parliament and of the Council of 20 May 2021 on the Strategic Innovation Agenda of the European Institute of Innovation and Technology (EIT) 2021-2027: Boosting the Innovation Talent and Capacity of Europe and repealing Decision No 1312/2013/EU. *Official Journal of the European Union*, 1–28.
[8] Yu E. and Sangiorgi D. (2014). ***Se****rvice design as an approach to new service development: reflections and futures studies*. 194-204. Paper presented at ServDes.2014. Fourth Service Design and Innovation Conference "Service Futures", Lancaster, United Kingdom. http://www.servdes.org/wp/wp-content/uploads/2014/06/Yu-E-Sangiorgi-D.pdf .
[9] Morelli N., de Götzen A. and Simeone L. (2021). Service Design Capabilities. *Springer Series in Design and Innovation*. doi: 10.1007/978-3-030-56282-3.
[10] Katzan Jr. H. (2011). Essentials of Service Design. *Journal of Service Science* (JSS), 4(2), 43–60. https://doi.org/10.19030/jss.v4i2.6644.
[11] Mager B., Sistig M., Chen Y., Ruiz K. and Corona C. (2020). *The Future of Service Design.*
[12] Miettinen S. (2009). An emerging field. In M. Koivisto (Red.), *Designing services with innovative methods: perspectives on service design* (pp. 27–43). University of Art and Design Helsinki.

BEHAVIOURS, PRACTICES, ACTIVITIES, DOINGS: MAKING THEM SUSTAINABLE THROUGH DESIGN

Wanjun CHU[1] **and Renee WEVER**[2]
[1]Department of Computer and Information Science, Linköping University, Sweden
[2]Department of Management and Engineering, Linköping University, Sweden

ABSTRACT
The Design for Sustainable Everyday Life course aims to provide students with three theoretical lenses (behaviours, activities, and practices) to understand and develop design interventions that improve sustainability by impacting people's everyday doings. This paper reports on the result of and our reflections on the course over the past two years with a particular focus on identifying the challenges and benefits that the students faced in learning and employing the three different theoretical lenses in sustainable design. We found that facilitating students to apply theoretical lenses that are typically outside of their previous design education constitutes a challenging task in the course, let alone presenting students with three theoretical lenses on the topic of design for sustainable everyday life. However, results show that the three lenses supported students in choosing an appropriate unit of analysis and systematically developing sustainable design interventions at a target level. Moreover, the course also offered an entry point for students to (re)discover and align their existing understanding of design with new concepts introduced by the lenses. Furthermore, the analytical and design approach that the lenses advocate also enabled students to explore and experiment with different design intervention strategies to influence people's (un)sustainable daily doings.

Keywords: Design for sustainable behaviour, design for sustainability, sustainable design education, activity theory, practice theory

1 INTRODUCTION

The discussion around how to effectively design products and services to better promote people's sustainable behaviour has gained growing attention over the past two decades [1–3]. Researchers working on this topic have adopted and adapted different theoretical perspectives, especially from psychology and sociology, to understand sustainable and unsustainable doings in people's everyday lives [4]. However, to what extent these theoretical perspectives, from outside of the traditional design disciplines, can be employed in courses which focus on sustainable product design has been seldom explored.

Many existing studies argued that sustainable product design education should not merely focus on inserting a sustainability dimension into the existing design education curricula. Instead, it needs to offer students relevant knowledge and skills for them to identify, select, and apply different sustainable design approaches in their design projects and practices [5]. With this broader perspective in mind, we developed the Design for Sustainable Everyday Life course (hereinafter referred to as DfSEL). DfSEL is a new graduate course that we created in the Department of Engineering and Management at Linköping University. The course focuses on a design research perspective. It is more grounded in academic literature and research than the average design course. The objective of the course is to provide students with three theoretical lenses – a *behaviour-based lens* from *Design for Sustainable Behaviour Models,* a *practice-based lens* from *Social Practice Theory,* and an *activity-based lens* from *Activity Theory* – to better understand people's daily life doings and develop design-oriented interventions to improve the sustainability aspects of people's everyday lives.

However, from a teaching perspective, facilitating students to apply theoretical perspectives that are typically outside of the design discipline constitutes a challenging task in the course, let alone presenting students with three completely different theoretical lenses. The paper reports on how we approach this particular challenge in the DfSEL course. Specifically, we aim to identify the difficulties that students encountered in applying the three different theoretical lenses (behaviour models, practice theory, activity theory) in their design projects. The paper contributes to Design for Sustainability education by shedding light on how to better guide students to understand, choose, and employ different theoretical lenses to promote people's sustainable doings in everyday life contexts.

2 COURSE SET-UPS

The DfSEL course (course code: TMKA10) officially started in the spring semester of 2020. The course is mainly offered for students from three programmes: Master of Science in Design and Product Development, Master of Science in Energy - Environment – Management, and Master of Science in Design. DfSEL runs throughout the entire Spring semester from January to June. It mainly comprises three modules (as shown in Figure 1). The first module of the course is focused on introducing the three theoretical perspectives – Design for Sustainable Behaviour Models (DfSB), Activity Theory (AT), and Social Practice Theory (SPT), and presenting different domain-specific case studies in which the theoretical lenses were employed. The domain-specific case studies mainly consist of sustainable energy consumption, sustainable food consumption, and sustainable mobility. The second module of the course centres around project implementation. In this module, students need to decide the specific sustainability problem and the application domain of their design projects, select a theoretical lens, and carry out the project. They can choose to either first conduct research and then propose sustainable design interventions or start with developing a design intervention and then evaluate the effects of the design intervention. In the third module of the course, students present the project and reflect on their application of the three lenses. The intended learning outcomes of the course are:

- Articulate the different approaches to designing a sustainable everyday life.
- Design research set-ups for studying everyday life interactions with designed interventions.
- Articulate design approaches based on insights from research into (un)sustainable everyday life.

Two features made the course distinctive. First, the course aims to enable students to explore and apply multiple perspectives on people's everyday life (un)sustainable doings. This is achieved by offering students with three different theoretical lenses – DfSB, AT, and SPT. Second, the course enrols both design students, who take design as the context and explore sustainability of people's everyday life within the frame of their current design interests and practices, as well as sustainability students, who take sustainability as the context and explore how design can be used as a tool to achieve sustainability goals [6]. In the course, we aim to bridge the gap between the students coming from these two backgrounds by encouraging them to work in multiple-disciplinary.

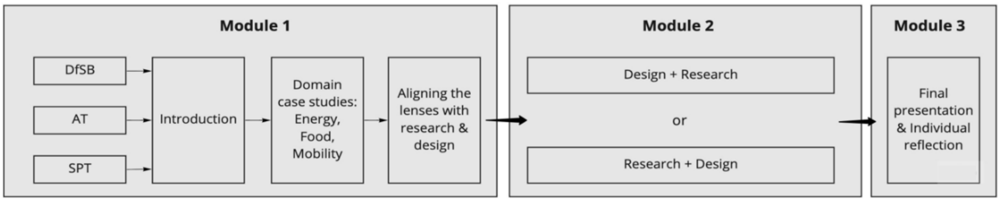


Figure 1. The three modules of the DfSEL course

3 BEHAVIOUR, PRACTICES, AND ACTIVITIES

DfSB, AT, and SPT are chosen in this course because they are currently three mainstream theoretical lenses being adopted in the field of Design for Sustainable Everyday Life. However, when used in design, they advocate different unit of analysis and approaches for investigating and tackling sustainability challenges (see Table 1). DfSB takes behaviours as the unit of analysis. It focuses on studying the interaction between an individual user and the specific attributes of an artefact. Design studies guided by DfSB often demonstrate clearly defined sustainable consumption goals (e.g., promote eco-friendly food consumption, raise awareness of energy consumption, reduce fridge door opening time, etc.). The fundamental question that DfSB aims to explore is how to help people make more informed consumption decisions to mitigate the underlying impacts or promote desired behaviour in the usage phase of products.

SPT, on the other hand, takes people's routinized practices as the unit of analysis. It views users of products as the carriers of socially constructed practices. In contrast to DfSB, design studies guided by SPT often take a bottom-up approach and ask the question: what can be a more sustainable way of carrying out the routinized practice? It focusses on reconsidering the status quo and bring more disruptive changes to people's existing unsustainable doings.

AT takes the middle group between DfSB and SPT. It takes activity as the unit of analysis and focuses on analysing how purposeful need-based human activity is mediated by the use of artefacts. From this perspective, users of products are regarded as participants in activities. When applied in design for sustainable everyday life, AT can be used to help designers understand why and how sustainability problems take place in users' complex activity systems, and how to redesign the mediating artefacts (products that people use in their everyday activities) so that the whole activity system can evolve towards a desirable direction. Specifically, it emphasizes the importance of understanding the context of people's activity system before changing it. To facilitate the transition towards sustainability, design should take socio-cultural background, history development, subject-object relationship, and tensions and contradictions of people's activity system into consideration. Given the focus of this paper, we don't intend to present these theoretical lenses in detail. A comparison of the three theoretical lenses from a sustainable design perceptive can be found in [7–10].

Table 1. A brief summary of the theoretical nature of DfSB, AT, and SPT

	DfSB	AT	SPT
Origin	Psychology	Socio-cultural background in psychology	Sociology
Unit of analysis	Individual behaviour in relation to the particular attributes of products	Purposeful need-based interaction between subjects (users) and the objects (world) mediated by artifacts	Routinized practices
The fundamental questions	How to make users become more willingly to mitigate the underlying product impacts, thus achieving pre-defined sustainability goals?	How to evolve the whole activity system towards a desirable direction	What can be a more sustainable reconfiguration of the existing practice?
Design approach	Help users make more informed behavioural decisions	A milder approach that seeks to re-mediate the user-goal (subject-object) relationship	Explore fundamental and disruptive reconfiguration of practices

4 MATERIALS AND METHODS

Data collected from the course mainly comprise student individual reflection documents and group project reports. Students submitted both documents after their final presentations. These documents can complement each other in terms of understanding students' learning outcomes. For example, information such as how the design project was conducted, what and how the theoretical lens was applied in the process, and what critical decisions and aspects of design were considered along the way, can be extracted from the group project reports. On the other hand, students' individual reflection documents also provide us with an in-depth view of why students are interested in a particular lens and what knowledge and understandings were generated from applying that lens in their projects.

Based on the qualitative nature of the data collected from this course, we performed a thematic analysis to identify, summarize, and report patterns within data. An inductive approach was used during the coding process. We adopted the six-step thematic analysis procedures suggested by Braun & Clarke [11]. Raw data, including project aims, rationales behind choosing a theoretical lens, data collection methods, and toolkits used in the project, design deliverables, reflections on the course and project, knowledge generated from the course, and collaboration within the project group were extracted into an Excel document. Then we collated data into different themes and refined the specifics of each theme. After that, all the themes were related back to the aim and research question of this study. Key results from the analysis are presented in the next section.

5 RESULTS AND DISCUSSION

So far, twenty-nine students have completed the course, resulting in twelve design projects addressing a broad range of social and environmental sustainability challenges in people's everyday life contexts. The theme of the projects covers energy conservation, sustainable food consumption, waste sorting, sustainable packaging, sustainable clothes, and household water usage. Nine students are from the Master Programme of Energy - Environment – Management. They have previously gained a sufficient knowledge on the topic of sustainability. Twenty are from the Master Programme of Design and Master Programme of Design and Product Development with expertise in product and service design.

5.1 Students' overall reflection on having three different theoretical lenses for design

As previously indicated, students enrolled in the course didn't have any prior knowledge of the three theoretical lenses. Therefore, we set up three teaching modules for students to get familiar with these theoretical lenses. The lecture module serves as entries for students to understand the background, key concepts, strengths, and limitations of each lens. In the project module, students need to select one lens, articulate their choice, formulate a project plan, and apply the lens in the project. Insights regarding the application and applicability of the lens are then reflected in the final presentation, group reports, and individual reflection documents.

Specifically, in the lecture module, we divided the introduction to DfSB, AT, and SPT into six lectures, each with a specific focus. The course started by introducing the background, fundamental concepts, theoretical models, and key constituents of each lens. After students gained an overview of these three lenses, we moved to present how the lenses have been previously applied in domain-specific and design-focused case studies. Then, we compared the three lenses and identified differences and overlaps between the lenses. Finally, we summarized the implications that these three theoretical lenses can bring to designing sustainable everyday life doings. Overall, most of the students appreciated this setup. For example, students indicated that "*the introduction offered a sufficient basis for setting one's interests and delving into the most intriguing direction"* (P18), "*I learnt more in the first (theoretical) part of the course. Then to actually apply one of the lenses definitely gave me a deeper understanding of it*" (P21), and *"the lectures and the literature reviews gave us an understanding of both these approaches which could support the choice of lens that were used during the project"* (P16). Furthermore, students also emphasized that having access to different theoretical lenses can enable them to try *"different perspectives to see a same problem"* (P10) and "*broaden my scope of study from the basic use…to more complex, social and psychological questions*" (P10).

5.2 Articulate the different lenses to designing a sustainable everyday life

As presented in the preceding section, after the lecture module, students need to select, articulate, and apply one theoretical lens in their projects. We found that two factors were frequently mentioned by the students when they articulated the rationales regarding why they chose a particular theoretical over the others. The first factor is students' interests in relation to their study background – *"The psychology lens fit my desires and felt more fitting for my education"* (P2) and *"I became more interested in the social practice theory along the way as it shifts the focus from the individual to a routinized practice which is embedded in a whole societal context"* (P17). The second factor lies in students' interpretation of how design should be used as a way to influence people's everyday life. DfSB, AT, and SPT represent different approaches to intervening and influencing people's (un)sustainable doings. These differences would inevitably influence the perspective and focus of the adopters of these approaches. It appears that some students tend to choose the lens that aligns with their perceptions of the meaning of design's capability and designers' responsibility. For example, one student chose SPT over DfSB and AT because *"A designer, in my opinion, should look to push boundaries within reason and frame a bold vision into a digestible, realistic proposal that both addresses a client or a group's needs, but also speaks to the broader human condition. The social theory practice lens was an excellent tool in this respect"* (P13). Similarly, another student chose AT instead of other lenses as *"I believe designers can be of great value to help change behaviours and patterns, but we should be aware that this is what we do and what implications our actions might have. This was the main reason why I was interested in a milder approach to design for sustainability, as opposed to more forceful ways of steering with technology"* (P8).

Some students also took an explorative path and decided which lens should be adopted after they had figured out the benefits a particular lens might bring to their project. Students reported that the lens helped them locate the appropriate unit of analysis and develop sustainable design interventions at a proper level. For instance, one student pointed out: "*My primary focus was how details can make a great difference…. However, throughout the course, along with me learning about the lenses and implementing them in a case, my interest shifted to understanding systems and people as a mass rather than individuals"* (P16). In their project report, they further elaborated on the rationale for choosing SPT – *"it was a crucial step to understand the bigger picture of what people's practices in the supermarkets look like and how meanings, competences and materials interrelate in them. This should support the group's research for a solution that fits to the average people's practice and thus ultimately reduces the amount of waste produced by packaging."*

We also found that some students encountered difficulties identifying and understanding the differences between the three lenses. This problem became prominent especially in the project module of the course as students started seeking more support on how to better connect the chosen theoretical lens to the research and design process of the project. To address this, we believe that the course should provide a more in-depth comparison between the behaviour, activity, and practice perspectives. In particular, one student commented: *"I think that there was quite a lot to learn in a short time in the beginning of the course and I had some struggles with differentiating the lenses from each other. However, that became clearer after the lecture compared the lenses to one another which I appreciated a lot"* (P19). In particular, one student suggested that "*although they [referring to the lenses] were extensively discussed within the lectures, and that was already quite helpful, more visualizations (maybe even created* *together) in the lecture could have been helpful to grasp the differences in more depth*" (P17). Therefore, from a teaching perspective, the characteristics, strengths, and limitations of the three lenses should be more explicitly articulated and presented to students for them to build up their confidence when applying the lenses in their projects.

5.3 Knowledge and aspirations that students acquired from the course

Four of the twelve project groups were mixed with students from both Design background and Sustainability background. Feedback from these students showed that they were able to complement each other's knowledge and skillsets in a project setting – *"We had different and complementary things to offer during the group work"* (P21), *"We had different perspectives and qualities to contribute which improved the work"* (P23). Furthermore, the cross-disciplinary group collaboration also enabled students to learn from each other and adopt new ways to investigate and address sustainability challenges from a design perspective. In particular, one student noted that *"I feel like we all could bring what we have learned from before and "was good at" …. Thanks to the group, I feel like I have learnt new ways to find, investigate and solve problems, by finding and designing solutions"* (P4).

Regarding the most useful knowledge and aspiration that students acquired in relation to the three theoretical lenses offered in the course, we found that reflections from the Design students and the Sustainability students are slightly different. The design students stated that they developed a deeper understanding of the potential impacts of design on people's everyday life doings – *"Before, I always made a design solution just based on requirements of the new product, but without thinking about the environment…. During the course I became more aware of the importance of sustainable design and how we can influence people to be more sustainable by making good designs"* (P11). They also highlighted that the different theoretical lenses and tools can be particularly useful for them to reflect on the sustainability aspect of design in their future projects – "*I will include the 'design with intent' cards in my own personal toolkit to use for future projects and I will definitely continue to read more about this area of design to develop my knowledge further*" (P1), "*Now I have more tools and knowledge about different approaches and lenses, I think the different design approaches and learnings will help me identify both problems and solutions in future projects*" (P20).

In addition, the different theoretical lenses also enabled the Design students to realize that real-life sustainability issues are wicked problems. The lenses can provide students with a systematic approach to uncovering the complexity of human doings and better framing sustainability challenges in the context of people's everyday life. For example, many students noted that *"since climate change and creating sustainable solutions and changes is a complex problem and area, I think courses like this is very important to highlight the different perspectives and lenses within sustainability and design that needs to be discussed"* (P20), *"That you have to really understand the best way to design for the context and the people you design for, and not only make the design product itself sustainable, for a solution to truly be sustainable in the long run"* (P21).

On the other side of the spectrum, the Sustainability students pointed out that the course has broadened their views on sustainability as it introduces what design is capable of in shaping people's daily life doings. For example, one student wrote: *"In my education, we learn a lot about industrial development and climate actions in a larger scale…. Therefore, I found this course interesting since it treats the subject through another perspective. I have learned a lot of new things about behaviour and psychology, and I think the knowledge will be useful together with what I have learned in other courses about sustainability"* (P27). Similarly, another student commented: "*I am happy that I took this course since it has broadened my perspective on sustainability and how people's behaviours can be influenced to become more sustainable*" (P26). Furthermore, we found that the course also provided a complementary view to Sustainability students' focus on technology and policy-oriented solutions by providing a user-centred design perspective into their existing knowledge and toolboxes: "*I have gotten a new way to look at behaviours, from something unpredictable and unknown to realizing it is actually something that can be studied and analysed. I think this perspective is a good one to have as an engineer to be able to see beyond technology and understand what possibilities and limitations that is caused by people*" (P19).

6 CONCLUSIONS

The DfSEL course aims to provide students with knowledge on how to select and apply three different theoretical lenses – a *behaviour-based lens* from *Design for Sustainable Behaviour Models* (DfSB), an *activity-based lens* from *Activity Theory* (AT), and a *practice-based lens* from *Social Practice Theory* (SPT) – to better understand and develop design-oriented interventions that improve the sustainability aspects of people's everyday doings. In summary, the study shows that the three theoretical lenses (DfSB, AT, and SPT) can support students in choosing an appropriate unit of analysis and systematically developing sustainable design interventions at a target level. However, we noticed that students often encountered difficulties understanding and articulating the differences between different lenses. This is partially due to students not being used to the theoretical concepts from psychology and sociology in their previous education, let alone combining the theoretical perspectives with an array of research methods in their design projects. Keeping this limitation in mind, in the future, the course should put more focus on highlighting the unique characteristics, strengths, and limitations of different lenses to designing a sustainable everyday life, thus guiding students to make more informed decisions on which theoretical lens matches their project themes and long-term learning goals on sustainable product design. Furthermore, we found that the course offered design for sustainability aspirations to different groups of students. For students with a solid design background, we found that the theoretical lenses enabled them to take a more systemic approach to analysing and envisioning the potential impacts of design on people's everyday life. On the other end of the spectrum, for students with a strong sustainability background, the course broadened their view by encouraging them to incorporate a user-centred design aspect into technology and policy-oriented sustainability solutions.

Finally, drawing upon our experiences of teaching the DfSEL course so far, we believe that the perspectives of behaviour, activity, and practice, along with the theoretical lenses of DfSB, AT, and SPT, can offer an entry point for students to (re)discover and align their existing understanding of sustainable product design with new concepts introduced by the lenses. Based on the different theoretical nature and theoretical approaches to understanding and tackling sustainability challenges, students are able to explore and experiment with different design intervention strategies to influence people's (un)sustainable daily doings. As one student noted: *"I believe that the different ways of describing what I previously referred to as just "behaviours" in different ways - such as practices, activities, actions, habits and so on, was especially interesting. Looking at people's "doings" with different lenses is powerful and provides a lot of new insights and knowledge."*

REFERENCES

[1] Boks C. and Diehl J. C. Integration of sustainability in regular courses: experiences in industrial design engineering, *J. Clean. Prod.* 14 (2006). https://doi.org/10.1016/j.jclepro.2005.11.038.

[2] Watkins M. and Lofthouse V. A review of sustainability within product and industrial design courses in British universities, in: DS 62 Proc. E PDE 2010, *12th Int. Conf. Eng. Prod. Des. Educ. - When Des. Educ. Des. Res. Meet*, 2010.

[3] Cooper R. Design research – Its 50-year transformation, *Des. Stud*. 65 (2019) 6–17. https://doi.org/10.1016/j.destud.2019.10.002.

[4] Ceschin F. and Gaziulusoy I. Evolution of design for sustainability: From product design to design for system innovations and transitions, *Des. Stud*. 47 (2016) 118–163. https://doi.org/10.1016/j.destud.2016.09.002.

[5] Watkins M., Casamayor J. L., Ramirez M., Moreno M., Faludi J. and Pigosso D. C. A. Sustainable Product Design Education: Current Practice, *She Ji J. Des. Econ. Innov.* 7 (2021) 611–637. https://doi.org/10.1016/j.sheji.2021.11.003.

[6] Fletcher K. and Dewberry E. Demi: a case study in design for sustainability, *Int. J. Sustain. High. Educ.* 3 (2002) 38–47. https://doi.org/10.1108/14676370210414164.

[7] Chu W., Glad W. and Wever R. A meta-synthesis of the use of activity theory in design for sustainable behaviour, *Des. Sci*. 7 (2021) e17. https://doi.org/10.1017/dsj.2021.17.

[8] Selvefors A. Design beyond interventions–supporting less energy-reliant activities in the everyday, C*halmers University of Technology*, 2017.

[9] Daae J. Informing Design for Sustainable Behaviour, *Norwegian University of Science and Technology*, 2014.

[10] Kuijer L. and Bakker C. Of chalk and cheese: behaviour change and practice theory in sustainable design, *Int. J. Sustain. Eng*. 8 (2015) 219–230. https://doi.org/10.1080/19397038.2015.1011729.

[11] Braun V. and Clarke V. Using thematic analysis in psychology, *Qual. Res. Psychol*. 3 (2006) 77–101. https://doi.org/10.1191/1478088706qp063oa.

AGILE: ADRESSING VUCA AND AFFECTIVE FACTORS IN DESIGN & DESIGN ENGINEERING PROJECT BASED LEARNING

Stephen GREEN[1], Suzan ORWELL[1], Freddie PAGE[1], Tiffany CHIU[1] and Ahmed PATEL[2]
[1]Imperial College London
[2]Middlesex University and Imperial College London

ABSTRACT
The volatile, uncertain, complex and ambiguous (VUCA) global context, amplified by two years of COVID has a profound effect on the predominant project based learning approach within design and design engineering curricula. Project management and affective or emotional factors are evidenced as significant but often overlooked within this context. Linking literature on the topics with data from n=200 participants from 3 HEIs, three aspects of popular industry Agile project management approaches are shown to correlate directly with addressing the VUCA context together with a model as a basis for considering the alignment of the topics.

Keywords: Agile, project based learning, affective domain, VUCA

1 INTRODUCTION
With a 50 plus year history of design research, much of which has been focused on design process there has been more limited attention to two categories of factors which logically have a profound effect on the outcomes of design, engineering and innovation activities. These categories are identified here as: (i) affective factors and (ii) project management factors. These are extensively explored in other fields but represent significant gaps in the design research field. Studies of design and engineering education (D&DE), where a predominant strategy is Project Based Learning (PBL), have also tended to focus on process with limited attention to a comprehensive view of factors affecting learning and project outcomes. In an earlier study Green et al highlighted how Volatility, Uncertainty, Complexity and Ambiguity (VUCA) factors are impacting the affective or emotional domain of learning [1]. The recent global COVID context has amplified recognition of affective factors in learning. Considering project management and affective factors in combination leads to the primary motivation for this work: to explore how to better support student learning and to address affective learning challenges in design engineering subjects.

1.1 VUCA
The VUCA concept and acronym can be seen as an approach to ‘black swan’ events, originally 9/11, but now COVID. We can initially consider VUCA factors in relation to three nested spheres of influence: the global ‘external’ context, the pedagogical context and the student or student teams’ ‘internal’ context [2]. As a direct result of the global COVID pandemic a number of scholars have referenced the VUCA model as a basis for exploring the ‘forced’ adjustments needed in teaching and learning practice and pressure on students’ wellbeing [2,3]. As a foundation for considering these affective factors, the value of translating the VUCA terms in various contexts including education has been noted in a number of studies [1,2,4]:

- **Volatility** is associated with fluctuations and turbulence with acknowledgement that D&DE teaching is yet to fully embrace these dynamics, whether in shaping attitudes, transforming pedagogic delivery or predicting future professional roles.
- **Uncertainty** is defined as a psychosocial construct which can have positive and negative implications for how issues and events are managed considering levels of confidence and understanding. For example, in D&DE learning and the relationship between student risk aversion and creative thinking.

- **Complexity** is manifest in many contemporary contexts where multiple factors that interact with each other can lead to experiences of chaos and stress. However, Don Norman notably states: 'Design schools do not train students about … complex issues…'[5].
- **Ambiguity** is a lack of clarity about how to interpret situations with incomplete, contradicting, inaccurate or 'fuzzy' information. Pedagogy contexts require us, not just to consider ambiguity between context and process factors, but also the conscious and unconscious ambiguity in the psychosocial factors amongst students and faculty.

Our earlier paper [1] evidenced the link between the VUCA categorization and student emotions or affective factors, in particular within the uncertainty and ambiguity categories. Uncertainty in PBL was seen in the student data to directly influence anxiety, stress and confidence levels. Many students saw the time and effort required to deal with uncertainty as a negative in their learning. Ambiguity was typically viewed by students as a fault of tutors' teaching plans or materials, for example perceptions of ambiguity in assessment rubrics. Therefore, we can see that the VUCA concept has value for identification and decomposition of affective factors, but with considerable scope for more nuanced understanding and recommendations for mitigation.

1.2 Affective factors

Whilst affective factors have been a well-recognised part of Bloom's three domains of learning outcomes [6] it is increasingly recognised that the affective domain is under researched. The domain is seen as fundamental to the cognitive and psychomotor domains but has been marginalized due to the challenges of objective evaluation [7]. Organisations including OECD and UNESCO recognise the importance of resilience and social-emotional competencies as part of learning, but also that teachers are poorly prepared for supporting their students [2]. Studies show that stress in learning environments is 'contagious' and affecting both students and staff, and there is a need to address the balance between disciplinary knowledge and skills content with cultivating emotional resources and agency [2]. Bloom's affective domain has evolved into a low-to-high hierarchy of factors based on work by Krathwohl et al. [2]: Receiving (e.g., teaching and learning content & experiences), Responding, Valuing, Organising and Characterising (internalising and personalising a value system). Scholarly exploration of affective factors in the education field leans heavily on Bloom's work and typically discusses interventions following this hierarchal model.

The psychology field defines that emotions and motivation are determined by social-historical contexts. A further classification identifies three levels of consciousness in relation to emotions: i) total subconscious emersion, for example being consumed by anxiety, ii) students having awareness of their emotions, and iii) adding conscious actions in response to emotions or having the facility to regulate emotions [8]. Therefore, connecting the regulation of emotions to motivational factors and self-efficacy. Acknowledging the complexity of studies of affective factors, Figure 1 maps understanding and frameworks from psychology [8], through the educational field [2], to Agile applications in education [9].

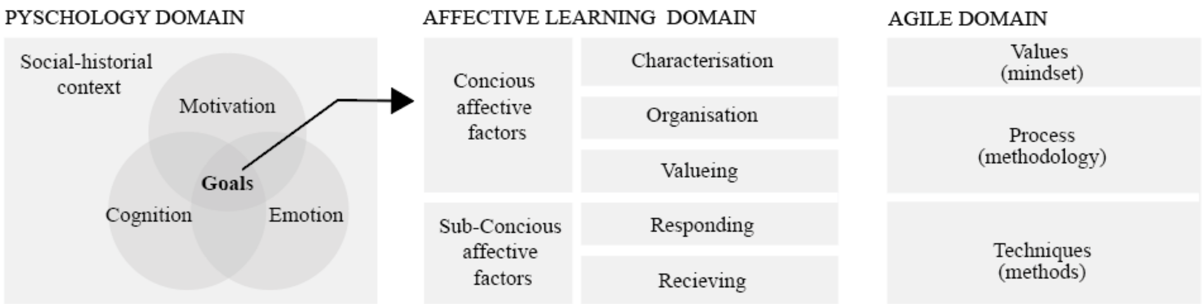


Figure 1. Mapping affective factors from psychology to Agile in education

1.3 Project Management, Agile and the HE context

Agile is a popular iterative project management approach used in industry since introduction in 2001 to manage software engineering projects and teams [10]. It emphasises clear communication, incremental delivery and empowerment of team members. The use of Agile in learning and teaching has been implemented for several years with some earlier research establishing the relationship and similarities between Agile principles in industry and education in general. For example, both domains focus on planning, organising, frequency in assessing, appreciating feedback from different sources, monitoring quality and controlling success criteria [11]. The continued and embedded practice of feedback and reflection is an important element to consider in the higher education context as a basis for developing some of the necessary professional competencies, capabilities, and expertise for desirable graduate employability attributes. Agile methods may create positive influences on team collaboration and communication and improve the structure of PBL and team activities, leading to better collaboration, communication, self-efficacy and systematic thinking [12]. Parsons & MacCallum analysed Agile in teaching and learning at three levels: values, processes and techniques with the values level providing a foundation for promoting student agency with a focus on outcomes and improvement [9]. The processes level encompasses key concepts such as iterative and reflective learning and time boxed steps. The techniques level is synonymous with methods including, rapid prototyping, peer learning and 'stand-up's' (rapid presentation and reviews). Linking Agile values, processes and techniques to affective factors in PBL; time-related demands such as high workloads, deadlines and the challenges of self-organized learning are associated with stress but could be decreased with enhanced project management practices [9]. The outcomes focus of Agile values links with PBL and positive emotions. At the techniques level, time boxed steps support a sustainable pace of learning, with regular feedback and reflection on actual learning outcomes. Supporting students in self-managing this approach can help build confidence and alleviate uncertainty.

1.4 Emergent VUCA – PBL model

Considering affective factors (amplified by COVID), and the predominant PBL mode of teaching and learning in D&DE, leads to a development of a model (Figure 2) which shows a more nuanced alignment and influence of VUCA factors with students and projects in educational settings than our earlier work [1]. Starting at the middle of the model we can see that VUCA factors, especially Uncertainty (and associated emotions) have a direct internal influence on students and therefore their learning (indicated by an outward pointing arrow). The PBL context, or zone of influences, is often further complicated by group working. Students are working within a predominantly PBL context, which, to varying extents, is mediated or scaffolded by tutor input in what can be described as the zone of proximal development (ZPD) – the space between what students know and what they can potentially learn [12]. It has been pointed out in relation to reflection, as a higher level of learning, that; 'Teachers themselves may firstly have a zone of proximal development to negotiate' [13] and that Ambiguity for students (and associated emotions created in the PBL context) can be influenced by effective scaffolding. The PBL context is usually strongly aligned with and influenced by Volatility and Complexity in the external context. Therefore, this model serves as a useful reference for a further decomposition of research questions within the refined goal of: how to better support student learning and address affective learning challenges in the ZPD with Agile approaches?

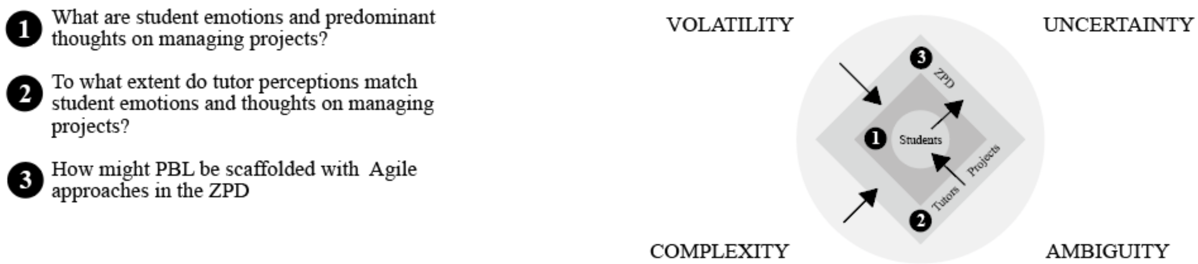


Figure 2. Alignment and influence of VUCA factors on students and projects

2 PRIMARY RESEARCH METHOD

A method to gather data to understand student and tutor perspectives in a time efficient way was developed for the study. This involved using an online interactive survey platform (Mentimeter) with a selection of students and tutors at institutions involved with undergraduate and postgraduate design, design engineering and innovation study. Overall student participants n=209. and tutors n=22 from three HEIs took part in the survey. A common format was used for students and tutors, with tutor questions adjusted to ask about their PBL plans for students and perceptions of student thoughts. The questions and related rational were as follows:

Q1 **Year of study** (1st year undergraduate to 4th year postgraduate level)? It was anticipated that student views and tutor strategies might evolve over the period of HE study and in turn may relate to levels of educational scaffolding.

Q2 **Size of project** (length and mode variables)? What is known as short-fat and long-thin modules, or projects of varying lengths are predominant features of D&DE programmes. This data is intended to reveal any overall factors in relation to year of study and levels of scaffolding.

Q3 Words associated with **managing D&DE projects**? Each participant was invited to provide up to 5 words. This was intended to provide an understanding of the predominant thoughts and therefore practice of the participants on their project. Correlations with tutor responses may indicate variations between student experience and practice and tutor strategy and perceptions.

Q4 Words associated with **emotions on D&DE projects**? (up to 5 words per participant) In this case the accompanying information encouraged providing words which might cover a range of emotions. This will allow for significant sentiments to be identified and the overall weighting of sentiments on different potential axes. Student – tutor variations may indicate different perceptions and areas of concern.

Each of the following questions had multiple choice answers on a 5 point Likert scale ranging from minimal to extensive activity. This format allows for both qualitative and quantitative analysis of the resulting data.

Q5 **What goals** do you set for yourself when working on a project? (students); To what extent do you define goals for students' projects? (tutors). This potentially links to Agile values and principles.

Q6 How much **project structure** do you independently define in your process? (students); How much structure or defined process do you provide for your students' projects? (tutors). This question links to Agile operation or structure.

Q7 To what extent do you **formally record-review-reflect** on your project process & decisions? (students); To what extent is student record keeping, reviewing and reflecting integral to your planning for student project work? (tutors). This is linked to Agile concepts of review and reflection.

Q8 How much of your own **decomposition and sensemaking** do you do in your projects (rather than what staff provide)? (students); How much of your own decomposition and sensemaking do you provide students & require them to follow? (tutors). This is relating to Agile decomposition for planning and workflow.

Finally, students were asked to provide short comments on the **relationship between project management activities and feelings** during project work, or for tutors, their understanding of their student's thoughts.

3 RESULTS

The qualitative data in the form of keywords and short statements provided a rich initial indication of perceptions of project management and affective factors. The complete dataset for the two keyword questions is considerable. In the form of word clouds (e.g., Figure 3) the data provides a clear overview of factors. For Q3 **project management** it is notable that theories and frameworks are largely absent, but there is clear recognition of time being the most significant factor. Specific tools or methods such as Miro or Gannt also feature strongly. One can also see that the sample can be strongly influenced by their immediate experience. For example, responses from a 2nd year group reflected the significance of communications in team working as part of project management. For Q4, asking for key words associated with **feelings or emotions,** there is a clear overall dichotomy between the excitement, motivation and student's inherent commitment to their subject area, contrasting with, at the negative end of the spectrum, words including: 'stress', 'anxiety', 'confusion', 'low confidence'. It is also interesting to see more nuanced factors such as: 'imposter syndrome,' 'feeling neglected,' 'overwhelmed' and others. For both questions there is clear evidence of correlations between project management and affective factors, for example students listing 'mental health,' 'stress' and 'anxiety' in the project management question, and 'team dynamics' and 'being lost'' in the feelings question.

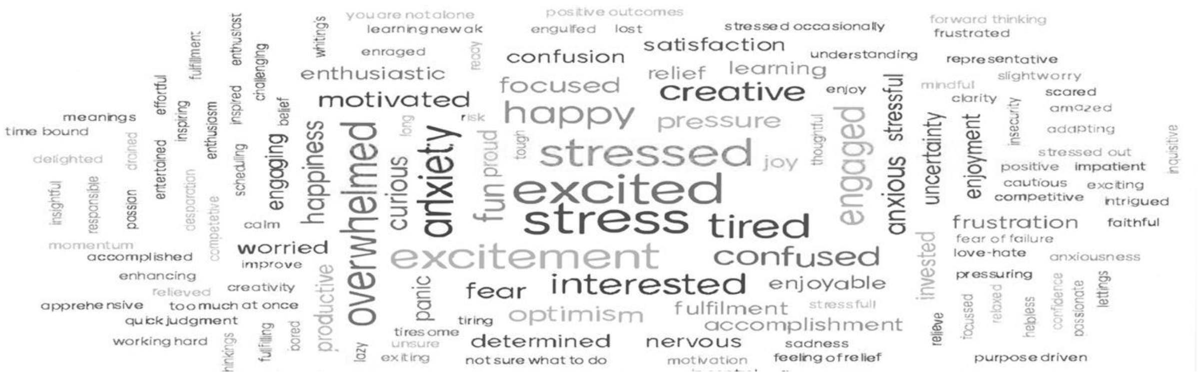


Figure 3. Q4 Word map of feelings from one of the study HEIs

The quantitative data from Q5-Q8 provided limited basis for analysis and insight. The averages of the tutor responses (n=22) on the 5 point Likert scale broadly matched the overall student results, however individual responses also included tutors marking all questions at both the low and high end of the scale, suggesting highly individual views on the topics. The student responses across all 4 years and 3 HEIs were broadly in line, with some indication that 4th year students were more reflective and objective in their answers than lower years. There was a common profile of scores across year groups and the four questions. Q5 **Goal setting** had the highest ratings with >70% scoring in the 4-5 range. Q6 **Project structuring** scored lower with the majority >66% scoring in the 3-4 range. Scores shifted lower again for both Q7 **Recording-reviewing-reflecting** and Q8 **Decomposition & sensemaking** with a wider spread of results and a smaller majority, around 40% scoring at the midpoint of 3.

The short phrase responses to the final question, linking project management with feelings, provides the richest source for research insights. From an overall *n*106 detailed comments an initial coding exercise reveals a number of predominant themes ordered by numbers of instances. The highest instance is students recognising, in their own work, the value of project management and that this supports mitigating stress. This potentially shows confirmation bias but does indicate a useful level of reflection on this important correlation. The second most frequent factor is the mention of motivation. This links to the earlier key word exercise with terms such as 'excitement,' 'engaged' or 'invigorating.' Significantly this links to another common theme discussed as the "ebb and flow" of feelings within the course of a project. The social dimension, often linked to teamworking is frequently reported. Distributed across the results one sees considerable evidence and awareness of the negative impacts of stress and anxiety, but often with what one might consider as poor levels of, or misplaced agency in managing negative feelings. A spectrum of intrinsic and extrinsic motivating factors also emerges from the data. From the tutor comments one can see some awareness of student affective factors, but limited strategies or confidence in providing cohort level content to address these factors.

4 CONCLUSIONS AND FURTHER WORK

Returning to our 3 key questions we can draw conclusions from the relationships between our data findings, earlier theory and recommended further development. Firstly, we expose an important and underexplored topic (the relationship between PBL, project management and student emotions) which, confirmed by our evidence, is a significant topic to address. Secondly, and with considerable scope for further work, we evidence awareness of students' affective factors amongst tutors, but somewhat limited cohort level strategies to address the challenges. Finally, the main outcome of our work at this point is, based on review of relevant literature and correlations with our research data, that three aspects of Agile approaches to project management provide a basis for addressing affective factors in D&DE PBL. The aspects of Agile are: 1) **Agile values** – Agile methods emphasise establishing an agreed set of values at the outset of activities, 2) **Agile operation -** which embraces iteration, review and reflection as integral to the underpinning values, this also links with PBL and experiential learning qualities and 3) **Agile decomposition**, the process for identifying and managing discrete chunks of work in a collaborative and sustainable manner supports managing ambiguity and what was described as the 'ebb and flow' of emotions in PBL. Table 1 maps these three elements to a summary of potential action areas for tutors. There is considerable scope for further research in the confluence of topics and we would hope that the broader D&DE PBL community will respond with targeted research and practical interventions.

Table 1. Mapping Agile elements to PBL, Project and Feelings management

	Agile values	Agile review & reflection	Agile decomposition & workflow
D&DE PBL factors	Recognising motivation & emotion in setting values	Review and reflection are an overlooked aspect of PBL	Decomposition for PM & managing ambiguity are key attributes for PBL
Project management support	Co-creating and establishing working values and principles in PBL	Building-in and developing agency in review and reflection practice	Scaffolding decomposition as a more explicit part of PBL
Managing feelings & emotions	Collaboratively defining values addressing the affective domain	Using review and reflection to target affective factors in PBL practice	Attending to scaffolding for decomposition & developing agency

REFERENCES

[1] Green S. et al, 2019, *Proceedings of the 21st International Conference on Engineering and Product Design Education* (E&PDE 2019), University of Strathclyde, Glasgow. 12th -13th September 2019.

[2] Hadar L. L., Ergas O., Alpert B. and Ariav T. Rethinking teacher education in a VUCA world: student teachers' social-emotional competencies during the Covid-19 crisis, *European Journal of Teacher Education*, 2020, 43:4, 573-586.

[3] López-Alcarria A., Olivares-Vicente A. and Poza-Vilches F. 2019. A Systematic Review of the Use of Agile Methodologies in Education to Foster Sustainability Competencies, Sustainability 11, no. 10: 2915.

[4] Bennett N. and Lemoine G. J., 2014, What does VUCA Really Means for You, Harvard Business review, Jan-Feb.

[5] Norman D. 2010, Why Design Education Must Change, Core 77, available at: *http://www.core77.com/blog/columns/why_design_education_must_change_17993.asp* (accessed on 18/12/18).

[6] Bloom B. S., Engelhart M. D., Furst E. J., Hill W. H. and Krathwohl D. R. 1956, Taxonomy of educational objectives, *Handbook I: The cognitive domain*. (New York: David McKay Co Inc.).

[7] Dorji P. and Yangzom. 2021, Affective Domain: The Uncharted Area of Teaching and Learning in Tertiary Education, 2021, *Asian Research Journal of Arts & Social Sciences* 13(1): 51-65, 2021.

[8] Schutz P. A., Hong J. Y., Cross D. I., et al. 2006, Reflections on Investigating Emotion in Educational Activity Settings. *Educ Psychol Rev* 18, 343–360.

[9] Parsons D. and Maccallum K. 2019, Agile and Lean Concepts for Teaching and Learning, chapter in: *Agile and Lean Concepts for Teaching and Learning*, Eds Parsons D & MacCullum K, Springer.

[10] Martin A., Anslow C. and Johnson D. 2017, Teaching Agile methods to software engineering professionals: 10 years, 1000 release plans, in *Lecture Notes in Business Information Processing*. Springer Verlag, pp. 151–166.

[11] Stewart J. C., et al. 2009, *Evaluating Agile Principles in Active and Cooperative Learning*.

[12] Vygotsky L. S. 1978. *Mind and Society: The Development of Higher Psychological Processes*, Cambridge, MA: Harvard University Press.

[13] Coulson D. and Harvey M. 2013, Scaffolding student reflection for experience-based learning: a framework, *Teaching in Higher Education*, 18:4, 401-413.

ARTICULATING MODERN ENGINEERING CHALLENGES USING AN ARTEFACT STUDY THROUGH TIME

Jeff BARRIE
School of Civil, Aerospace and Mechanical Engineering, University of Bristol, United Kingdom

ABSTRACT
Typically, an artefact study allows engineering students to dissect a product or device to understand its inner mechanical workings, manufacturing and materials. This paper discusses a broader artefact study which asks students to choose a man-made artefact from the 20th century or earlier and discuss the implications of designing or constructing such an artefact in the 21st century. Students were asked to consider contemporary design processes, changes in market needs as well as a deeper appreciation of the environment, socio-cultural issues, sustainability, ethics and climate change. For example, what if the Great Pyramid of Giza was constructed today? What if the Sinclair C5 was a new sleek, contemporary, and modern form of transport for 21st century commuters? First year engineering students were asked to choose an artefact that was interesting or meaningful to them-and encouraged to consider design changes, new technology and new needs and challenges associated with the 21st century. The work produced from the students was fascinating and insightful; showing that modern engineers can learn from the past.

Keywords: Artefact study, reflection, sustainability, Engineers Without Borders, curriculum design

1 INTRODUCTION
As part of a new introductory design unit, 700 first year engineering students from a broad range of disciplines were given key knowledge, skills and competencies essential for 21st century engineers. This entailed hands-on workshop and practical skills, Health and Safety inductions and electronics, an ice-breaking group design project supported by Engineers Without Borders, as well as developing skills in technical drawing and Computer Aided Design (CAD). The unit was also supported with asynchronous design content using online video-based lectures and activities, supported with weekly online drop-in sessions. The content covered key unit learning outcomes which were difficult to achieve through practical, studio-based work alone. This included an introduction to design processes, how to define and bound an engineering problem and seek new opportunities, as well as appreciating 21st century challenges engineers face, such as sustainability, ethics, socio-cultural factors, design for the environment and the climate emergency. The unit (part of a new curriculum) was designed to act as a foundation for all engineering students in the school, to give them key professional engineering and design skills as well as basic knowledge that will support them in discipline specific project and design units they will undertake the following term. As such the unit had to be sufficiently broad and relevant to a range of engineering disciplines, from Civil Engineering to Electrical Engineering.

Students were introduced to the design process, teamwork and global responsibility by undertaking the Engineering for People Design Challenge with Engineers Without Borders in the first week of university, with randomly selected 4-person teams from their larger teaching groups. For some students, their first day as an engineering student was to be inducted in Health and Safety practice and the University workshop and lab spaces (much like workplace training). These activities set a precedent to what the expectations and responsibilities are for a 21st century global engineer.

The studio-based activities focused on basic technical drawing and CAD exercises (part of what was called a skills certification) which formed part of their portfolio of work. Throughout the unit the students were introduced to weekly topics on design via online lectures, and to complement the new direction of teaching, the final piece of coursework students were expected to deliver was an essay based artefact study and individual reflection (reflecting on teamwork, skills and competencies learned in the unit). An overview of the unit schedule and parallel activities can be found in Figure 1.

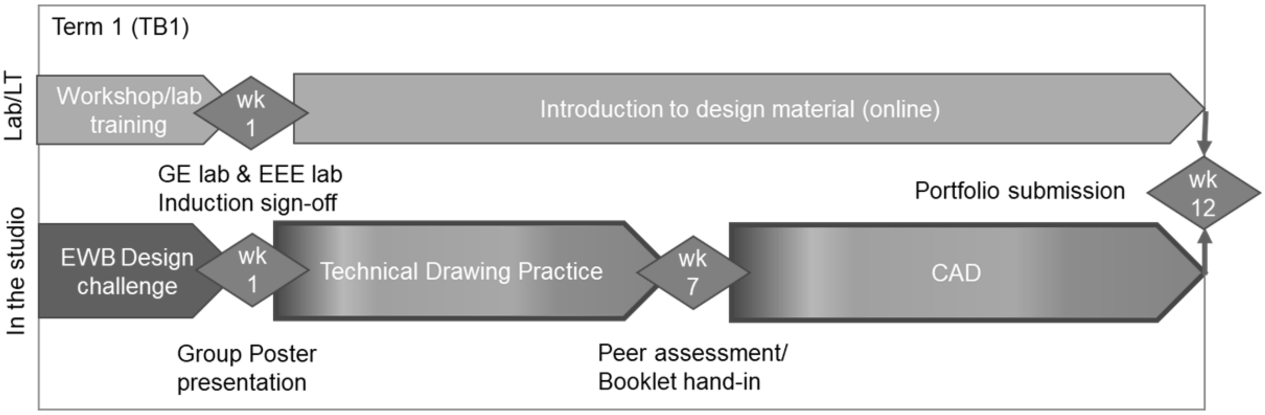


Figure 1. Unit content over the term

2 A DIFFERENT TAKE ON A TYPICAL ENGINEERING ARTEFACT STUDY/MECHANICAL DISSECTION

The original idea of the artefact assessment was to allow individual students to design and make their own artefact using their newfound CAD and technical skills. Unfortunately, this was not feasible due to the scale of the unit, the burden on the workshops and labs at a busy period during term as well as the timing of CAD sessions which would leave little time for students to develop their own designs. There was also the issue of mapping the assessment to some of the trickier design-focused Intended Learning Outcomes (ILO's) of the unit (as the group design activity was formatively assessed). Instead of creating their own artefact, students were instead asked to undertake a study of an existing engineering artefact.

A study of an engineering artefact (or mechanical dissection) is an approach identified in the teaching of engineering design, in particular Stanford University's ME99 Mechanical Dissection course where students learn the *"vocabulary of mechanical systems"* to Strathclyde University's vehicle dissection, introducing first year Mechanical Engineering students to component functions, materials, manufacturing and analysis [1].

Stanford took a broad approach to mechanical dissection (as it's not *just* about taking things apart and finding out how they work) by building students awareness of the design process and improving their communication skills. When the ME99 course launched in 1999, it was offered to students who did not fit the target criteria of an engineering major-but were curious about the world around them. In general, the course provided an opportunity to be more inquisitive and take a problem-solving approach to their learning [2].

Strathclyde's approach also allows students to build an awareness of the design process and develop communication skills but is more group-based (most likely to cope with the cohort size) and took a more analytical approach. [3].

Whilst it is acknowledged that a hands-on mechanical dissection is a useful activity in satisfying an engineering students curiosity of how things work and how they are made, the constraints and challenges of offering a such activity to a large cohort of students is also highlighted in a study by Armstrong Atlantic State University (AASU) which used multi-media technology to provide students with a virtual strip-down of the components of an electric toothbrush-which generally yielded positive results and comments-and provided an alternative method to the traditional lab or workshop-based approach [4].

The dissection activities described at AASU, and Strathclyde dealt with cohort sizes of 190-200 students. Given the constraints on the lab and workshop spaces, a typical mechanical dissection-based approach would not be suitable for a broad engineering course with 700 students, given that the cohort was mixed discipline and the first year Mechanical Engineering students within the cohort had yet to undertake any units on machine components, mechanisms, material or manufacturing.

Another observation from the mechanical dissection activities described in Stanford, Strathclyde and AASU is that there is little or no consideration of sustainability or environmental impact. Given the findings are from 2010 or earlier indicates that such considerations were not as critical at the time and may have subsequently been included in the curriculum.

With such focus on materials, function and analysis, the engineering approach to studying an artefact is somewhat different to that in Archelogy, which help archaeologists not only understand the technical aspects of material and construction, but wider societal aspects. For example, an archaeological approach to understanding artefacts may entail how an object builds into a picture of the society that made and used it, how cultural and economic factors as well as the material properties influenced how an object is made as well as a deeper understanding of the object's biography [5].

Whilst mechanical dissection is still a relevant and useful activity for Mechanical Engineering and Product Design students. An archaeological approach, in a way, would allow a Civil Engineering student to 'take apart' a bridge or building, or an Aerospace Engineering student to understand cultural, economic and societal aspects of a particular aircraft. It is also acknowledged that students do not necessarily need to take a product physically apart to understand materials and function, bearing in mind that AASU developed a virtual approach-and from what is assessed in the activities at Stanford and Strathclyde-students can gain an understanding of the design process and develop their communication skills from the activity.

This approach also maps better to the intended learning outcomes of the unit, which not only asks students to explain the common stages, processes and methods of engineering design but to articulate the wider context of modern engineering challenges, such as sustainability, ethics, socio-cultural issues and climate change. These challenges have been recently highlighted as critical considerations in professional engineering, such that they form a key area of learning for all engineers and their role in society [6].

3 LEARNING FROM THE PAST; AN ARCHAEOLOGICAL APPROACH

By taking an archaeological approach to understanding an engineering artefact or product, students can delve into history, and reflect on the societal and environmental impact of man-made artefacts. There are many interesting engineering artefacts students across time can choose from, such as architectural wonders such as the Great Pyramids of Giza, to the industrial revolution with James Watt's steam engine, not to mention Isambard Kingdom Brunel's iconic Clifton suspension bridge or SS Great Britain, to 20th century innovation in aviation with the Boeing 747 and Concorde.

Such artefacts are discussed as case studies in engineering lectures, and many can be found on posters adorning hallways of most engineering schools. But to engineering students who will eventually be senior professional engineers in the mid-21st century they represent a bygone age-at a time when the world and society was very different-where design for environment and sustainability were alien concepts. Even engineering in the late 20th century now seems outdated, for example the Boeing 777 was the first aircraft to be fully designed using computer-aided design (CAD) software, to reflect a cultural change in design and manufacturing practice. It's a recognizable, modern aircraft still in service today-but in design and development terms it's nearly 30 years old (for anyone under 30-year-old that's 5 generations of the Sony PlayStation).

However, there is a lot that 21st century students can learn from products and engineering artefacts of the past. This concept was recently explored in a paper by engineering academics at the University of Derby, who asked what students can learn about 'ancient' methods that will assist them in computer led design today, and what can be learned from the past that will help them in the future. The paper concludes that students appreciate the use of calculations and appropriate analysis to understand failures of the past [7].

By understanding an engineering artefact from history, students have access to a wealth of information about its conception, development, manufacture or construction and whether the artefact was a success or not. Students can also access decades of information on the societal and cultural impact of engineering innovations, not to mention their impact on the environment and climate change. Such is the gift of hindsight that students now have almost unlimited access to-but one has to bear in mind that the call to action for sustainable development and formation of guiding principles has been around since the 1980s [8].

An important factor to consider was bridging a link with the practices and challenges that 21st century students face now as well as the future-and that of engineering artefacts of the past. Inspiration on how to approach this came in the form of news article from New Civil Engineer, which hypothesized that *"if you were to get a time machine and bring Isambard Kingdom Brunel to your project site, his mind would* *be blown"*[9]. The article comments on the advancements of civil engineering practice, but also remarks on some useful learning of the past.

This led to the idea of a 21st century Brunel, and the changes to technology and professional approaches that one must adapt to. What if the Great Pyramids of Giza were constructed today? What would be the considerations of designing a Boeing 747 or Concorde using modern aerospace practice and materials? These questions formed the basis to how students were to be individually assessed on their understanding of 21st century engineering challenges and design processes.

4 THE DESIGN PORTFOLIO

The artefact study formed part of a portfolio of coursework that assessed students on their understanding of the unit outcomes, which included a personal reflection on the skills and knowledge each student has learned on the unit, as well as the challenges of teamwork within the Engineering for People Design Challenge. Students also submitted technical drawing exercise and CAD work. Overall, the portfolio of coursework was assessed under Pass/Fail criteria due to the skills and competency-based approach to the unit assessment. Where students could express individual creativity, and allow some differentiation between student coursework, was the artefact study.

Students were encouraged to choose an engineering artefact, from the 20th century or earlier, that they were interested in or had some sort of meaning to them-preferably affiliated with their programme of study.

Some examples were given to the students, to help them understand the context of the exercise, and dialogue with students helped develop some interesting ideas. For example, some approaches on a modern Pyramid of Giza included not only using modern building materials but appreciating the current socio-cultural situation of modern day Egypt. Ideas included a multi-purpose building that could be used more by the community (rather than a tourist site)-other ideas included a centre for displaced Syrian refugees, or a venue for underground Egyptian street music (a modern day Pyramid does exist, in Memphis as a Bass Pro shopping centre, which includes an alligator habitat). See Figure 2.

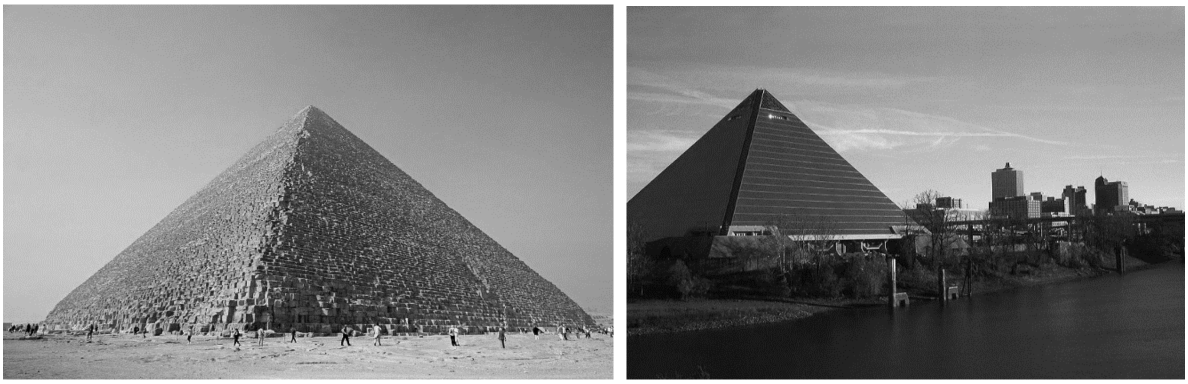


Figure 2. Right: The Great Pyramid of Giza and Left: The Memphis Pyramid (Wikipedia)

The Boeing 747 was also used as a case study example, where its iconic fuselage design is in part influenced by its end-of-service life as a cargo aircraft (the fuselage is big enough to fit a container into it) which students were quick to point out it's re-use cycle in a Life Cycle Assessment. Students were also able to appreciate the environmental impact of carbon fibre usage balanced with weight reduction and subsequent reduction of fuel. Students were also able to appreciate the design process using this example, as early concepts of the 747 included ideas not too dissimilar to (the now withdrawn) Airbus A380, and a daring concept that had the cockpit positioned at the bottom.

Another case study example was the Sinclair C5, a 1980's invention and transport revolution that did not meet commercial success. By investigating the Sinclair C5 in a modern context, students were able to appreciate the changes in society and explore new needs and opportunities in sustainable transportation in cities, such as taking advantage of lightweight material and improved battery technologies. See Figure 3.

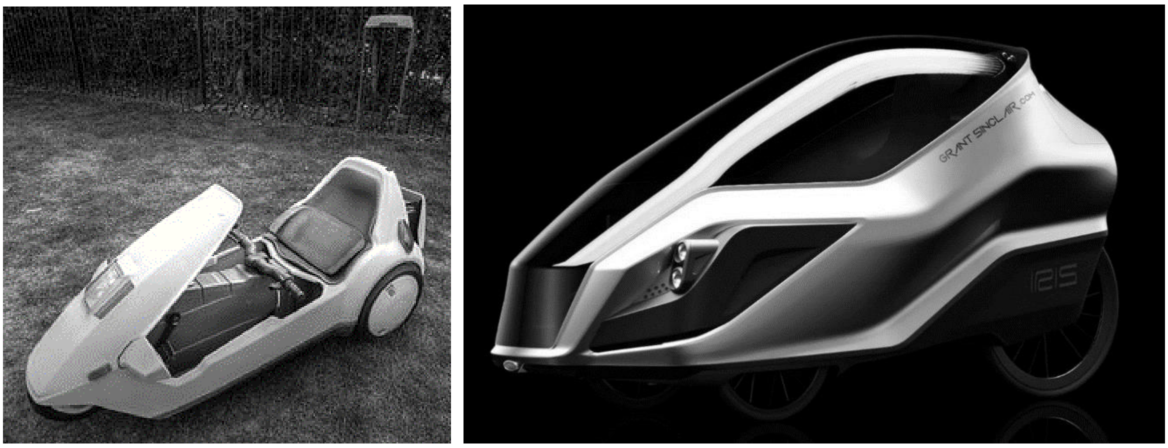


Figure 3. Right-Original Sinclair C5 (Wikipedia) Left-Sinclair C5 update (Telegraph)

5 DISCUSSIONS AND CONCLUSION

Students feedback on the exercise was mixed, for some they did not understand the context well, and preferred to work within the safe confines of the case study examples used (rather than choose their own artefact), others misunderstood the exercise and provided a history of the artefact, as opposed to a reflective study of how it fits into the 21st century and associated challenges. Another consideration was the online delivery of lectures, and expectation for students to work on the artefact study as out-of-class coursework. Much of the unit delivery was studio-based and thus focused on the more practical sides of the coursework which could be facilitated in such an environment. Some students struggled with the format, given they had little experience of essay-based or reflective writing. Nonetheless, many of the artefact studies submitted were thought provoking, insightful, varied and sometimes deeply personal.

For a first-year student, the artefact study provides a broad introduction to design processes and 21st century challenges facing engineers today-and provides a deeper insight into the socio-cultural, environmental, and ethical impacts of engineering artefacts. However, the artefact may be more appropriate as a consolidation tool rather than a summative form of assessment, and possibly more useful in latter stages of study after first year students gain the essential knowledge and skills they need as a foundation. The artefact study seems more suited to an activity where students can deepen their research skills and develop and integrate their engineering knowledge.

Nonetheless, the archaeological approach to an artefact study does have enormous potential to help engineering students to understand the context of 21st century engineering as well as their place and responsibility in the world, beyond just taking things apart and seeing how they work.

REFERENCES

[1] McLaren A. Approaches to the Teaching of Design. *The Higher Education Academy Engineering Subject Centre*, 2008.

[2] Sheppard S. D. Mechanical dissection: An experience in how things work. *Proceedings of the Engineering Education: Curriculum Innovation & Integration* (1992): 6-10.

[3] McLaren A. J. and Jenkins P. Mechanical dissection in an introductory engineering design module. *6th International CDIO Conference*. 2010.

[4] Goeser P. T., et al. A VIEW on Mechanical Dissection for Freshmen Engineering. *Proceedings of the American Society for Engineering Education South East Section Annual Conference*. 2010.

[5] Caple C. Objects: Reluctant Witnesses to the Past. *Routledge* 2006.

[6] The Accreditation of Higher Education Programmes (AHEP) 4th Edition. *Engineering Council*, 2020 p35.

[7] Sole M., Barner P. and Turner I. Mechanical Engineering Design, Does the Past Hold The Key To The Future? *International Conference On Engineering & Product Design Education 9-10 September, VIA Design, VIA University College, Herning, Denmark* 2021.

[8] Brundtland G. H. Report of the World Commission on Environment and Development: Our Common Future *World Commission on Environment and Development (WCID)* 1987.

[9] Bajrakurtaj E. The Future of Engineering Means Bringing Back The Construction Of Brunel 2021 [Last accessed from *https://www.newcivilengineer.com/latest/the-future-of-engineering-means-bringing-back-the-construction-of-brunel-07-03-2021/* on 10/03/22].

IS THERE A ZERO WASTE IN A FASHION DESIGN?

Māra BINDE[1] and Aija FREIMANE[2]
[1]Art Academy of Latvia, Latvia
[2]School of Art and Design, TU Dublin, Ireland

ABSTRACT

Each year around 400 billion m² of textiles are produced in the world in the linear economy. About 15% of the fabric used to make clothes end up in the waste during the cutting process. Although there are a number of recycling initiatives in the fashion industry towards circular economy, the application of zero-waste principles in fashion design practice and production are only solitary cases.

Traditional fashion education methods emphasise the primary satisfaction of the designer's ambitions and there is a myth in fashion design that it is not possible to produce aesthetic clothing of any silhouette, assortment, and size with zero-waste principles. The work process is considered time consuming and too complicated.

This paper analyses zero-waste fashion design learning-teaching square assignment method, its challenges and opportunities to help students to practice the form and style, technological and prototyping towards sustainability in fashion design.

The analysis shows the purposefulness of the constraints in the experimental fashion design process and reveals the importance of missing skills, as well as prejudices of using zero-waste principles versus traditional fashion design technologies. Developed zero-waste fashion design learning-teaching methods are an alternative educational paradigm that provides students with knowledge and skills towards real sustainable revolution in fashion design and production.

Keywords: Zero-waste fashion design, sustainability fashion

1 INTRODUCTION

Over the past two decades the fashion industry and research community have become increasingly aware of the scale of the fashion's environmental problems [1] the linear economy – the 'take-make-use-dispose' model of production and consumption – date from the Industrial Revolution, considered an unsustainable [2], as the dominant approach in the fashion design education. The challenge for the fashion industry is transition towards circular economy practices [3]. Fashion design pedagogy asks the students to create a product assortment based on their unique vision of living or dressing, in a top-down design process that rarely starts from ecological considerations of the raw materials or sites of production [4]. Addressing the circular economy requires a new focus on the knowledge, skills and competencies required to create sustainable production and consumption [5].

As designers facilitated development of the linear economy, the paper discusses the method of the zero-waste fashion production cycle. Some existing practice theories suggest that appropriation (the use of goods and services to accomplish personal and social practices) and appreciation (the symbolic, communicative, and aesthetic aspects of consuming) are important processes [6] in practicing sustainability. Young designers must be sustainability literate; however, the fashion industry is reluctant to engage in sustainable design [7]. It is argued that changes in the design thinking and practice should occur if education for sustainable development is thoroughly embedded in the design curricula. Material efficiency is one of the principles that can be applied in designing and production cycle. Hence, this paper argues for a particular fashion design assignment by applying total zero waste methodology, namely, square of the fabric.

Fashion design education teaches the theoretical knowledge and practical skills of the design process, which are manifested through the application of the style, shape, materiality, colour radiances and pattern elements of a trendy item in fashion design. The silhouette and cut lines that define the fashion image, its style and attributes that tell the story of the fashion design collection, are very important. Designers are playing key role in converting clothes into the fashion [8]. The paradigm of the new, sustainability approach is a change in attitudes and priorities regarding the fashion design process, changes in the thinking process that amend the sequence of actions and permit to stop using fabric waste in the fashion design process. The task of the fashion education is to nurture a sustainable attitude in the future designers, to develop knowledge and skills that help to develop an ethical understanding and the skills of practical application [9], and to make zero waste fashion design as an integral part of life by integrating it into everyday work. Students with a fresh view and creative approach are the real messengers of the new age, which is unthinkable without gentle attitude towards the environment and its inhabitants. Traditionally, the steps in the clothing design process are definition of the idea, identification of the problem, depiction of the image, technical drawing of the design, selection of fabrics, selection of the processing technology, manipulations with the dress-pattern modelling, development of the design pattern. Each step can include choices in favour of sustainability [10] if the fashion design process is implemented for an aesthetic as well as an ethical end product that points to the crucial importance of the designer's understanding, responsibility and craftsmanship [11].

This research uses an evaluative case study approach to demonstrate how zero-waste fashion designing assignment is embedded in the fashion design teaching programme and what impact it has on the students' development. In examining the teaching practice across a selection of the undergraduates it is argued that application of the zero-waste approach to the curriculum design can promote fashion innovation and stimulate deep learning. It proposes a method for the education for sustainable development in fashion design curriculum and identifies frameworks required for the transition towards embedding sustainability in the fashion education.

2 METHODOLOGY AND METHODS: THE PURPOSEFULNESS OF THE RESTRICTIONS IN TASK SQUARE

Specific restrictions of the square assignment help to reveal the missing knowledge and skills in education for sustainability in fashion design and to develop an understanding of the consistent patterns and the ability to identify them towards circular economy. For students, the assignment is a mind exercise through empirical experience that develops design thinking, the ability to see the clothing production process in a contextual perspective, provide the understanding and skills needed for professional work.

Why the square assignment? The use of the full-width fabric is well known in the fashion history. It has long been used in the manufacturing of Japanese kimono and Indian sari, ancient Greek Chiton and many other historical clothing, as well as traditional folk costumes. Timo Rissanens identified five fashion creation methods - the traditional "Cut & Sew", "Full Fashioned", "Jigsaw" puzzle and sustainable clothing design methods Cradle to Cradle and A-POC [12].The Jigsaw puzzle method is a version of the "Cut & Sew" sewing method, where the cut-offs are joined together along the length of the fabric like pieces of a puzzle, so that no waste is created and the pieces of garments fit together in one layout. This method of cutting can be seen in the traditional folk costumes of various nations, also in everyday clothing until the Industrial Revolution in Europe [13]. Assortment restriction helps to focus on the silhouette, shape and size of a particular part of the body. In the process of generating ideas, changes in the sequence of actions cause stress and confusion and change the way we think. The steps of the traditional clothing design process during the prototyping stage - depiction of the image, technical drawing of the design, selection of fabrics, selection of the processing technology, modelling and manipulations with the cut lines, development of the design pattern must be planned simultaneously. The tools of lateral thinking are incorporated in the square assignment –the challenge, focus, concept and direction [14].Creation of clothes without clippings is already a challenge as pre-prepared pattern blocks can be changed, trim details, fabric direction, pattern placement and other conditions must be envisaged and an understanding which of them can be changed, while maintaining the focus on the implementation of the idea in the fabric, without clippings, should be faced. The analysis of the student's survey conducted at the end of the assignment as a fashion design module shows that the restriction of the fabric area is an important catalyst for the paradigms of the thinking process towards sustainability in fashion design education.

In the process of developing the assignment "Square", an empirical research method is the key, based on the application of the traditional design, cutting and sewing skills, analysis of sustainable fashion design practices, practical experiments with the shape and cut lines in clothing. Exploration of creative thinking in the practical prototyping process reveals the opportunities of the assignment based on various limitations to expand the traditional fashion design approach to the rules and techniques in the production of clothing. Determined restriction - the amount of fabric indicates a limited amount of fabric that can be used in the development of a particular model. By choosing the square as the area of the fashion design work, where the width of the fabric is equal to the length of the fabric (usually 140cm x 140 cm), type of the fabric, structure, the students create a layout using a block of basic cuts. Defining the exact pattern at the beginning of the first stage is a big challenge and a big risk, because the traditional sketch-cut-sewing technology will create fabric clippings, here we need to change the algorithm of thinking to keep all aspects in focus by manipulating with the skills and knowledge simultaneously. The width of the industrially woven fabric depends on the width of the loom and the type of the fabric attachment, which can be 90 cm-300 cm wide. This is an important factor at the stage of the fabric selection when the model is planned since it will influence the choice of the size and assortment. According to the experience in prototyping clothing, the proportions of a person's height can be compared to 1.4-1.5 m, which is the amount of fabric used on average to make trousers, dresses, coats, jackets or shirts, thus, this restricted area offers a sufficiently wide range of choices, selecting an S/M standard for both women and men to create a prototype. The recommended fabric width for the assignment "Square" is 1.4 m. The restriction of the type of clothing - shoulder clothing - marks the possibilities of the assortment, which are still relatively wide and can be matched with the idea and corporality. Restriction - the developed model must be wearable - determines the need for ergonomics, freedom of movement and indicates that the model is sewn by planning and performing the processing, fastening and other elements in accordance with the concept of the idea and the intended functions. The designing methods to be used in the design of the zero waste models are:

- Free arrangement of geometric shapes according to the idea.
- Use of the basic shoulder clothing cutting blocks.
- Combined use of draping and cutting blocks.
- Draping.

Students use constructive methods which each of them is more familiar with and have become known to them earlier, or better suits to the concept of the idea.

At the stage of the cut-off layouts, the greatest changes are possible in the silhouette of the model and in the cut lines, because clippings are formed from the mismatch between the trajectories of the curved lines when using the basic cutting blocks. In addition, the arrangement of all necessary parts and the compatibility of the parts must be envisaged. The use of the remaining pieces of fabric as shape modulation materials, for instance, to increase the size of the sleeves, pockets, trim details, or as décor, is the easiest way to use the leftovers. It is at this stage that the greatest lack of experience is revealed, which is confirmed by the results of the survey, as well as the experience in the laboratory work process. During the production phase of the mock-up in a scale 1:1 layout, errors and corrections in shapes, silhouettes or ergonomics are revealed, which require the correction of the cuts and the change of the layout again.

Zero waste clothing design assignment course is part of the third-year bachelor's programme and the first year of the master's programme of the fashion design programme to develop a sustainable thinking paradigm and practical skills for application of zero waste clothing design in everyday fashion designer practice based on traditional design prototyping knowledge. The participants of the course are fashion design students with previous experience who have so made at least one capsule collection before and understand the principles of modelling and sewing designs (Figure 1).

3 CASE STUDY ANALYSIS OF THE TASK SQUARE ASSIGNMENT

Within the framework of the assignment, the stage of the idea generation is the biggest challenge, because when you start working, by inertia, you sketch models forgetting about the restrictions, this stage is facilitated by creating an inspiration board to define the visual parameters of the idea and research of the shape with a 1:4 scale. Although in the survey after completing the Zero Waste course at 2021-2022 study year first semester where took part five bachelor programme students from Art Academy of Latvia and four master's programme students from the Estonian Art Academy fashion design department, to the question "Which methods made it difficult to implement the idea?" 50% of the respondents specified the small model in a scale 1: 4 as burdensome, however, the method acted as a catalyst in the start-up process (Figure 2).

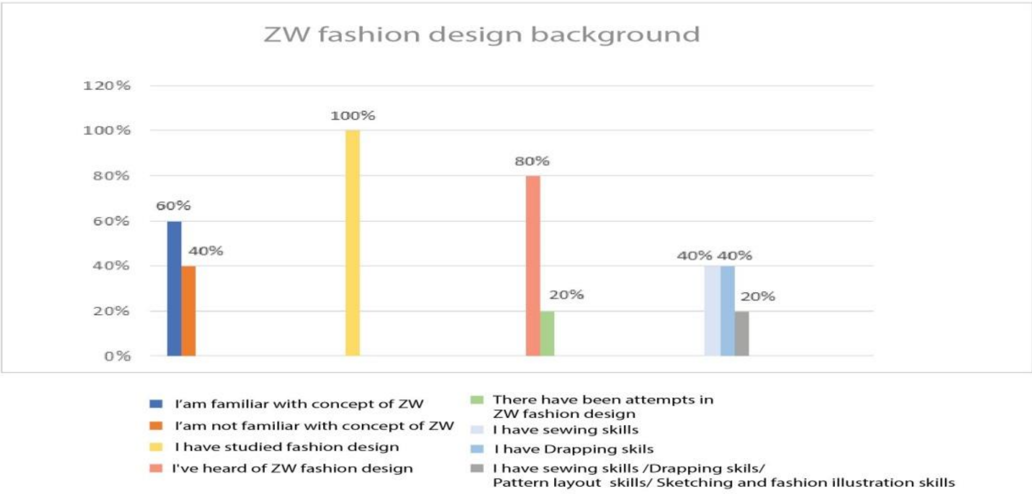


Figure 1. Survey summary by Zero Waste courses 2021, student's previous experience in fashion

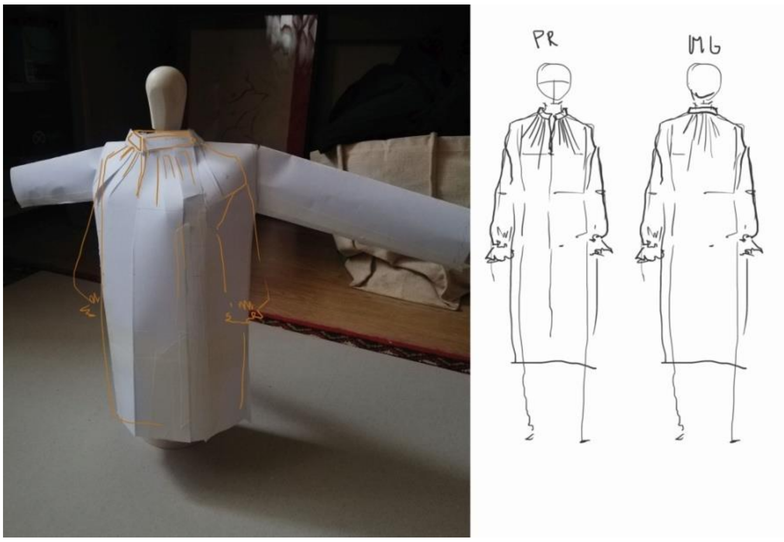


Figure 2. Laura Kreivina BA 3rd year student Art Academy of Latvia Fashion Design department 2021

Students have free choice of their stylistic expression in the process of creating models. In the search for the shape and development of the mock-up on a scale of 1:1, some students prefer the drapery technique; here they face the problem of converting the drapery into the cutting blocks and reproducing the model from the chosen fabric, which can be explained by lack of experience and underestimation of the importance of accuracy. Using pre-made basic cutting blocks in the design process, students arrange them as areas for marking different parts and configure them according to the idea; here it is important to understand the potential consequences of changes to give the product the intended shape, size and ergonomic capabilities. The dress created by the student Kirke Talu (Figure 3) is an example of an experimental search for shape, where the leftovers are used to model the shape of the garment and the finishing details on the collar.

Figure 3. Kirke Talu MA 1 year student Art Academy of Estonia Fashion Design department 2021

The use of traditional clothing shapes, such as the Japanese version of the kimono, helps to organize the layout of the cutting areas owing to the potential for a clear and predictable result, such as silhouette, assortment and shape of the garment. The ability to react to changes at the stage of the design pattern development is of great importance in the process of completing the assignment, as shown by the analysis of the survey, 50% of students adjusted the silhouette of clothing to avoid having textile trimmings (Figure 3).

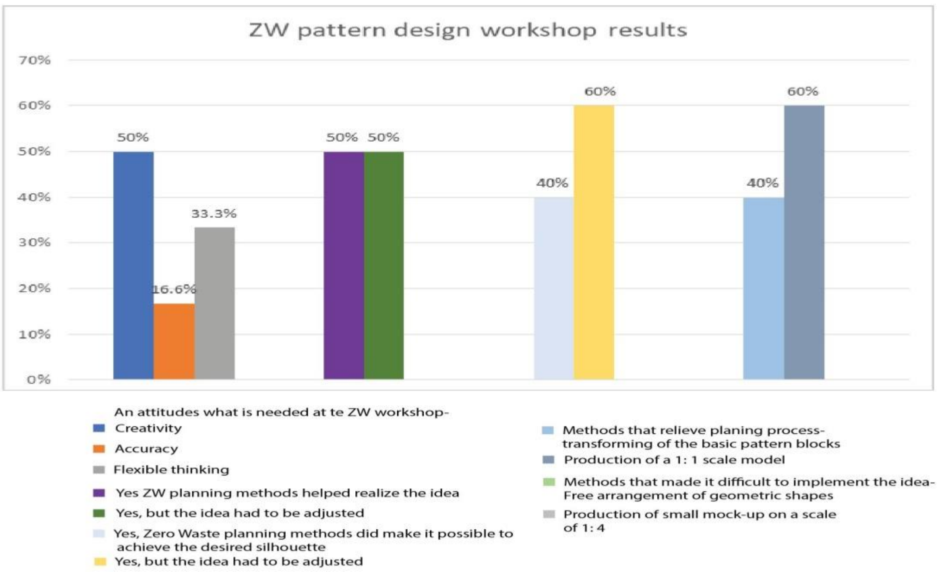


Figure 4. Survey summary by Zero Waste courses 2021

4 CONCLUSIONS

Experiments of the clothing prototyping assignment show that most of the course students have prior knowledge and previous experience in fashion design, have knowledge of the clothing design process, skills to depict the idea, model the cut-offs and sew. A survey of students conducted after the course shows that the ideas of sustainability as such are not unfamiliar to students, but most of them lack the experience to apply them in their daily work in the fashion design process. The garments created at the end of the course and the answers to the question "Did Zero Waste planning methods help to implement the idea?" (Figure 4) show an unlimited variety of styles, which confirms that the Zero Waste square method does not restrict the variety of stylistic possibilities of the models developed by future designers. During the work on the assignment "Square" the weakest and missing skills were detected, which complicated the model development process. It was confirmed by the results of the analysis of the students' survey after the course that students recognize the need for the designing and layout skills in the Zero Waste fashion design. Students with prior knowledge of designing have a better understanding of the cut-off layout, the ability to identify potential opportunities and freely manipulate with the shape, silhouette and cut lines of the garment. These findings points to the need for practical skills in the process of sustainable fashion design. 50 % of students indicated creative approach, 33, 3% - flexible thinking and 16, 6% - accuracy as the required attitude to solve the assignment "Square", which confirms the importance of creative thinking for the achievement of the paradigms of the fashion design education. Responding to the question is there a zero waste in a fashion design, it should be said that it is not yet fully recognised by the fashion design education as production system. Implementation of the square method – assignment into the sustainable fashion design programmes in fashion education as a learning-teaching method will provide students with knowledge, skills and support zero waste design thinking, practising towards real sustainable fashion design and production.

REFERENCES

[1] Mohajer va Pesaran D. 2018, Hack the black box: Consumer agency in the sharing economy, *Journal of Art, Design & Communication in Higher Education* Volume 17 Number 1, pp. 73-87

[2] Andrews D. 2015, The circular economy, design thinking and education for sustainability; *Journal of Local Economy* Vol. 30(3) 305–315

[3] Ghisellini P., Cialani C. and Ulgiati S. 2016, A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, 114, pp. 11–32.

[4] Mohajer va Pesaran D. 2018, Hack the black box: Consumer agency in the sharing economy, *Journal of Art, Design & Communication in Higher Education* Volume 17 Number 1, pp 73-87.

[5] Hall N. and Velez-Colby F. 2018, AMFI's Reality School: A circular economy agenda for fashion education, *Journal of Art, Design & Communication in Higher Education* Volume 17 Number 1, p 11-24.

[6] Warde A. 2005. Consumption and theories of practice. *Journal of Consumer Culture* 5, 131-153.

[7] Andrews D. 2015. The circular economy, design thinking and education for sustainability; *Journal of Local Economy* Vol. 30(3) 305–315

[8] Yuniya K. 2005. Dress, Body Culture Fashion-ology An Introduction to Fashion Studies, *4 Designers: The Personification of Fashion*, pp 58-70.

[9] Salolainen M., Leppisaari A. M. and Niinimäki K. Available: MDPI, Arts, 24 December 2018, Article: *Transforming Fashion Expression through Textile Thinking https://www.mdpi.com/2076-0752/8/1/3/htm*[Accessed on 2021, 31 December]

[10] McQuillan H. 2019 Licentiate thesis, Zero Waste design thinking,*6. Theoretical models of Zero Waste design* pp 162-192

[11] Rissanen T. From 15% to 0:Investigation the creation of fashion without of fabric waste. 2005, *Creativity: Designer Meets Technology conference*, Copenhagen pp 2-7. Available:*https://www.academia.edu/3762020/From_15_to_0_Investigating_the_creation_of_fashion_without_the_creation_of_fabric_waste?email_work_card=view-paper*[Accessed on 2021, 31 December].

[12] Rissanen T. *From 15% to 0: Investigation the creation of fashion without of fabric waste.*2005, *Creativity: Designer Meets Technology conference*, Copenhagen, pp 2-7. Available:https://www.academia.edu/3762020/From_15_to_0_Investigating_the_creation_of_fashion_without_the_creation_of_fabric_waste?email_work_card=view-paper[Accessed on 2021, 31 December]

[13] Rissanen T. and McQuillan H. *Zero Waste Fashion design*, (Bloomsbury 2016), pp 12-17

[14] De Bono E. *Think! Before it's Too Late.* (The MsQuaig Group Inc.2009 Translation copyright2012), pp 52-77

TESTS IN MOODLE IN ENGINEERING EDUCATION - A PRE-STUDY IN THE FIELD OF LEARNING ANALYTICS

Joachim GUENTHER
Hochschule München, University of Applied Sciences, Germany

ABSTRACT
Learning Analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs [1]. One of the sub-objectives in this research area is to make teaching and learning behaviour more individualized [2]. Students who complete test assignments in the Learning Management System Moodle [3] leave behind a data set or "digital fingerprint." These data sets provide a basis for a variety of investigations. Discussing analyses and results of a study of Moodle tests is the content of this paper. Online semester means that lectures and exercises were held live via videoconference during the Covid-19 pandemic. Classroom means that lectures and exercises were delivered live in the lecture hall. Mixed forms of the lecture, e.g., that part of the students participate in the lecture hall and part in the video conference, are not considered. The main questions investigated are:
- What is the participation rate of students in Moodle tests and in the exam?
- Are there differences between male and female students?
- Are there differences between students in the first or second semester?
- What are the differences between classroom and online semesters?

Keywords: Learning analytics, digitalization of teaching, face-to-face and online teaching, tests in Moodle, gender in engineering education

1 INTRODUCTION
What is Moodle? Moodle is a platform independent open source learning management system that offers many features, for example, support for group work, various exercise scenarios, discussion forums and chats. With Moodle, educators can provide students with both instructional materials and activities that support the learning process in the virtual classroom.
Why use Moodle? Access to a virtual classroom is an extension of the virtual world in which students operate today. Since today's students are very intuitive with digital media (communication via tools like WhatsApp, Facebook and Email, use of eBooks instead of hardcovers, lecture notes on the laptop, ...) Moodle usage is not an obstacle. The virtual classroom can be designed by the teacher to complement his lectures and exercises in the lecture hall. Collaboration among students can be intensified through the use of Moodle.
What contribution can the study provide for other lecturers?
The study shows that by using exercises in a learning management system, information about the learning progress of the students can be obtained, both activities in the self-study between the lectures, as well as the learning progress becomes more transparent. It also provides information about the usage behaviour of different student groups in Moodle, e.g., female and male students.

2 THE LECTURE AND THE MOODLE PLATFORM
In a lecture "Engineering Mathematics 1" for freshers in the industrial engineering and management bachelor programme at the "Hochschule München, University of Applied Sciences" the learning platform Moodle has been used for several semesters. For students attending the course, there was the possibility to register in Moodle and to complete four tests in Moodle (working time approximately one hour) during the course of the semester that accompanied the lecture. Participation was voluntary and one could not earn bonus points for the exam by taking the tests. Each of these tests included several tasks to apply the content from the lecture.

What students will find when they log into Moodle in our maths course in a classroom semester:
a) the lecture notes as a pdf document (for download).
b) the assignments for the exercises (pdf), which will be worked on in the following week.
c) recommendations for self-study tasks (pdf).
d) the tests that we examine in this paper.

In the online-semesters, the Moodle platform was used more intensively for student support, communication and interaction. In addition to the materials a) to d) mentioned above, the following content was provided:
e) some video tutorials on selected theory topics created by the author.
f) a question and answer forum which was set up for students to interact with each other.
g) hyperlinks to learning videos and mathematical animations (example sine oscillation) on the internet.
h) three times the lecture was recorded during the course of the semester and made available in Moodle because some students could not attend the lecture in terms of time.

As part of a written survey using a questionnaire, course participants were asked the question: Do the tests on Moodle provide a benefit to your learning? 78 out of 101 student (77%) gave a positive answer to this question [4]. The following reasons describe the main benefit students perceive by working on the Moodle tests regarding their learning progress. The quick feedback on their own knowledge level and the additional practice opportunities are main arguments to participate in the tests in Moodle.
One example of a benefit for the instructors is that they are able to identify which tasks students are having difficulty with and discuss them again in the practice sessions [5].

3 ANALYSES OF THE DATA AND LIMITATIONS

When we examine Moodle data of students, anonymity is very important. It must not be possible to draw conclusions about individuals or specific semesters. This is ensured by coding all personal data immediately after collection. Consent was obtained from students to make their data available for anonymous analyses.
The analyses presented here are not part of a funded research project with multiple collaborators, but a lecture-based pre-study by the author for a future research project. The results relate to the author's course “Engineering Mathematics 1” and the Moodle tests used there. They should not be generalized. The processing of the tests by the students represents only a small area of self-study. We do not know the conditions under which students work on the tests. Possibly some work in quiet environments, others with lots of distractions. The main goal of the study is to win ideas for a research project.

4 OVERVIEWS OF THE STUDENT POPULATION

The population for our study groups is 212 (in classroom semester) and 185 students (in online semester) from several consecutive semesters, all of whom attended the same lecture Engineering Mathematics 1 and registered for the exam. All percentages in the following evaluations refer to the number of students registered for the examination, which is set as a reference value of 100%. The students could voluntarily register in the Learning Management System Moodle and complete tests in Moodle during the semester. The same tests were used on the classroom and online semesters. The students are distinguished in the coding into:
- Students registered or not registered on Moodle.
- Test takers or non-test takers in Moodle.
- Female and male students.
- Students in their first or second semester.
- Exam participants respectively non-exam participants.

Since the individual semesters had very similar histograms to the analyses below, the individual participants from several semesters were combined into one data pool, overview Table 1. These 212 (185) students can be divided into female and male students, In the figures below, these are abbreviated F and M respectively. In addition, the data pool can be broken down into participants who are studying in the first or second semester. In the following illustrations these are abbreviated SEM1 and SEM2 respectively. Students in the second semester either failed the exam once or deferred the exam, i.e., did not take it in the first semester. There is an average percentage of 20.4% female students in the total population of our study. In following Table 1 the 73.1 % of students who registered in Moodle are not the same students who took the exam. The number match is a coincidence.

Table 1. Distribution of students in the study

	classroom semester		**online** semester
	n=212		n=185
students who are registered for the exam in %	100.0		100.0
registered in Moodle in %	73.1		100.0
participated in the exam in %	73.1		51.9
participated in Moodle tests in %	49.1		34.1
female F / male students M %	23.1 / 76.9		17.3 / 82.7
SEM1 / SEM2 students in %	50.0 / 50.0		42.2 / 57.8

5 RESULTS OF THE CLASSROOM SEMESTER

5.1 Registration in Moodle

In our first analysis, we examine registrations on the Moodle learning platform in average during the classroom semester. 155 students out of 212, that is 73.1% sign in on Moodle. 94.3% of the SEM1 students register on Moodle, of the SEM2 students only 51.9% register. The registration rate of female students in Moodle is 79.2% in average (see Figure 1), while that of male students is 71.3%. The percentage of female SEM1 students logging in is the highest at 95.5%, while of the group SEM2 male students log in only 47.5% on Moodle.

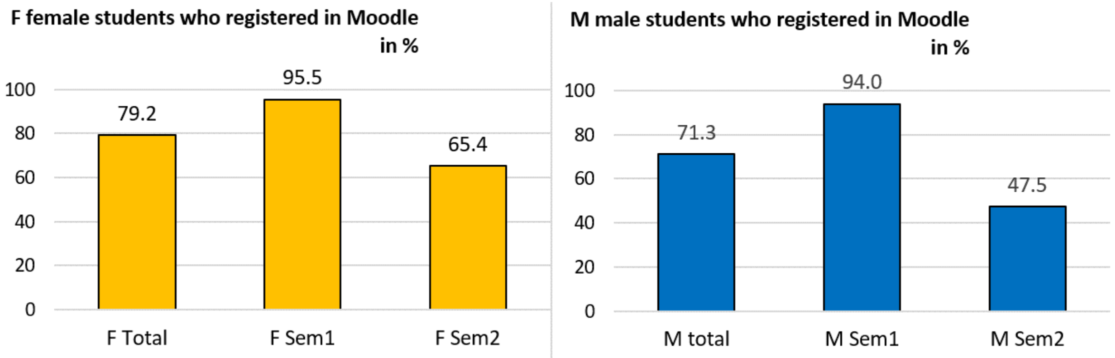


Figure 1. Registration rates in Moodle

We can note that especially first semester students log on to Moodle during the classroom semester and female students log on slightly more often than male students. However, this still does not contain any statement about the use of the tests available on Moodle. We can only guess why 26.9% of students do not log on to Moodle. It is possible that not all students have computer equipment and sufficient internet access.

5.2 Participation in the Moodle tests

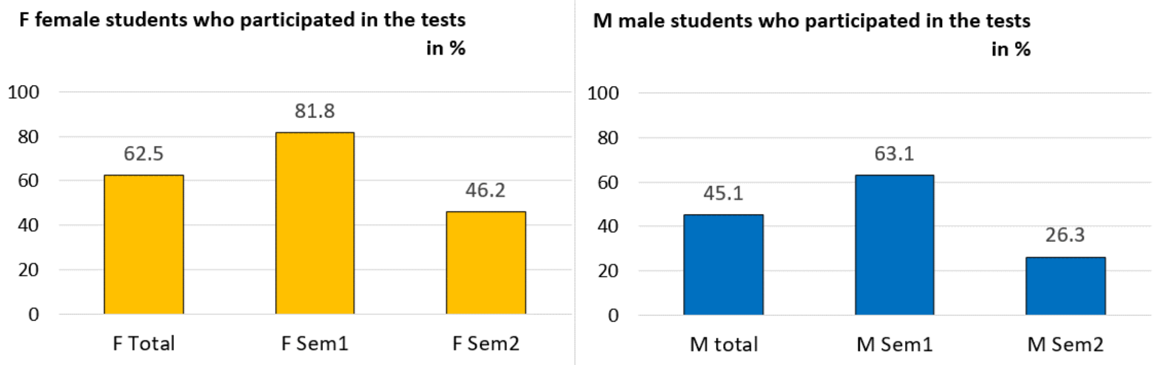


Figure 2. Participation rates in the tests

Of all classroom students, 49.1% participate in the Moodle tests, and of first semester students, 67.0% participate. This is two thirds of the SEM1 students who are the main target group for the course. Figure 2 shows the percentages of test takers in the female and in the male student group, i.e., students who took at least one of the four tests. A particularly high value is shown by the first semester female students with 81.8%. In the male student group, the participation rate averages 45.1%, with 63.1% in the SEM1 group and a particularly low value of 26.3% for male SEM2 students.

5.3 Participation in the exam

Figure 2 depicts the participation rates of students in the exam. Female students (85.4%) participate in the exam with a higher rate than male students (68.9%). SEM1 female students show the highest exam participation (90.9%) among the groups studied. The differences between first semester and second semester are less pronounced but show the same trends as in Figure 1.

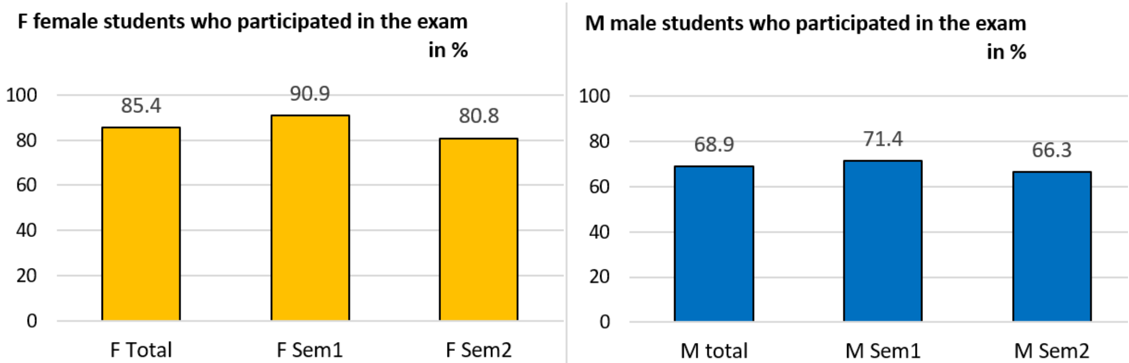


Figure 3. Participation rates in the exam in percent

6 DIFFERENCES BETWEEN CLASSROM AND ONLINE SEMESTER

In the face-to-face semester 73,1% of the students had registered in Moodle, in the online semester this was number was 100% (see Table 1). The 100% population again consists of all students who had registered for the exam. The reason for this is that content was provided on the Moodle platform without which one could not participate in the course at all, e.g., the internet links to the video lectures or exercises.

If we look at the face-to-face semester, 73.1% of the students had registered in Moodle, while in the online semester this percentage was only 51.9% (see Table 1). The online-end-of-Semester exam was a written exam under video observation, calculation had to be documented on paper and results had to be entered into Moodle. Free navigation between tasks was not possible. Each task had to be completed in a given time, then the next task followed. The restriction of free navigation is necessary to minimize digital cheating by third party support. After the working time, the students had to scan their calculation sheets with their smartphone and upload them to Moodle. In the face-to-face semester 49% had participated in the tests in Moodle, in the online semester only 34%. This is a low number especially considering the high registration rate in Moodle of 100%. It can be assumed that the tests in Moodle are less noticeable and less used in the context of the diverse materials which was available on Moodle in the online semester - see Section 1: material a) to g). Overall, the instructor and his colleagues had the experience that the number of active participants in the online courses was lower than in the face-to-face courses / Aktivität in Online Vorlsungen und Übungen.

More SEM2 students are registered for the exam in the online semester (41% SEM1 to 58% SEM2). Only 50% of the SEM1 and 55% of the SEM2 students participated in the exam (compared to 74,5% in classroom SEM1 resp. 69.8% in classroom SEM2). How can this be explained? The lecturer has interviewed some students about the low rate of participation in the exams. Several effects may account for this. Some students explained that they were unsure of their own level of performance and then preferred not to take the exam. In the covid-19 Semesters, students in the first semester in particular lacked the opportunity to get to know each other personally, form study groups, and engage in joint activities. In addition, students perceived the exams in the online semesters as more difficult. This is consistent with results by other researchers [8] those technical problems with access to the Moodle platform, as well as in the unstable video connection via the Internet and limited navigation, cause difficulties for students in online exams that do not occur in face-to-face written exams. The Hochschule

München, University of Applied Sciences extended all deadlines in the Corona semesters. This means that the deadlines for examinations in the first semester, for repeat examinations and the maximum permissible duration of study were extended by one semester. Thus, a students had no disadvantages if they postponed an exam into the next semester.

6.1 Comparison of female and male students

In the online semester, females taking Moodle tests to males shows a difference of 44.4% to 31.3% in Figure 4 when we compare the total groups. The low participation rate of SEM1 female students is striking. Female students use Moodle tests more intensively in both the classroom semester and the online semester. The change from classroom semester to online semester shows no significant changes In the percentages of female and male students in exam participation. Female students attend the exam significantly higher than the male students.

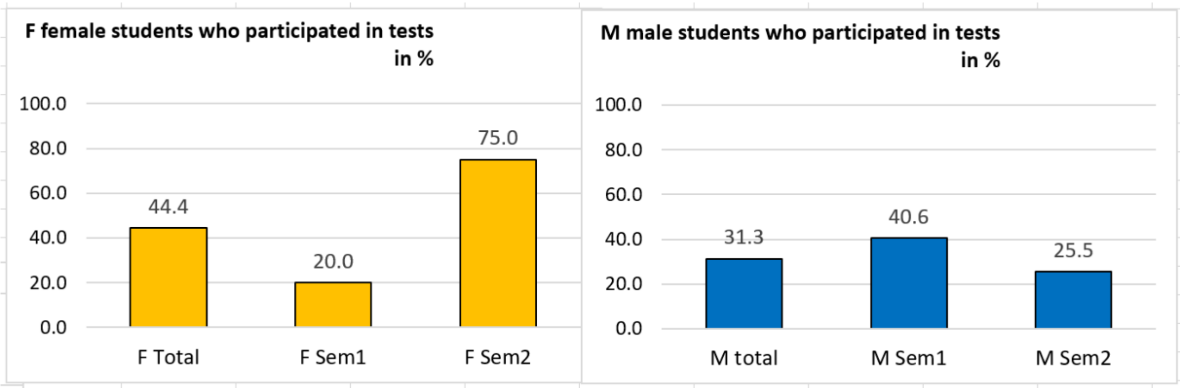


Figure 4. Participation in the Moodle tests in the online Semesters

7 DISCUSSIONS OF THE RESULTS

Statistics should not be the main focus of our investigation. Nevertheless, some results, e.g., the correlation between gender and test participation, were tested for stochastic independence using the chi-square test. When the calculated p-values are below the error level of 0.05, 0.01, or 0.001, we refer to significant (*), very significant (**), or highly significant (***) results. The statistics help us to give more weight to some results and hypotheses in the following discussion.

94.3% of first semester students register on Moodle and 67.0% take the tests in a classroom semester. These are high participation rates that encourage continued use of the Moodle Learning Management System and tests in future teaching. We can derive the following hypotheses from our study:

First semester students are more likely to register on Moodle than second semester students (***) and are more likely to participate in the Moodle tests offered than second semester students (***).

The low registration rate of second semester students on Moodle of 51.9% (and the low test participation 30.8%) is surprising. Actually, these students should be particularly interested in good learning material and also in passing the exam in order to progress in their studies.

Female students are more likely to log on to Moodle than their male counterparts (79.2% to 71.3%, and they are more likely to take Moodle tests than male students (62.5% to 45.1%, ***). These data support the hypothesis that female students are more active in using the Moodle platform and taking the tests.

Price [9] found in a study that female students prefer online assignments. Arrenberg and Kowalski [10] reasoned that those female students are not in direct competition with others there. Keller and Köhler [11] also documented that those women favour new teaching methods where they do not compete directly with male fellow students. Female students who are registered for the exam are more likely to take the exam than male students (85.4% vs. 68.9% see Figure 3,**). The high exam participation rate of female students can be interpreted as an indication of a clear study organization with the personal requirement to take exams in the planned time schedule. According to [10] female students take their studies more seriously than male students, and they take a more formal approach.

The change from classroom to online semester significantly increased the registration in Moodle to 100% of the students registered for the exam, but the participation rates in the tests and the exam dropped sharply. This means that participation rates in the exams will increase sharply after the Corona pandemic, when courses and exams will be held in the classroom again.

8 IDEAS FOR A RESEARCH PROJECT

It would be interesting to investigate the reasons why students, especially in the second semester, do not use the Moodle offerings and tests (availability of internet access, digital literacy, fear of surveillance...). Students' motivations for registering for exams and then not taking them are also worth investigating, as this behaviour directly leads to longer study times. Sociologists and psychologists should be involved in these studies.

Plans for the research project are to revise and expand the scope of our Moodle tests, which have now not been changed for several semesters. One idea would be to use uniform tests on Moodle in lectures taught by different instructors. For a comprehensive research project, it would be very helpful to use entrance and exit tests to record students' competencies in order to be able to measure the increase in competencies due to digital learning support.

In addition, it would be very interesting to identify further teaching and learning formats that address women and men differently in order to be able to support the learning process of female and male students through suitable teaching methods.

REFERENCES

[1] Homepage of the Society of Learning Analytics Research (SOLAR) https://www.solaresearch.org/about/what-is-learning-analytics [Accessed on 2020, 10 July]

[2] Leitner P. and Ebner M. (2017): *Learning Analytics in Hochschulen*. Handbuch Kompetenzentwicklung im Netz. Erpenbeck, J., Sauter, W. (Hrsg.). Schäffer-Poeschel Verlag. Stuttgart. S. 371-384

[3] *Learning Management System Moodle*. https://moodle.org [Accessed on 2014, 8 February]

[4] Günther J. and Brunnhuber M. (2016): *Aktivierende Lehr- und Lernmethoden in der Ingenieurmathematik – Ein Erfahrungsbericht*. In: Wege zum Verständnis bauen – Das Projekt HD-Mint. Herausgeber: Zentrum für Hochschuldidaktik (DiZ). ISSN 1612-4537 / 2016 / page 40 – 52.

[5] Günther J. (2018): *Vorlesungsbegleitende Aufgaben auf Moodle – ein digitaler Fingerabdruck der Studierenden*. In: Waldherr F.; Walter C. (Hrsg.): Forum der Lehre 2018 – Digitale Akzente setzen. ISSN 1612-4537 / DiNa Sonderausgabe 2018 / page 79 – 84.

[6] Rebucas Estacio R. and Callanta Raga R. (2017): *Analysing students online learning behavior in blended courses using Moodle*. In: Asian Association of Open Universities Journal, Vol. 12 Issue: 1, page 52-68.

[7] Ciolacu M., Tehrani A., Rick B. and Popp H. (2017): *Education 4.0 – Fostering Student Performance with Machine Learning Methods*. IEEE - 23rd International Symposium SIITME, 2017, Constanza Romania, Seite 225-226.

[8] Elsalem L., et al. *Stress and behavioural changes with remote E-exams during the Covid-19 pandemic: A cross-sectional study among undergraduates of medical sciences*. Annals of Medicine and Surgery Volume 60, December 2020, Pages 271-279

[9] Price L. (2006): *Gender differences and similarities in online courses: challenging stereotypical views of women*. Journal of Computer Assisted Learning. Blackwell Publishing Ltd, page 349–359.

[10] Arrenberg J. and Kowalski S. (2007): *Lernen Frauen und Männer unterschiedlich? Eine Studie über das Lernverhalten Studierender*. Forschungsbericht, Fachhochschule Köln, Fakultät 04. http://fh-koeln.arrenberg.com/pdf/gender-artikel-formatiert.pdf [Accessed on 2019, 3 March)

[11] Keller U. and Köhler T. (2015): *Aktivierende Lehrmethoden in den MINT-Fächern aus der Genderperspektive.* In: Kammasch, G. (ed.): Anwendungsorientierung und Wissenschaftsorientierung in der Ingenieurbildung – Wege zur technischen Bildung. Universität Siegen 2016, Seite 124 – 131.

HOW GRAPHIC DESIGN CAN INFLUENCE THE PERCEPTION OF SUSTAINABLE FOOD PACKAGING

Henrik Kongsli GJERDE
OsloMet University, Norway

ABSTRACT
This master's study is a pilot research project that investigates the effects packaging and graphic design has on consumers' perception regarding renewability and waste, in conjunction with the 2021 Norwegian research project *Sustainable Eaters.* The project has the aim of reducing plastic and food waste through placing the consumer in the centre of the research and studying their behaviour. Response to packaging and awareness of waste are both issues that focus on human emotions and behaviour. This study dwells into how the use of different packaging and graphic design may affect the users' perception of a products' renewability. Using concepts such as cue utilisation, research design and previous peer reviewed articles to aid it, this study aims to investigate how user awareness can contribute to the Norwegian issue of food and plastic waste. This research was limited to Norwegian's attitude towards packaging in order to remain relevant as pilot research for the *Sustainable Eaters* project, as well as to limit the otherwise vast scope of such a project. A similar study conducted in the United States was used as a basis for this research project, and this paper acts as a supplement to the study.

Keywords: Green design, graphic design, packaging, consumer attitudes, cue utilisation

1 INTRODUCTION: SUSTAINBALE PACKAGING AND CONSUMERS
On an everyday basis we encounter situations in which we are slowly killing and harming our planet. Not so in a despicable and cruel way, but rather through material usage and the vast waste production. Going by the *cradle-to-cradle* principle [1], much of packaging materials consumers use today is not sustainable due to mixed materials and ability to recycle products. Therefore, the need for an alternative is imminent for our planet. This alternative should be a disruptive and innovative solution, rather than relying on previous environmentally hazardous ways of production. As Nigel Steenis et al. mention in their research about the role of packaging materials, modern packaging is made in a way where it often outlasts the content itself [2]. Many consumers also have a limited knowledge about packaging and its sustainability factors. The result is that many consumers rely on personal perceptions and assumptions rather than researching themselves. This also misleads those with green and sustainable motivations. Other studies by Carolien T. Hoogland, Joop de Boer and Jan J. Boersema found that something as simple as the colouring of the packaging was a determining factor in users' perception about a products' ecological friendliness and sustainability [3]. Relating this to the Norwegian consumer and food market, *The Sustainable Eaters – Consumers in sustainable Norwegian food system research* project have the goal of reducing food waste in Norway by enlightening users about the products they are using. This can be done through increasing the awareness and knowledge people have about the products they consume. Especially important tasks for the project include the educating of Norwegian high schoolers and the redistribution of leftover food, as well as designing environmentally friendly food packaging. Relating this to the field of graphic design, the issue of packaging and visual representation of a product can contribute to aiding customers determine the quality of the different products they buy. From an educational viewpoint, this new insight about consumers response to the physical appearance of a product, can aid researchers and designers in making better products with traits that encourage clear and concise recycling for the consumer. In that regard this paper acts as a pilot study for the *Sustainable Eaters* project for understanding consumer behaviour regarding food choices. A pilot study can be defined as a small, preceding study with the goal of dissecting certain components of a larger study. This is to determine whether the parts of the larger study are feasible [4].

2 BACKGROUND AND LITERATURE REVIEW

Peter Glavic and Rebeka Lukman defines sustainable packaging as packaging which has a low environmental impact compared to its' alternatives based on different life-cycle assessment models [5]. The aforementioned article written by Nigel D. Steenis et al. [2] talks about the issue of consumer response to packaging design. What is interesting about this article in conjunction with the *Sustainable Eaters* project is the focus on the individual. According to Steenis's research, most users does not determine the renewability of a product by researching, but rather through one's own lay beliefs. This is supported by Helén Williams' study about recycling in Swedish households [6]. Williams' research showed that something as simple as a yoghurt cup was treated different than milk cartons, despite their material composition being similar. This was due to the mixture and feel of the material presented to the consumer. Williams further explains the confusion a lot of consumers feel when encountered by products made of different materials. Mixture of materials, as well as the stickiness of food products, caused several participants to disregard recycling plastic or hybrid plastic products. 0 out of the 10 participants never recycled milk cartons, while 6 out of 10 never recycled yoghurt products, partly due to material mixture and the effort required to clean the leftover packaging. Williams' study inspired the concept of presenting vaguely determinable materials to the test subjects, as well as asking participants how they recycle the material. The primary purpose of this study is to investigate the effect and impact awareness about packaging can have on the Norwegian population, and what perceptions Norwegians have about said packaging. In conjunction with this, the research question for the article is as following: "*How can graphical appearance and user awareness reduce food waste in Norway?"*. The research question itself is more inductive and in line with qualitative research, however, these qualitative findings were used to explain the quantitative data collected. This paper thus takes advantage of mixed methods research to conduct the study. Other studies and peer reviewed articles act supplementary, however, Steenis article is what this study bases itself on in conjunction with the *Sustainable Eaters*.

3 METHODS: MIXED METHODS RESEARCH AND CUE UTILISATION

3.1 Quantitative and qualitative research

This article uses mixed methods research (MMR), a mixture of qualitative and quantitative research [5]. The quantitative research consists of a survey research method, specifically a cross-sectional design form. A qualitative, semi structured interview is used to extract meaning from participants and correlation between the quantitative and qualitative data. Integration is the practice of relating qualitative and quantitative research data, and this study will be focusing on the integration method of *explaining the data* [7]. Using quantitative survey research method, this study gathers users' opinion regarding a selection of made-up packaging designs. The idea was to create six different packaging designs, using Adobe Illustrator and different principles to create a "sustainable" look, and then ask the participants to rank them based on which they believed to be more sustainable. These graphic shells might not be real packaging found in store but are made to replicate several of the traits one might find on the outside of products in an average daily grocery store. A qualitative interview was then conducted with some of the participants to get a better understanding of their reasoning. Did the colour affect their decisions making? The perceived feel of paper? Any symbols associated with ecological sustainability and renewability?

3.2 Use of cue utilisation

The relationship between consumers and their products relies on communication. Visual graphics are meant to help us understand, judge and rework information. The human being has developed to understand colours, shapes, placements, and size, as this remains relevant for our evolution even to this day [8]. Packaging both signalise a sense of quality for a product, while also serving more beneficial factors such as portability. However, taste and renewability are hard to determine factors for a consumer through packaging alone. Despite this, a first-time purchaser will use the packaging and their beliefs to determine the content's renewability and its' taste, since these are the determining factors, the user have available to them [2]. We are then presented with the phenomenon of cue utilisation. According to Olsen and Jacoby [9], cue utilisation is when a user lacks knowledge of a product, and so they ascertain multiple cues about the given product to determine its' predictive and confidence values. Predictive value is to what degree a cue is associated with positive or negative benefits, while confidence value is the users' confidence in their decision making based on the given cues. Cardboard-like packaging is a cue that might resonates with healthy environmental benefits, while it is up to the user's confidence to determine to what degree this product provides any real, actual environmental benefits. The graphical appearance affects user opinions and are vital cues for many in determining products' renewability [2].

3.3 Graphic design and data collecting

The experiment conducted by Steenis et al. focused mainly on the physical packaging design, however, rather little on the graphical [2]. Initially it would be interesting to see how the users would react with a wider range of "eco-looking" packaging and more graphical cues to utilise. As such, this pilot research project is mainly focusing on the graphical appearance and perceived textures of a product. Using a standardised Norwegian liquid carton, the graphic design is the only variable that differs between the products. Environmental logos were utilised to make a product appear more environmentally friendly, sustainable, and "green" to the users [10]. The appearance of cardboard and metallic background was another cue. High use of ink and colours vs low use of ink and colours was another contrasting cue. Some of the text also altered between designs, either being cut out or emphasised to different degrees. Finally, some of the designs were made to be more appealing either through images, simplified designs, or playful and colourful appearance. Figure 1 below consists of all the different designs, design **1** being to the very left, and design **6** being to the very right. All design were inspired by some existing products, with the Norwegian orange brand *Sunniva® Original Appelsinjuice 1 liter* being the template for the redesigns. Participants viewed Figure 1 on an Apple iPad when conducting the research. The participants ranged from the ages of 23 to 26, with a total of 10 participants. Each participant performed a quantitative ranking of each design, before then moving on to a qualitative interview about their reasoning behind. Additionally, the participants were tasked to choose one product which appeared more appealing and more likely for them to buy during grocery shopping. All participants names and further information are kept secret to respect their privacy. Participants were assured that all feedback was subjective and valid.

Figure 1. Cartons were designed by author and researcher Henrik Kongsli Gjerde.

4 RESULTS

4.1 Users' response and reasoning

All participants but one agreed that design **1** appeared most environmentally friendly out of the different designs. The use of cardboard-like-colour was the main contributing cue, with the eco-logos being another contributor. The lack of ink usage made many feel as the manufacturer had taken the absolute stand to be as resourceful as possible. Meanwhile, 7 out of 10 participants, 70%, agreed that design **3** appeared to be the least environmental. The predictive value of design **5**'s nature-imagery cue varied quite between participants. Two subjects said they thought the design was least environmental, mainly due to the excessive use of colours to create the background image. However, other participants ranked this design as one of the more sustainable. The use of clear blue skies and mountains gave the packaging a feeling of nature, thereby associating the juice with natural ingredients. Design **6** ranked high among the participants, which was reasoned for as a due to the minimal use of colours, saving ink and thereby the environment. Some felt this made the product look cheap, while others felt the minimalism made it look expensive and of high quality. In the middle place was design **2** attracting no strong opinions. Some expressed the saturated sky and cheap design made it appear as the company behind it would not care much for renewability either. The use of an orange and "Grønt punkt" logo made it more appealing to some. However, "Grønt punkt" is not a sign of the renewability of a product, but rather that the company has aided financial in making sure the product is brought into the recycling process, not that the material can be fully recycled [10]. Design **4** did not provoke any strong opinions regarding eco-friendliness, though it ranked lower than the previous design due to excessive use of ink. None of the participants mentioned the notice of whether the juice was from a concentrate or not.

4.2 Participants' personal preferences

While this study focused mainly on what is perceived as sustainable, it is also important to take notice of whether the customer would take this into consideration when conducting their shopping routine. When given the choice to buy whatever of the products desired, regardless of price, several participants chose different from what they believed to be the most sustainable. Many participants felt design **6** had an appealing design that felt simple and almost exclusive to a degree. Another group of participants preferred design **4** due to the more playful and sweet design. This was affirmed by other participants referring to the design as sugary and childish. Two participants chose design **5** as their favourite, the reasoning being the packaging gave the product a more sincere and fresh feel. On the contrary, design **2** and **5** was considered cheap looking by a few participants, often associated with the Norwegian brand "*First Price*". One person expressed appreciation for the effectiveness of design **1** in conveying its green message. Design **3** had several participants sceptical of the industrial-like appearance. All participants believed the cartons to be recycled as paper, except for one person who believed for design **3** to be recycled as residual waste. It should be noted that the participants were asked a leading question regarding the recyclability of design **3** due to beliefs and insecurities regarding glossy, shiny, and metallic looking packaging.

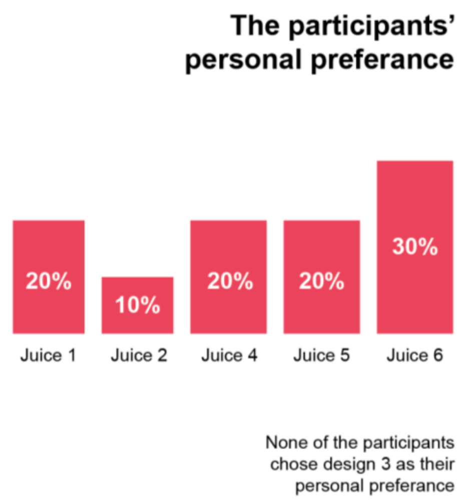


Table 1. The participants personal preference

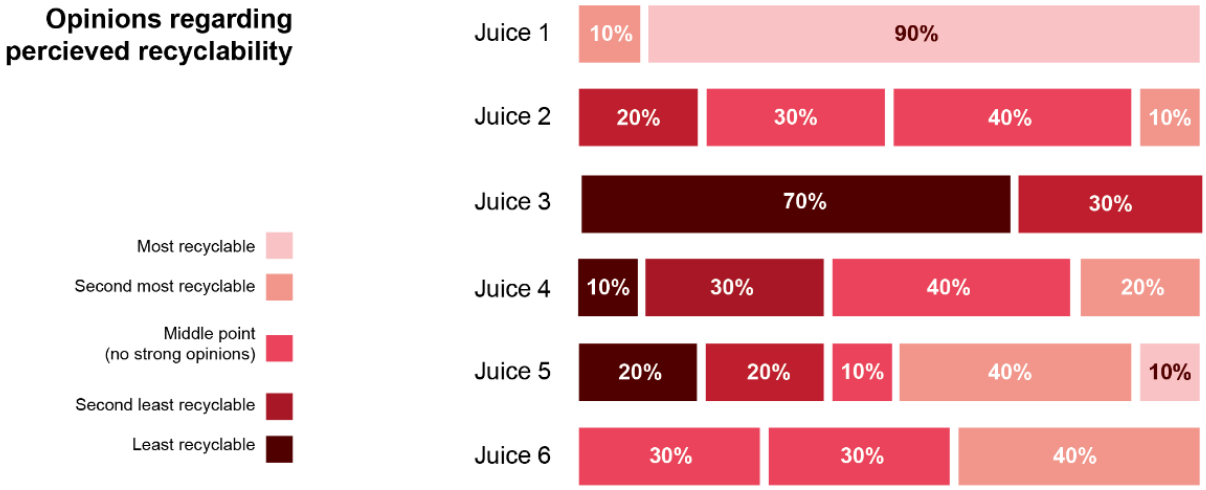


Table 2. The quantitative findings from the research expressed through percentage

5 DISCUSSIONS: ASUMPTIONS, AFFIRMATIONS AND SUPRISES

The minimal use of ink had an overall positive effect on the participants' perception of eco-friendliness. However, a product being sustainable did not seem to be among the top priorities for most participants when buying the actual product. Even so, the packaging design still aided the user in knowing how to recycle a product. The overall most important cue seemed to be the material, or rather the perceived material. Every packaging was meant to be made from paper, only the coating on the outside would in theory differ from each other. The simpler designs, especially the cardboard-like design, made it clear it was to be recycled in the paper bin. Predictive values and users' confidence value was high for the cardboard utilisation cue. Contrary, the metallic and glossy-looking packaging made the test subjects uncertain on how to deal with the waste, resulting in lower user confidence value. Design **1** lead almost all subjects to believe it was the most sustainable, and none had any doubt on how to recycle it. Even though almost all participants would recycle design **3** as paper, the several participants were uncertain by the glossy metal packaging. Cues such as the eco-labels had a minimal effect on the test subjects. Only a few dictated their buying decision by them, though only to a slight degree. One subject mentioned the lack of the "Nyt Norge" label, though this label only highlights a Norwegian product from other foreign products [11]. However, this can be seen as a sign that Norwegians care about quality and animal treatment, and products from Norwegian farms are believed to be within their desired quality. The overall effect of eco-labels as a cue might have changed with more participants. Another notable cue was the lack of colour or printed ink. As mentioned in the book *Cradle to Cradle* the ink used might in itself be poisonous for the environment, so the lack of print would in that regard be beneficial [1]. Some felt this might make the product look cheap and of low quality. This would however depend on the overall graphic design, and some of the participants who felt this way about the lack of ink would later note that the lack of print on other designs made them look more efficient. It would be interesting to see the strong points from the different designs combined into one product for future research experiments. The paper-like feel of design **1**, somehow combined with the nature-like feeling of design **5**, as well as the simple but exclusive feeling some felt from design **6**. Similar to Steenis et al. study, the sustainable packaging appeared more likely to be accepted when it enhanced perception of the product itself and what was contained inside [2].

6 CONCLUSIONS

The results and research design from this study can aid the *Sustainable Eaters* project in making products more easily to recycle and determine for consumers. The main purpose of the results was to see how graphic cues influence perceptions within the food industry, however it could also be seen as a lesson in brand perception as well as educate about green washing. With companies trying to change their image in more recent years to be perceived as more sustainable despite their business practices, being aware of cues and how they affect us is important. Insight from the study shows that packaging can matter in how we perceive the quality of a product. One can conclude that a simpler, more paper-like packaging design would be efficient at aiding users on how to recycle, while glossy, over the top design may confuse the user. The current study can also contribute to graphic designer in general on how to research to design for more sustainability and with more awareness of users and interaction design. It should be noted that participants perception of renewability was highly diversified, but with a few aforementioned, repeated common traits. Many participants relied on utilised cues such as colour, amount of print and nature imagery, with some taking note of the eco-symbols. As this is pilot research master's project, the study would need an increased and varied number of participants to provide beneficial for future research, as low variation within age groups and the number of participants is one of the shortcomings of this research. The current study still provides some valuable insight into what cues young grocery shoppers view as most important. It also provides educational value for both product- and graphic designers, and in addition proves how graphic design can contribute within the field of research design.

REFERENCES

[1] Braungart M. and McDonough W. *Cradle to Cradle – Remaking the way we make things*, 2008 (Vintage Books). pp. 59 – 60.

[2] Steenis N. D., van Herpen E., van der Lans I. A., Ligthart T. N. & van Trijp H. C. M. Consumer response to packaging design: The role of packaging materials and graphics in sustainability perceptions and product evaluations. *Journal of Cleaner Production*, 2017, pp.164, 286 – 298.

[3] Hoogland C. T., de Boer J. and Boersema J. J. Food and sustainability: do consumers recognise, understand and value on-package information on production standards? *Appetite*, 2007, 49(1), pp.47 – 57.

[4] Cadete L. *What is a pilot study?* Available: https://s4be.cochrane.org/blog/2017/07/31/pilot-studies/ (Accessed on 2021, 10 October), (2017) 31. July.

[5] Glavic P. and Lukman R. Review of sustainability terms and their definitions. *Journal of Cleaner Production*, 2007, 15(18), pp.1875 – 1885.

[6] Williams H. *Kan emballasjedesign og atferdsvitenskap forbedre kildesorteringen?* Available: https://www.youtube.com/watch?v=kqKbc_fw17I&ab_channel=Gr%C3%B8ntPunktNorge (Accessed on 2021, 26 September), (2021) 21. September.

[7] Leavy P. *Research Design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*, 2017 (Guilford Press). pp.101, 139, 164, 172 – 179.

[8] Cairo A. *The Functional Art*, 2013 (New Riders). pp.112 – 113.

[9] Olson J. C. and Jacoby J. *Cue utilisation in the quality perception process*: In: Paper presented at the third Annual Conference of the Association for Consumer research in Chicago, IL., 1972.

[10] Renas.no. *Dette betyr miljømerkene.* Available: https://renas.no/dette-betyr-miljomerkene/ (Accessed on 2021, 4 October), (2017) 14. November.

[11] Norskmat.no. *Merkeordningen Nyt Norge*. Available: https://norskmat.no/no/nyt-norge?gclid=CjwKCAjwtfqKBhBoEiwAZuesiAFzQ1eKHrIFdklj_X9dMW3YsQtHt7P74XGxz52dBrPo6Sh2jeyHYBoCh9QQAvD_BwE (Accessed on 2021, 7 October).

THINKING BEYOND THE PRODUCT MOMENT: ADDRESSING ISSUES AROUND "KEEPING"

Clare GREEN[1,2]
[1]ISD Rubika, France
[2]UNIMES (Nîmes University), France

ABSTRACT
Designing for a more sustainable economy implies consideration for the whole of longer, more optimised product lifetimes. It is increasingly important to encourage reflection on the multiple aspects of product life beyond conception, production and sales moments. This concerns the much longer period when "products" are integrated into everyday life and progressively become "things" and "stuff". A major part of longer product lives that may currently be overlooked is "keeping". In circular consumption models' everyday goods need to be maintained in conditions permitting repurposing, repair and remanufacturing, implying various forms of shorter and longer term keeping. Existing product consumption phases don't adequately represent the periods of passivity where products are kept awaiting reuse or divestment. While keeping possessions seems inherent in many of the transitions between phases of active use to phases of devaluation and divestment, our attitudes to keeping things are ambiguous. Design and design education traditionally focus on use and rarely on passivity in relations with products or services. In this context, the notion of "keeping" may be useful for encouraging different ways of thinking about our everyday material relations.
Part of ongoing research into how issues around keeping might be successfully integrated into design education, two recent case studies are presented and discussed. This research highlights the need to give a more holistic view of the different forms of keeping existing today. Our research also indicates how studying keeping can help sensitise students to everyday aspects of circular and sustainable behaviour.

Keywords: Sustainability, circular economy, sustainable behaviour, longer product lifetimes, keeping

1 INTRODUCTION
As designers, researchers and educators we are getting better at thinking about sharing, circularity, repairing, reconditioning, about collection systems and recycling. But as leading researcher in sustainability Conny Bakker [1] highlighted in her *Ten Golden Rules of Design for Sustainability* (2019) "design for long use and reuse… creating products that last and that can be loved and cherished, maintained, repaired, reused, upgraded, adapted, personalised, refilled and repurposed for as long as possible" remains a key priority. This involves encouraging design approaches applied to everyday life behaviour, to living with artefacts more than their acquisition [2]. This concerns the second, often overlooked moment in (product) design projects. The design act is clearly incomplete "if we do not address what happens to the project's output when it starts its life in the social world" [3]
The notion of keeping [4] might be a useful way of framing thinking around part of sustainable behaviour, as it questions our everyday relations with materiality in the short and longer term, and relations that are often passive. Keeping does not only concern widely researched emotionally durable objects [5, 6], but also products that have become simple "things", stuff and clutter [7].
Given this possible gap in sustainability thinking, and by extension teaching, seeking ways to address the passive phases of product lives in the design curriculum seems relevant. The aim of this paper is to define keeping in relation to existing research into longer product lifetimes. Based on ongoing research, some findings that help to structure understanding of domestic keeping are introduced and discussed. Finally, two recent design teaching modules on the theme of keeping are presented. These examples of introducing the keeping theme highlight aspects that appear successful, but also illustrate a certain number of issues that could be improved for more effective teaching of the subject.

2 PASSIVE PHASES IN LONGER PRODUCT LIFETIMES

The link between keeping and longer product lifetimes would appear to be evident, for example "...keeping existing products in use for longer periods of time can theoretically slow consumption" [8]. Keeping can be linked to continued use, but equally can be linked simply to not replacing, to holding-on-to [4]. Keeping can refer to passive states in product lives, awaiting repair [9] or linked to hibernation [10], which might be described as a 'dead storage period' of goods no longer in use, but whose value could be 'reawakened' and recaptured [11]. In a study of stored small Waste Electrical and Electronic Equipment) [12] objects are described as being abandoned/lurking, consciously stored, or kept due to emotional attachment. These different states highlight how kept objects within the home can exist on very different levels of status and visibility [13] and indicate the possibility of multiple keeping moments ranging from relatively active use through to pre-divestment.

Models of product ownership [14], e.g., proposing six phases: Acquisition, Appropriation, Appreciation, Devaluation, Divestment, Disposal, give structure for understanding evolving relations with things. But a drawback of this type of structure is the implied linearity and notion of logical transitions.

Addressing keeping involves questioning the regularity of our everyday practices and involves trying to look at stuff that is no longer the focus of our everyday attention, things 'that should have been left unspoken... inappropriately foregrounded'[15]. Focussing attention on kept stuff also may imply looking at the meaningless or disturbing intervals between animated, useful phases, things out of context and out of control [16]. This definition echoes Steve Baker's [17] definition of "clutter": "disordered things that impede movement... that part of our "self" that escapes "our" control, "proper" control...the revenge of objects on design." Studying keeping may be a valuable exercise for designers.

3 ASPECTS OF KEEPING

Given that the theme "keeping" covers a very wide range of everyday material relations and also objects and contexts, it is important to highlight some ways of structuring our understanding. As keeping may overlap with passive phases of product lives awaiting repair, the dimensions identified by Hielscher &

Table 1. adapted from Hielscher & Jager Erben, dimensions relevant to repair (and keeping) in daily life

Objects in need of repair as part of performing everyday life	Socio-spatial arrangements of objects in everyday life
- Invisible workhorses, - Visible workhorses - Daily tools - Home-making objects - Collections - Memory objects - Assemblages & containers - Overflow objects - Morally worn-out objects.	- Hidden spaces: garages, cellars, second ceiling, spaces at the back of the cupboard, top drawers and cupboards - Waiting spaces: cupboard, baskets - Rotation spaces: laundry basket, dishwasher - Routine spaces: kitchen cupboards, shoe rack - Display spaces: mantel piece - Spaces outside the home -

Table 2. overview of attitudes towards domestic keeping

co-existing reactions/attitudes/coping strategies	Sub themes
Oppressive	too much, stigma (hoarding, laziness, procrastination) easier to bin, declutter, guilt…
Coping / Questioning	hard to throw away, illogical, storing problems: 'mess' place, judging/evaluating…
Projection / keeping for…	useful for, just in case, might use, plan to give away, plan to sell, in transit…
Managing visibility / presence	disappearing, convenience of out of sight, staying aware of, access, finding…
Conscious use / keep using	keep using, reuse, long use, using 'right up to the end', want to repair…
Attachment / reassurance	safely stored, protect, attachment, reassurance of things, memories…

Jager Erben [18] can be a useful start point, establishing categories of object types and spaces concerned - both by repair, but also by keeping. See Table 1.

As part of ongoing research [4] into the theme of keeping as a longer product lifetime and sustainability issue, six different attitudes towards keeping in the domestic context can be identified (See Table 2).

The research highlighted that generally these different attitudes, ranging from the very negative (feeling of oppression) to the very positive (keeping for attachment, pride and reassurance reasons) co-exist, and also should be considered as potentially in flux, and likely to evolve.

4 KEEPING IN THE DESIGN CURRICULUM

The theme of keeping was used in two different teaching modules in 2021. These two examples are interesting to compare and discuss, as both involved 15 students, but at two different levels of study. The theme was addressed with a group of second year Product and Service design students, as part of a project-based design methodology module. Building on some of the insights from this module, the keeping theme was also addressed in a week-long intensive workshop with 5th year students on a Design for Social Innovation Masters course. "Keeping" in this module was used as a case study for exploring user-research tools for everyday behaviour [19](e.g., Probes) [20]. The structure of the two teaching modules is outlined in Tables 3 and 4 (heavy type indicating the more successful activities).

Table 3. Overview of teaching module - 8 weeks, 2nd year cohort (15 students)

INTRODUCTION TO SUBJECT, SELF-ANALYSIS, SENSITISATION (2 DAYS)	Auto-ethnography - observe throwaway things I keep
	Analyse reasons why I keep some throwaway things
	Creativity exercise - reapplying "keep" qualities
GUIDED USER RESEARCH (1 WEEK)	**In-depth interviews into keeping behaviour (2 per student minimum) verbatim transcribed**
	Analysis of results (in groups) and mapping findings
	Presentation and class discussion
"OBJECT"/ARTEFACT RESEARCH (2 DAYS)	Research (benchmarking) on existing furniture for keeping things
	Analysis of a piece of existing "keeping" furniture through cardboard modelmaking
INDIVIDUAL DESIGN PROJECT , WRITE-UP PROCESS (5 WEEKS)	Furniture design project based on an identified "keeping" issue/opportunity *(see table 3)*
	Detailed written report covering all steps on the "Keeping" theme

In both cases the students were introduced to the theme of keeping through exercises encouraging them to explore their own keeping behaviour [19] [7], followed by a phase of user research. In the case of the 2nd year cohort, the user research was guided, with students carrying out a small number of in-depth in-situ interviews. Students were asked to produce a verbatim transcript and were given some possible questions that they could use as a start point for building their own semi-structured interview framework.

Table 4. Overview of teaching module - 2 weeks, 5th year cohort (15 students)

INTRODUCTION TO SUBJECT, SELF-ANALYSIS, SENSITISATION (2 DAYS)	Illustrate an emotionally durable object I own
	"Everything I touch" exercise, inventory (evening to following morning)
	Auto-ethnography, on some aspect of what, why, how I keep things - mini report (see table 4)
	Reading all reports and in-class discussion
USER RESEARCH - IN TEAMS OF 3 (1 WEEK)	Identification of a keeping related research question (based on previous exercises)
	Design a probe kit to investigate the question
	Make the probe kit
	Hand out probe kit to 3 different people/households
COMPILE RESULTS, WRITE - UP PROCESS (1 WEEK)	Analyse results of completed probes
	Document the process in the form of a written report, including participant and student feedback.

The interview transcripts were analysed by students in groups of three, and each team created a map to represent their understanding of keeping behaviour. These maps were presented to the class and discussed by the cohort as a whole.

For the much shorter 5th year workshop module, the initial sensitisation to the theme involved three different exercises, including two encouraging them to observe their own keeping behaviour at home [21]. Following this immersion in the subject, working in teams of three, students defined research questions related to keeping, and then focused on developing a probe tool to explore their questions. The main teaching content for this group of students during the week-long workshop was related to testing and designing user research tools. The analysis of their research findings, the evaluation of their probe tool and their feedback on the subject were compiled into written reports.

In the 2nd year module, the user research findings were used as a first phase of analysis to help students individually identify a keeping-related issue to be addressed in the context of furniture. As part of this design project, students explored existing furniture that could in-part answer the issues identified. These existing furniture archetypes were explored in a short model-making exercise. Working to personal re-briefs, students spent four weeks on their design project, and made both a short visual presentation and a written report of their project.

4.1 Towards understanding keeping

Both of these modules were first experiences addressing everyday behaviour issues using "keeping" as a framework, so should not be considered definitive. Nevertheless, these case studies can be assessed in terms of effectiveness for holistically exploring domestic "keeping" with design students at different levels of study. The small size of cohorts permits illustrating aspects of keeping addressed by the whole of each group (see Table 5) and comparing these to the object families identified in repair research [18] as well as the six attitudes [4]towards domestic keeping mentioned above.

Table 5 illustrates the keeping questions that each student (in the 5th year cohort) chose to investigate, in-situ, in relation to her or his own behaviour. The majority of this research addresses what could be termed positive keeping. Memory and symbol-related keeping are well represented, perhaps reflecting the idea [22], that designers may be more concerned with sign value than materiality in objects. It is also possible to conclude that students tended to focus on the keeping of objects with a certain value. Keeping in more mundane categories such as[18] "assemblages & containers" was not at all present. This may indicate the natural tendency, mentioned by Chapman [23] to not focus on the "myriad objects … [that] fill the rooms, cupboards and pockets of our daily lives". It is important to note that the workshop was carried out at the start of the school year, and that for many students what they had in their lodgings was already the result of a strict selection of what to "keep" with them.

Table 5. Auto-ethnography exercise on keeping habits, 5th year cohort

Research themes as described by students themselves (heavy type added by author)	Concerning which objects?
Why I keep them?	books, notebooks, wine stoppers, guitar
I wanted to **explore my memory box**…what it contains, its usefulness	Papers, birthday cards, flyers, gift wrapping
I wanted to explore **where we store or display emotional objects** and why	Soft toys, jewellery, gifts, "special" things
I have a **habit of collecting**…they all have one thing in common: **memory**	Hats, lighters, notebooks & perfumes
I wanted to explore the jewellery that adorns my body…**sentimental value**	Jewellery
explore **what I keep.. and what I digitalise** to improve personal organisation	Historical coins, medals etc. vs papers
Keep it? Things I left at home and things I brought with me	All his stuff - with him and in parents' home
How do I sort out my stuff? I classified things I keep (6 categories) and don't keep	All stuff in student lodgings
What objects **I have trouble throwing away** or that I always keep?	Un-worn clothes, empty perfume bottles…
I started to think about **a memorable object**…which can give you stars in your eyes	Sneakers with a story attached
What objects do I keep and why? "They **represent me**" vs "They are **useful**"	All stuff in student flat, beginning of term
…explore all the objects in my house **that I don't use everyday**	electric appliances, collections, old clothes…
What I wear in my daily life? …and **all the clothes I don't wear and why**…	all clothes in closet
..explore my **dressing** room. Where I accumulate the most **things I don't use**	all clothes
Moving out after more than 20 years…what to keep, what to throw, decluttering	Family house contents

Student briefs generated after more substantial user research by the 2nd year cohort, as could be expected, cover a slightly wider range of objects kept and attitudes to keeping. These briefs were also the result of research on a much wider user cohort, from teenagers through to grandparents. These briefs illustrate the prevalence of the *Projection/Keeping for* and *Managing visibility/presence* themes, which were much less present in the initial approaches by the 5th year cohort. Nevertheless, an over-representation of briefs related to attachment/memory objects can be identified. Equally, these briefs do not address the more negative attitudes towards keeping (*Oppressive, Coping/Questioning*). And again, the more mundane keeping issues related to low value objects (assemblages + containers, morally worn-out objects) [18] are not treated, suggesting that there are aspects of keeping that need to be better illuminated in order to have a more holistic understanding.

4.2 Effective research/teaching tools

The two teaching modules clearly highlighted the need to encourage students do both exhaustive exercises (e.g., Everything we touch) [21] and also very focused research in the initial sensitisation stages. Examples of this could be the memory-box inventory or answering the question exploring "all the objects I don't use every day" (table 5). In both cases students did detailed hands-on inventories, followed by photographic documentation, classification and analysis. The three fold sensitisation steps for the 5th year cohort seem to have been more successful than the approach with the 2nd year cohort. Also illustrating the importance of a hands-on approach, students commented very positively on the exercise of exploring furniture artefacts through modelmaking. This exercise also had the benefit of placing current keeping habits in a longer historical context.

User research from in-depth interviews by the 2nd year cohort generated very rich data - but detailed data analysis was hard for year 2 students. Nevertheless, students commented on the eye-opening nature of their interviews, and the shared mapping exercise collectively generated valuable insights.

The probes exercise given to the 5th year cohort produced more contrasting results. Certain teams lost focus of the keeping issue, and also a tendency to use existing "game like" strategies for their probe kit may not have been appropriate in keeping research. Nevertheless, two out of five groups did work very relevant to keeping issues - one exploring reasons for keeping, throwing away and triggers for changes in behaviour, showing how a negative vision of keeping often prevails. A second group was much more focused on mechanisms around keeping memory objects, a theme that may be a more automatic choice, but one that nevertheless exists in this context. We can note that the two fifth year groups who designed and successfully used probe tools to better understand aspects of keeping included students who did very detailed hands-on work in the sensitisation exercises, suggesting the importance of effective introduction exercises. Equally the students who had more difficulty in the probe exercises appeared to have built less on their self-documentation exercises.

4.3 Weaknesses and strengths

Using the term "keeping" aimed at covering the widest possible range of passive material relations in the domestic context - but the term did generate some definition difficulties for students. Another issue that needs to be kept in mind are the preconceptions that may automatically link keeping to emotional durability, overlooking, as mentioned previously, the majority of what is actually kept. The current media coverage given to de-cluttering [24] may also give a certain bias that needs to be anticipated.

Over-all "keeping" appears to be a theme students were able to relate to. The breadth of the subject also has the potential to initiate a very wide range of design briefs.

Beyond "keeping", these modules generated secondary benefits. Being a fine-grain subject to address in user research represents a good challenge in terms of creativity in research tool design (at Masters level). Student feedback also highlighted how the subject had raised personal awareness of the invisibility of stuff, which may be valuable learning for designers. The subject as a whole encouraged questioning the importance of emotional attachment and reassessing notions of function. Students also underlined how their research highlighted unexpected incongruities, divergence and idiosyncrasy in daily behaviour, showing numerous paradoxes and 'not easy answers'.

5 CONCLUSIONS

The two case studies presented here do not enable us to determine whether this type of subject is better addressed early in design studies, or at Masters level. We can, however, conclude that this theme could not be treated in short format for younger students, and even for 5th year masters' students a slightly longer format would have been beneficial. While the two case studies can certainly be improved, "keeping" appears to be a valuable framework for addressing over-looked passive material relations, particularly in the context of (product) design studies. We can conclude that exploring keeping involves addressing fine-grain aspects of sustainable behaviour and constitutes a way of (encouraging) looking at everyday paradoxes and complexity, rather than certitudes and templates. Finally, this theme appears to be an accessible way of confronting mundane but highly divergent material relations, which will be increasingly important for understanding and designing for sustainable behaviour and behaviour change.

REFERENCES

[1] Bakker C. Ten Golden Rules of Design for Sustainability, in *proceedings, 3rd PLATE 2019 Conference, Berlin, Germany*, 18 - 20 September 2019.

[2] Author. From Objects and Products to Things and Stuff. In *DC (S) Design Culture(s), Cumulus Roma, June 16 - 19, Roma*, 2020 (2021).

[3] Findeli A. Searching for Design Research Questions: Some Conceptual Clarifications, in *Questions, Hypotheses & Conjectures, Design Research Network, Berlin*, 2010.

[4] Green C. Questioning current attitudes towards “keeping” and their implications on longer product lifetimes. In *Product Lifetimes and The Environment (PLATE), Virtual Conference*, Limerick, May 2021.

[5] Chapman, J. *Emotionally Durable Design: Objects, Experiences and Empathy*, Earthscan Publications, London, 2005.

[6] Haines-Gadd M., Chapman J., Lloyd P., Mason J. and Aliakseyeu D. Design framework for emotionally durable products and services, in *PLATE, (Conference), TUDelft*, 2017.

[7] Green C. Objects, things and stuff; exploring the awareness of materiality in longer everyday product relationships in *3rd PLATE 2019 Conference Berlin, Germany, 18-20 September* 2019.

[8] Whalen K. A. and Milios L. Circular Economy Policy at a Crossroads: Encouraging Durable Products or Enabling Faster Cycling of Short-lived Products? in *3rd PLATE 2019, Berlin*, 2019.

[9] Özkan N. and Wever R. Again and Again; Triple Perspective on Design and Repair, in *3rd PLATE 2019 Conference, Berlin, Germany*, 2019.

[10] Glöser-Chahoud S. and Pfaff M. The role of unused storage phases (hibernation) in the overall lifetime of a mobile phone – an evaluation of simulation-based scenarios including their environmental impacts, in *3rd PLATE 2019 Conference Berlin, Germany*, 2019.

[11] Wilson G. T., Smalley G., Suckling J. R., Lilley D., Lee J. and Mawle R. (2017). The hibernating mobile phone: Dead storage as a barrier to efficient electronic waste recovery. *Waste Management, 60,* 521 - 533, http://dx.doi.org/ 10.1016/j.wasman.2016.12.023 [Access 27,04, 21].

[12] Casey K., Lichrou M. and Fitzpatrick C. Treasured trash? A consumer perspective on small Waste Electrical and Electronic Equipment (WEEE) divestment in *Ireland. Resources, Conservation and Recycling, 145. pp. 179-189*. 2019.

[13] Rinkinen J., Jalas M. and Shove E. Object Relations in Accounts of Everyday Life, in *Sociology 1-16 - Special Issue on Sociologies of Everyday Life, 2015.*

[14] Ortega Alvarado I., Pettersen I. N. and Berker T. Alternative consumption: a circular economy beyond the circular business model, in *3rd PLATE 2019 Conference* Berlin, Germany, 2019.

[15] Miller D. (2010). *Stuff*, Polity, Cambridge.

[16] Pétursdottir T. Things out-of-hand, The aesthetics of abandonment, in *Ruin Memories, Ruin Memories: Materialities, Aesthetics and the Archaeology of the Recent Past, Archaeological Orientations*, Routledge, 2014.

[17] Baker S. To go about noisily: clutter; writing and design, in *Emigre* No35, Summer 1995.

[18] Hielscher S. and Jaeger-Erben M. Resisting Obsolescence? The role of a ‘culture of repair’ fr product longevity, in *3rd PLATE 2019 Conference* Berlin, Germany, 2019.

[19] Lee J. The True Benefits of Designing Design Methods. *Artifact, 2014, Volume III, Issue 2,* 2014.

[20] Mattelmaki T., Lucero A. and Lee J. Probing - Two Perspectives to Participation, in P. Markopoulos et al. (eds). Collaboration in *Creative Design, Springer, Switzerland*, 2016.

[21] Zucotti P. *Every Thing We Touch: A 24-Hour Inventory of Our Lives*, Viking, UK, 2015.

[22] Verbeek P.-P. and Kockelkoren P. The Things That Matter, in *Design Issues*, Vol 14. No 3, 1998.

[23] Chapman J. Hadal or epipelagic? The depths, and shallows, of material experience, In *PLATE conference proceedings, Nottingham Trent University, 17-19 June*, 2015, pp57 – 61.

[24] Chamberlin L. and Callmer Å. Spark Joy and Slow Acquisition: The KonMari Method and its Impact on Moments of Consumption, in 3*rd PLATE 2019 Conference, Berlin, Germany*, 2019.

RE-EVALUATING LEARNING ENVIRONMENTS TO NURTURE STUDIO CULTURE

Ceri ALMROTT
Technological University Dublin, Ireland

ABSTRACT
Following the COVID-19 pandemic and the resultant remote teaching that lockdown enforced the requirements and suitability of physical learning spaces such as studios can be questioned. This paper seeks to understand the requirements of students in this decade of their physical studio spaces.
Using focus groups, surveys and user feedback activities students on the Product Design programme were asked to evaluate the studio spaces within the university as they returned to on-campus learning and provide qualitative feedback on their experiences.
It was found students still require physical studios that allow them to undertake their design work and utilise tools and the space in a way they are unable to in other learning and domestic environments. Most importantly students require a space that allows them to understand and conceptualise project work, engage in discipline-specific discourse and feel a sense of ownership to encourage creative thinking.

Keywords: Product design, studio culture, studio practice, learning environments, design education

1 INTRODUCTION
The nature of the educational practice of many design programmes has led us, as an academic discipline, to rely heavily on our physical studio spaces. Communication and collaboration are key skills that are required from design students in the development of their project work [1]. The physical studio provides a teaching, practice, and social space where students can work individually or collaboratively, as required on their various practice-based assignments.
Education post-COVID-19 is likely to face pressures to embrace a blended, if not fully digital model [2]. Design courses have invested considerable resources (both time and capital expenditure) to develop studio-based learning spaces which fulfil the needs of their often practice-led, learning styles.
COVID-19 and the related university closures, which in some cases lasted for entire academic years, have resulted in a novel situation in which many mid-programme undergraduate students have undertaken much of their design learning either outside of the studio environment or within an environment that is not optimised for the learning experience we would have previously promoted. Previously studios had been heralded as enabling spaces on which to base fundamental pedagogical models for other practice-based programmes [3].
Pressures to adapt our teaching practice presents a unique opportunity for educators to again evaluate and define the role that educational spaces have in our programmes, and how we use them to build engagement and foster our students' development. We cannot ignore lessons and new modes of working we have encountered during pandemic closures [4] and as such we should identify which new paradigms need to be integrated to create engaging studio spaces for this next generation of design students.

1.1 Current situation
The first step to understanding the future role of these spaces is to learn from our students' needs and experiences as they return from distance and blended study to again working in studios. Through exploring how students interact and engage with their learning spaces, using peer feedback, questionnaires, and student interviews, we can learn how we can best accommodate and facilitate a new generation of active studio learners working with both physical and digital educational tools.
Due to the length of time students have had to engage in remote learning there has been a loss of tacit knowledge on how to use and engage with the studio space within the student body. It has been noted that students have had a lower than anticipated engagement with the studio when they returned to campus in Autumn 2021 The culture which was present before the pandemic has not returned. Many

students, during online teaching, lamented the ability to meet in person and engage with their peers and so the slow return to the spaces was an unexpected outcome of the return to campus.

Figure 1. Classes in the three studio rooms currently available to students on the programme

Generally, during scheduled class time, utilisation of the learning environments is good. However, the mentality where students choose to stay to work and study within these spaces outside of class time, to engage in didactic discourse amongst peers, is much reduced.

2 METHODOLOGY

To develop an understanding of student feelings around the use of the studio it is important to capture a broad range of views to understand the specific requirements students in the 2020s require of these environments. User focussed and ethnographic research techniques are the mainstay of design research projects and so students should be familiar and comfortable engaging with these research approaches.

2.1 Student Feedback Exercise – I Like, I Wish, What If?

It is important to understand information about studio culture and behaviour among the student body to categorise and frame their experience. The Design Thinking exercise *I Like, I Wish, What if?* Is a quick, well regarded, research activity that seeks to understand a user's feelings whilst framing their feedback in positive and understandable statements[5].

To allow all students to engage with the studio spaces in a meaningful way it was planned to hold user feedback sessions in the last weeks of the Autumn semester during studio project classes. Due to increasing rates of infection in the student body, at the time of the research, some classes were moved to online teaching. To provide all students with an equal engagement experience the exercise was conducted via the online tool Miro. Students were emailed instructions and links to a virtual pin-up board to allow them to review their three studio spaces. Although not an ideal facsimile of the in-person task due to the inability to ensure broad and equitable engagement across student cohorts, this method allowed for strong and meaningful student engagement in a format most students were familiar with.

2.2 Focus group

A secondary exercise was undertaken in the first quarter of the second semester to gain a more detailed understanding of the voice of the student body. All year groups were invited to participate in a focus group held in the main studio. Invitations to interact with the focus group were offered to each class via their class representative with an opt-in for those students who wished to engage. The number of questions for the focus group was kept deliberately short, 4 in total, to encourage the maximum amount of discourse amongst the group and to allow for the development of narrative examples as suggested by Queensbury and Brooks [6].

2.3 Survey of cross-disciplinary year 3 students

Students in the third year of the Product Design programme were invited to engage in a survey that looked to understand their feelings around the use of pin-up boards as a tool for developing design outcomes and generating a feeling of ownership within the studio. These students were chosen as they were engaged in a live, cross-disciplinary project with Visual Communication students and this project provided them with the opportunity to work in a separate and distinct studio environment. Within the studio spaces in this programme Pin Up boards are a relatively new tool and students were actively encouraged to use them. The students were surveyed as to their feelings around interacting with this tool and how using the tool made them feel about using the unfamiliar space. The survey was designed for conciseness to capture maximum engagement amongst the student body whilst also providing targeted responses.

3 RESULTS

By using a broad range of approaches to gather data on the students’ feelings towards the design studios a broad amount of qualitative data was collected which could then be interpreted to gain a better understanding of the current sentiment of the student cohort to the studios on campus.

3.1 I Like, I Wish, What If?

The Miro boards provided an excellent medium for gaining a wide range of voices and collecting a variety of responses to the prompts: What about the Studio do you Really like? What about the studio do you think needs to change? And What else could be done with the studio spaces?

Responses were returned across the broad themes of *room architecture, practice activities, furniture, resources, use* and *room feel*. These responses were collated into one board with combined phrases that mirrored the *I Like, I Wish, What If* prompts. Where there were multiple responses dot voting was incorporated to show that there was a larger body of students who stood behind that statement.

Students were much in favour of studio spaces with high ceilings and bright, natural light (although some comments in the *I Wish* section would like to have more control over the light, either through the installation of roller blinds or through more user-friendly controls for artificial lighting.

Figure 2. Collated results from Student Feedback Exercise - "I Like, I Wish, What if?”

3.2 Student Focus Group

From the focus group activity, students were able to explore, in-depth, their feelings around the use of and engagement with the various studio spaces available to them. The focus group ran for just under an hour and provided answers to four questions: *What do you feel the role of the design studio is? How comfortable do you feel working in the studio? What makes for a good space to undertake design work? Who is responsible for the studio?*

The focus group was attended by eight students across the various years and was a forum where the students felt comfortable interacting with each other and discussing their different views. The ability to develop stories was a useful tool that allowed students to share experiences and relate across different projects and practices.

Figure 3. Thematic analysis of responses from the focus group activity

The themes which were identified by the focus group mirror those found in the student feedback exercise and are related to practice activities and what was required to undertake them, the feel and the types of furniture required.

3.3 Student Survey

There was good engagement with the student survey with twenty-two respondents among the product and visual communication students. Many students found the studios an engaging environment before the start of the project which is in line with the rest of the data. However, only 50% of students would have used the pin-up spaces and under sixty per cent of students felt a sense of ownership with the studio spaces. This is in line with anecdotal observation of studio engagement in Semester 1.

Pin-Up boards were found to be a tool that allowed students to better visualise their project work (77%) and of those students who replied favourably to using the tool most (88%) replied that having their work on display in a studio had a positive impact on how they felt about using the studio. Eighty percent of all respondents felt more inspired within the studio space when there was student work, which related to their projects, on display in the studio.

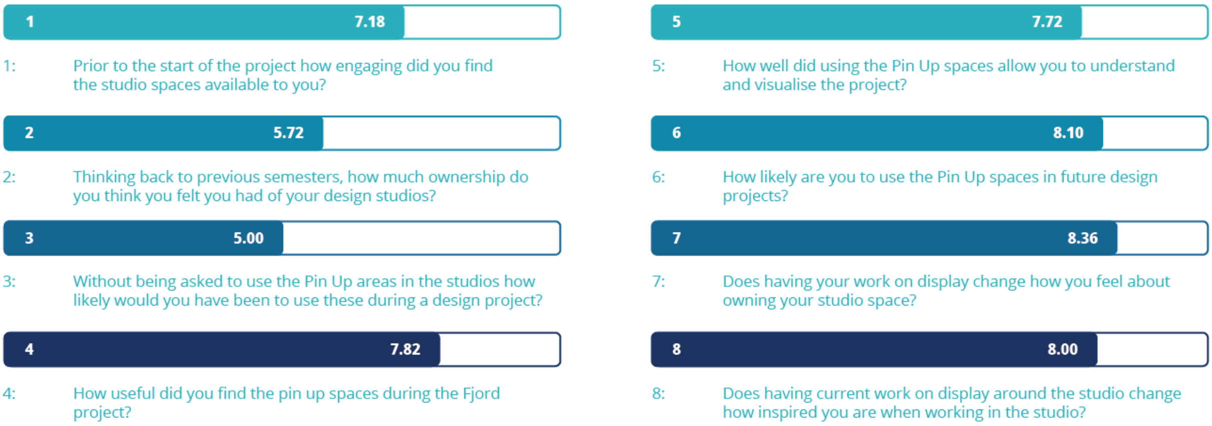


Figure 4. Results from Survey of Year 3, cross-disciplinary design project, participants

4 DISCUSSION

Students found that all rooms were appropriate for group work, which was seen as a large benefit and flexible spaces which were understandable and easy to alter were preferred. Also, all rooms were found to have plenty of seating, which was a positive – although this was referenced later and more specifically in the focus group as potentially hindering discursive behaviours. Students are individuals and the variety of seating on offer was, to some students, an issue although in the focus groups this was a matter of great debate and it became apparent that having variety, allows distinctive styles of work in each environment was required. Students also had a strong wish to embrace modern models of working with a preference for higher working surfaces and standing desks and general discontent with rooms that did not have these types of furniture within them.

but sitting up high it encourages you to just get up or get up and walk around

Students found that they had a sense of ownership of the studio spaces and especially liked studios where there was the facility for the display of work to their class group and other years. Students liked the ability to see work change and develop across projects and the academic year and were strongly in favour of having more space where they can visually understand their projects.

I think it also creates like a really welcoming space that you kind of want to go into that looks interesting [regarding work on display]

Students were not in favour of times when other programmes or student groups might require the use of space and felt a keen sense of ownership and defensiveness in these cases.

The location of general access prototyping tools such as hot wire cutters and 3D Printers was seen as a benefit that was enjoyed by the student body. However, although all rooms have some materials for cleaning students felt that these could be expanded upon and made more accessible. Design can after all be a messy activity and it is not surprising to find that students wished to maintain levels of cleanliness, outside of when contract cleaners might work in the room.

From the data gathered students were generally in favour of developing environments that were more, unlike the resources that they may not have access to outside of the university. A wish for more standing desks, more whiteboard spaces, a dedicated space to take high-quality photographs of work and access to specialist tools such as a materials library were all suggested. Students were very much in favour of more natural and wood-based finishes within the studio spaces feeling it provided an appropriate professional feeling. The student body felt that it had the right balance of modern design aesthetic with the ability to feel like a place where design work could be undertaken and Fell suggests that the biophilic nature of wood promotes the warm and welcoming feeling students suggested a studio requires [7].

a studio should be, like, welcoming, warm, but also give you the ability to develop ideas

Students had many opinions on how a studio should feel and the type of work that should be undertaken in them. There was a genuine appreciation for the studio spaces and a positive feeling toward them.

an environment devoted to creation

and

that quiet space [that] maybe you won't have at home where you can get your work done

It is important to note that not every student will have a space in their domicile where they can comfortably undertake design work and many University campuses will not have “chaotic” or “messy” spaces where students can work freely on design projects. This makes the studio an important space for providing an equal opportunity for all students to fully engage in their design practice.

5 CONCLUSIONS

Studio spaces require effort to develop and nurture if they are to provide a lasting positive influence on a design student’s studies. They are important for developing critical and discursive practice and for allowing cross-pollination of ideas within project-based learning and student cohorts. Students still see great benefit in the ability to physically interact with their peers and share ideas through mediums outside of screens and communication devices.

Students are more inclined to work with the studio if it offers them benefits outside of those they can develop elsewhere and can be simple in that they provide a “home” for the programme and where the students can relax and develop their creative practice. Students still favour foundational tools such as whiteboards, pin-up boards and basic prototyping and sculpting tools, even amongst a population that has had great agency to use virtual alternatives.

However, to nurture these spaces, we must ensure that environments be welcoming and that there is an agreement with the student body on how the space is run and managed. To generate a natural engagement there should be the facility for students to develop ownership and integration through the ability to store and display their work and have a voice within the management of the space.

It is also important to provide facilities to allow students to work remotely and develop their practice. Providing students, with the trust and ability to take ownership is seen as incredibly important for developing a powerful sense of ownership and engagement that a functioning studio space requires.

REFERENCES

[1] Voûte E., Stappers P. J., Giaccardi E., Mooij S. and van Boeijen A. Innovating a Large Design Education Programme at a University of Technology, *She Ji J. Des. Econ. Innov.*, vol. 6, no. 1, pp. 50–66, Mar. 2020, doi: 10.1016/J.SHEJI.2019.12.001.

[2] Whitehead T., Buck L. and Hewitt J. Blended Learning Technologies in Product Design Education, in *International Conference on Engineering and Product Design Education 9-10 September 2021, Via Design, Via University College, Herning, Denmark Blended*, 2021, no. September, doi: 10.35199/epde.2021.70.

[3] Milovanovic J. and Gero J. Modeling design studio pedagogy: a mentored reflective practice, in *Proceedings of the Design Society: International Conference on Engineering Design*, 2020, pp. 1765–1774.

[4] Petrova M. and De Monterrey U. The connectivist design studio, *Des. Technol. Educ. An Int. J.*, vol. 26, no. 3, pp. 341–352, 2021.

[5] Doorley S., Holcomb S., Klebahn P., Segovia K. and Utley J. Design Thinking Bootleg, *Des. Think. Bootleg*, p. 90, 2018, [Online]. Available: https://dschool.stanford.edu/resources/design-thinking-bootleg.

[6] Quesenbery W. and Brooks K. *Storytelling for User Experience: Crafting Stories for Better Design*. Brooklyn, New York: Rosenfeld Media, 2010.

[7] Fell D. R. Wood in the Human Environment:Restorative Properties of Wood in the Built Indoor, The University of British Columbia (Vancouver), 2010.

THE REDESIGN STUDIO: AN INTENSIVE EVIDENCE-BASED APPROACH FOR IDEATING PRODUCT AND UX/UI IMPROVEMENTS

Owain PEDGLEY and Bahar ŞENER
Department of Industrial Design, Middle East Technical University, Turkey

ABSTRACT
This paper describes a six-week design studio that set out to make 'redesign' an educationally rewarding activity, whilst developing students' skills in evidence-based designing. Final year industrial design undergraduates chose a personally owned household electrical or electronic product that they considered in need of improving or updating. The redesign studio guided students through five consecutive stages of briefings, activities, and critiques: (i) product anatomy analysis and part labelling, (ii) market analysis and market segmentation charts, (iii) hands-on peer contributed user experience (UX) evaluation, (iv) strategies for product improvement, and (v) design proposals. The educational aims of each stage are presented, with particular attention to the UX programme evaluation stage, where students were supplied with a special UX evaluation worksheet to accelerate their comprehension of UX terms and assist the collection and analysis of product evaluations. The results of a survey to gather students' views on the strengths and weaknesses of the redesign studio are also presented. Students gave overwhelmingly positive feedback, praising the closeness of the studio to 'real world' design practice. Their greatest challenge was time management: having to deal with the new experience of a high-intensity studio where they could not afford to ideate for excessively long periods or to procrastinate at any stage. The redesign studio is suggested to be a fruitful model for design instructors to adopt and modify in their own institutions for market-focused design briefs where rationalized incremental improvements are sought, rather than radical innovations.

Keywords: Product design, industrial design, redesign, evidence-based design, UX/UI

1 INTRODUCTION
Industrial design undergraduates are frequently given design briefs that are open in scope, allowing relatively free exploration of scenarios, products, services, mobile apps, and related systems that will be valuable and relevant to individuals and society in the near or farther future. The pursuit of innovative solutions is often an important criterion for design education. Rather less often, students are tasked with taking an existing product and lifting its specifications in one or more ways. Such projects, though seemingly mundane, represent a large amount of what professional designers do: moreover, they focus the mind on a product's physical and digital controls, styling, CMF (colours, materials, finishes) and graphics, and purposefully avoid changes in underlying product typology or morphology.
The work presented in this paper is a studio implementation of user-centred research and design, where industrial design undergraduates at Middle East Technical University were given the task to design the 'next generation' version of a small electrical or electronic household product that they owned and used at home. Entirely manual products were not suitable, nor were products that were very old or antique. Personal products (e.g., electric toothbrush, epilator, hair curler) were also not allowed, since they would be inappropriate for classmates to use and evaluate. Two emphases were made in the studio. The first was on redesign: students were taken through a journey of market analysis, user research, design prioritization, ideation, concept development, and product detailing, all centred on taking their existing product and replacing it with a newer version. The second emphasis was on generating an extensive evidence base for design decisions, counteracting temptations to rely on intuition or personal preferences. On completion of the studio, students' final design proposals were expected to be suited to their market sector in 12-18 months' time.

1.1 Orientation of UI, UX and related human factors terminology

Central to the redesign studio was a need for students to be savvy about the meaning and usage of the human factors / ergonomics terms 'user interface' (UI) and 'user experience' (UX), especially in the current era of product-service system (PSS) design, where physical (e.g., materialized product) and digital (e.g., mobile application) solutions are developed concurrently. At the initial briefing of the studio, students were introduced to the terms and made aware of the manipulability of their application. Industry trends have seen the emergence of UX/UI Designers and UxD (User Experience Design) as a field of work, but very often the main responsibility of these positions is to support mobile app design. The phrase "working in UX" has become practically synonymous with service design realized through digital platforms. These examples served to illustrate how the original conception of the terms UX and UI has become distorted and narrowed. Design educators undoubtedly have a responsibility to rise above trendy usage and at least make students aware of the degeneration of terminology [1]. To this end, the redesign studio instilled in students a reminder that UX and UI are indispensable terms that are not the preserve of mobile app design.

An explanation was given that all materialized products intended for interaction with somebody possess a user interface. At its heart, the UI is the means of accessing functionality. The UI can be no more complex than a handle on a jug that affords grasping and picking up. It can be the combination of controls, displays and other multisensorial feedback on a music synthesizer. Or, in the case of products with a voice user interface (VUI), it is the bridge between a spoken request and a confirmed output or command. A mobile app has a UI, and the use of that UI results in a UX, which all going well is close to the UX that the designer intended. But the mobile app and the process leading to its creation are not in themselves UX/UI. In proper terms, a mobile app is a particular type of graphical user interface (GUI). Having explained principles of UI to students, attention was turned to UX. Donald Norman [2] was introduced as the originator of the term UX, principally because in his view the practices of human-machine interface (HMI) design were too much concerned with usability testing and did not catch the breadth of experiences (or needs) that somebody may have with a system beyond usability. At this point, students were presented with Anderson's hierarchy of needs [3] as well as Hassenzahl's distinctions between pragmatic (useful) and hedonic (enriching) user needs [4]. In liberal interpretations, UX is regarded as a catchment phrase that defines how well a design fits to the people using or encountering that design, irrespective of whether the design originates from industrial design, interaction design, information design, visual communication design, web design, service design, etc. [5]. A common objective of centring on UX is to improve the lives of people through the products and services that they use [6] and, accordingly, UX is something that can be designed for and evaluated. Students went into the redesign studio having been exposed to these orientation principles.

2 THE REDESIGN STUDIO

The redesign studio was a six-week activity carried out with final year industrial design undergraduates (n=35) as part of their 14 ECTS 'ID401 Industrial Design V' module in the Fall 2021-22 semester. The module was delivered by a team of six tutors: two full-time faculty members, two part-time professional designer instructors, and two teaching assistants. Owing to the ongoing COVID-19 pandemic, a hybrid delivery was implemented. A total of 12 hours per week was timetabled, comprising eight hours face-to-face and four hours online (using Zoom). To satisfy the 14 ECTS quota, students were advised to contribute approximately 14 hours of self-study per week. The online collaborative application Miro was used to communicate design processes and outcomes between students and tutors.

Students were guided through five consecutive stages of briefings, activities, and critiques, requiring deliverables illustrated in Figure 1. A detailed description of each stage follows. Assessment was made at three points: Preliminary Jury in week 4 (25%), Final Jury in week 6 (50%), and Project Process Portfolio in week 6 (25%). Students chose their own pairs (n=13) or triplets (n=3) to work in. Members of each pair or triplet negotiated amongst themselves to decide on whose personally owned household product they would use for the studio. The following product sectors were represented: upright toaster, coffee maker, turntable, bread machine, hand vacuum cleaner, juicer, electric coffee pot, sandwich toaster, games console controller, iron, blood pressure monitor, hand mixer and air humidifier.

2.1 Stage 1: Product anatomy analysis and part labelling

At the first stage, aside from introducing the module, the redesign studio brief, and forming student pairs/triplets, students were instructed to take note of the sector of their chosen product, what the product does, its manufacturer name, its brand name (if different), and its model number/name. Students took photos of the product and labelled-up its parts with correct terminology.

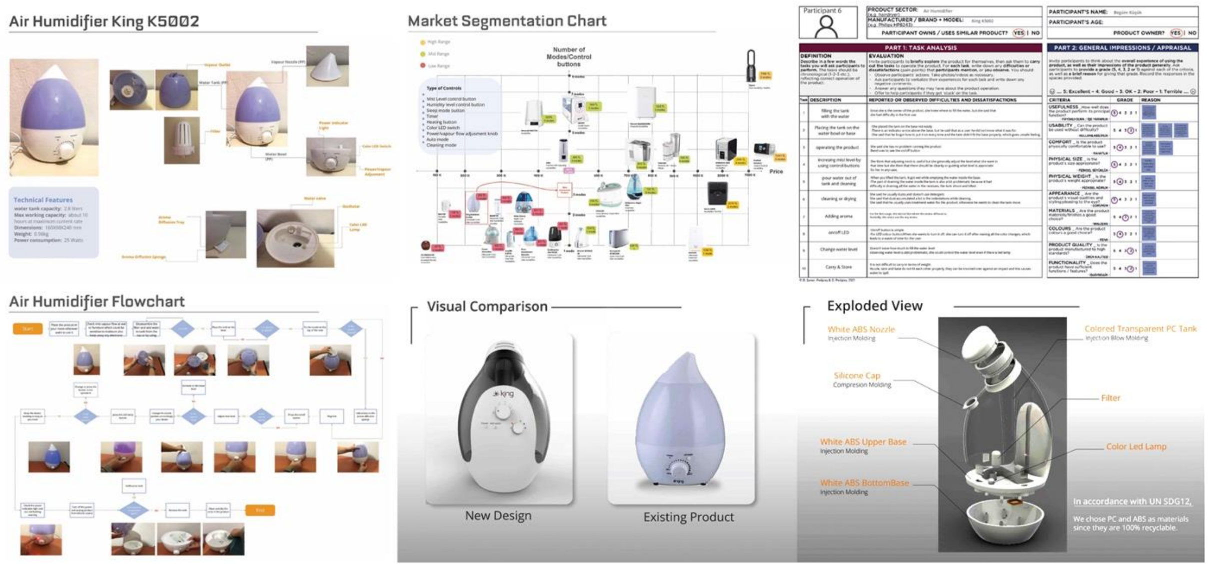


Figure 1. Example deliverables (left to right): labelled product photo, market segmentation chart, completed UX evaluation worksheet, operational flow chart, original product vs. redesign, exploded view (students: Elif Yıldırım, Begüm Küçük)

2.2 Stage 2: Market analysis and market segmentation charts

In preparation for the second stage, a briefing was given on techniques for market analysis. Students researched what the main points of differentiation were for their product sector and uncovered example products representing entry-level, mid-range, and high-end segments. These examples were then plotted to create market segmentation charts. The x-axis of the charts was always retail price, but the y-axis was chosen by students based on criteria relevant to their product sector. The existing product for redesign was requested to be highlighted at its (x,y) position on the chart. At this point, students were reminded that they were not permitted to propose a redesign that moved their product dramatically from its current market segment. For example, an entry-level product could not become high-end, but it might be raised closer to mid-range; a high-end product would not be downgraded.

2.3 Stage 3: Hands-on peer contributed UX evaluation

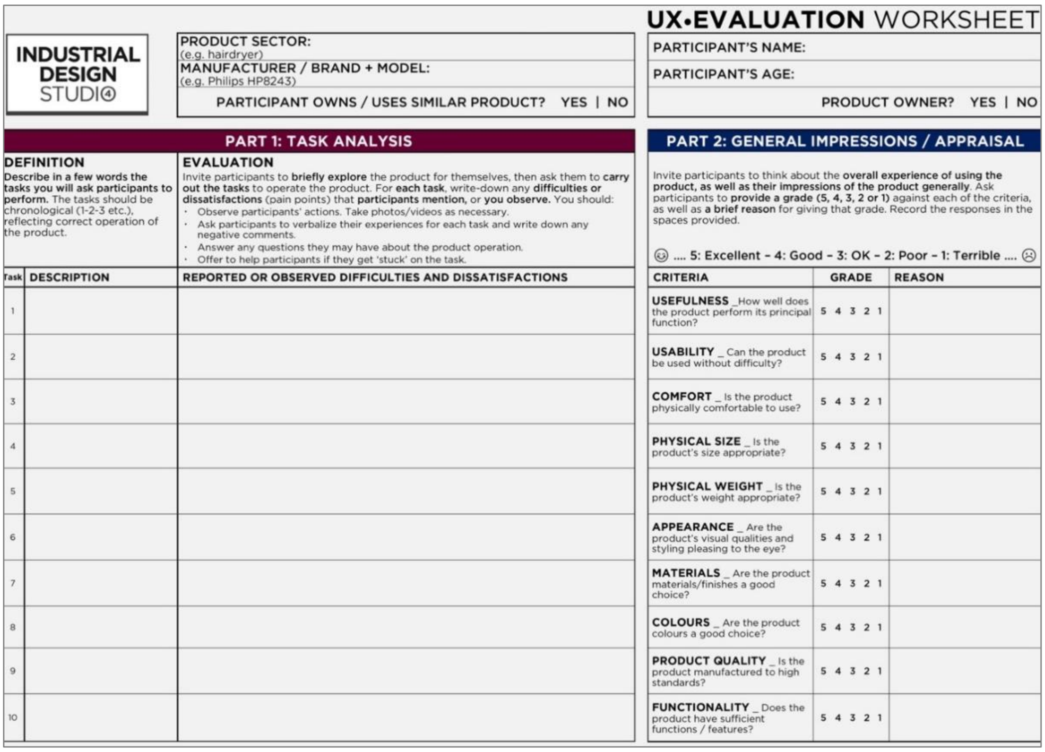
Stage 3 provided students with a rich data set from which they could decide how to improve their existing product through redesign. The stage commenced with a class briefing, entitled “What is UX evaluation of products?”, which built on the initial briefing of UX/UI terminology by focusing on the specific topics of UX testing, appraisals, and data analysis. The principles of task analysis, as step-by-step evaluation of product operation, were contrasted with general impression and perceived quality appraisals. Tools to generate UX evaluation data were introduced (e.g., observation, interviews, questionnaires, focus groups, self-reports, diaries for longitudinal use, etc.). Also, the kinds of data that can be collected were highlighted (e.g., measured vs. perceived, quantitative vs. qualitative, fixed criteria (e.g., scales) vs. open-ended (e.g., free text), small vs. large sample groups).

Students were supplied with a bespoke UX evaluation worksheet (Figure 2) designed to accelerate their comprehension of UX terms and give practice in collecting and analysing qualitative and quantitative product evaluations. The worksheet required a combination of self-reporting and observation, providing spaces for product owners to systematically record the results of classmates’ tests of their product. Part 1 of the worksheet was dedicated to task analysis. It required observation, interviewing, and videoing during the main steps of product operation, with the aim to capture difficulties or dissatisfactions. Part 2 of the worksheet was dedicated to general impressions / appraisal. It listed and defined ten common product evaluation criteria to be graded on a five-point Likert scale (usefulness, usability, comfort, physical size, physical weight, appearance, materials, colours, product quality, functionality). A translation for the local language was included to help with students’ comprehension of the criteria.

A briefing on research ethics, codes of practice and informed consent was given, so that students were aware of necessary procedures for conducting user research. Product owners were reminded to be very careful not to 'lead' participants to known problems, to share their personal judgements or opinions, or to otherwise bias the data. Their role during the UX evaluation was to be helpful but objective, so that participants could independently form their own judgements and opinions. Therefore, pair and triplet members were instructed to be physically present next to their participants during the evaluations, writing down responses and observations on the worksheet, answering questions, and giving impartial advice as necessary. Before the session started, pair/triplet members were reminded that they should:

- explain what the product is / what is does.
- show where the product features / controls are located using the correct product terminology.
- highlight any potential safety dangers (e.g., moving parts, hot parts) that should be avoided or handled carefully.
- pay attention to hygiene control due to COVID-19 (e.g., provide hand sanitizer and clean the product between evaluations).

Because of time constraints and restrictions on working with third parties, the UX evaluation was made with a small sample size (minimum six people): the product owner, the pair-triplet mate(s), and four other classmates. Evaluations were carried out one participant at a time. The small sample size had no negative impact on the educational experience or learning objectives. When completed, the worksheet formed an evidence base of pain points during product usage as well as positive and negative appraisals based on UX criteria.


INDUSTRIAL DESIGN STUDIO④

UX•EVALUATION WORKSHEET

PRODUCT SECTOR:
(e.g. hairdryer)
MANUFACTURER / BRAND + MODEL:
(e.g. Philips HP8243)
PARTICIPANT OWNS / USES SIMILAR PRODUCT? YES | NO

PARTICIPANT'S NAME:
PARTICIPANT'S AGE:
PRODUCT OWNER? YES | NO

PART 1: TASK ANALYSIS

DEFINITION
Describe in a few words the tasks you will ask participants to perform. The tasks should be chronological (1-2-3 etc.), reflecting correct operation of the product.

EVALUATION
Invite participants to **briefly explore** the product for themselves, then ask them to **carry out the tasks** to operate the product. For **each task**, write-down any **difficulties or dissatisfactions** (pain points) that **participants mention,** or **you observe.** You should:
- Observe participants' actions. Take photos/videos as necessary.
- Ask participants to verbalize their experiences for each task and write down any negative comments.
- Answer any questions they may have about the product operation.
- Offer to help participants if they get 'stuck' on the task.

Task	DESCRIPTION	REPORTED OR OBSERVED DIFFICULTIES AND DISSATISFACTIONS
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

PART 2: GENERAL IMPRESSIONS / APPRAISAL

Invite participants to think about the **overall experience of using the product, as well as their impressions of the product generally**. Ask participants to **provide a grade (5, 4, 3, 2 or 1)** against each of the criteria, as well as **a brief reason** for giving that grade. Record the responses in the spaces provided.

☺ .... 5: Excellent - 4: Good - 3: OK - 2: Poor - 1: Terrible .... ☹

CRITERIA	GRADE	REASON
USEFULNESS _How well does the product perform its principal function?	5 4 3 2 1	
USABILITY _ Can the product be used without difficulty?	5 4 3 2 1	
COMFORT _ Is the product physically comfortable to use?	5 4 3 2 1	
PHYSICAL SIZE _ Is the product's size appropriate?	5 4 3 2 1	
PHYSICAL WEIGHT _ Is the product's weight appropriate?	5 4 3 2 1	
APPEARANCE _ Are the product's visual qualities and styling pleasing to the eye?	5 4 3 2 1	
MATERIALS _ Are the product materials/finishes a good choice?	5 4 3 2 1	
COLOURS _ Are the product colours a good choice?	5 4 3 2 1	
PRODUCT QUALITY _ Is the product manufactured to high standards?	5 4 3 2 1	
FUNCTIONALITY _ Does the product have sufficient functions / features?	5 4 3 2 1	

Figure 2. Bespoke UX evaluation worksheet

2.4 Stage 4: Strategies for product improvement

Stage 4 comprised the bridge between the UX research and the generation of redesign proposals. Several briefings were given to students at this stage, including how to analyse UX evaluation data, generate results, reach conclusions and communicate the most important points using infographics. They were instructed to create operational flow charts to visualize the product operation and map associated pain points. A handout on 'ways to improve products' was provided to students, as a lens through which to examine their UX research. Additionally, it was important that students' redesigns would be suitable for 21st century sustainability goals. To this end, factsheets on the United Nations Sustainable Development Goal 12 (Responsible Consumption and Production) were provided to students [7]. They were asked to reflect on ways in which the goal could be relevant to their redesign, as a major factor or a supportive issue. From this point onwards, students were able to explain priority areas to improve their current product. They also referred to aspirational specifications of close competitor products, previously plotted on their market segmentation charts.

2.5 Stage 5: Design proposals

At this final stage, students generated design ideas and sketched product solutions in response to the headline results from Stage 4. Pair/triplet members managed their own ideation process as a combination of individual and group working. Students were reminded to be mindful during their ideation about the dynamics between cost (to manufacture), retail price (to purchase) and value (a qualitative judgement, concerning how much people are prepared to pay). They were not expected to know the exact cost of making improvements to their product, but were expected to be sensitive to the issue, making reasonable arguments based on knowledge of the product sector. The segmentation charts were very useful in this regard, forming a reference point for what can and cannot be considered reasonable around the targeted (x,y) position for the redesign. Students were also advised about generational evolution of products. When comparing their redesign with the existing product, there should be a 'family resemblance'. This focused students' minds on brand identity and product styling/semantics. Finally, students were instructed to use only existing or just-about-to-be-commercialized technologies and that their final proposals should be detailed for manufacture and assembly in specific materials, using 3D CAD programs such as Rhino and Fusion. All the studio assessments were made during Stage 5, which covered the final three weeks of the studio.

3 FEEDBACK AND DISCUSSION

An online survey completed by all students (n=35) one week after completing the redesign studio revealed areas of success and suggestions for improvement. The survey had ten questions in total. All questions were prepared bilingually (English and Turkish) to aid students' comprehension. Questions 1-9 required students to express their level of agreement or disagreement with positively phrased statements linked to experiences during the studio. A five-point Likert scale was used with the descriptors 'strongly agree', 'agree', 'neutral', 'disagree', and 'strongly disagree'. Figure 3 contains the results, with all figures expressed as a percentage of the n=35 sample. The mean result across questions Q1-Q9 was extremely encouraging: 80% of students either strongly agreed or agreed with the statements, whilst only 5% disagreed or strongly disagreed. Overall, students expressed appreciation of the redesign studio, whilst their responses confirmed that the intended learning outcomes related to both the worksheet and the studio had been achieved. Certainly, students' attention to UX/UI in their design proposals was elevated and competent, suggesting the worksheet had been effective.

The final question (Q10) was a free text question: "Please provide any comments – strengths and/or weaknesses – to improve the UX Evaluation Worksheet and/or the 'Redesign Studio' generally." The answers were analysed using an iterative free coding process. The most prominent feedback (n=7) for the UX evaluation worksheet related to part 2 (general impression). Most students found the numerical scale very helpful, since it easily led to defining a general evaluation result for each criterion. It also formed a quick reference for ideation, to ensure that new design ideas were grounded in the researched (rather than fictional) priority needs and problems. Students provided praise but also constructive criticism about the worksheet in general. One student wrote, *"the worksheet really helped me to visualize the UX process. I will try to use a sheet similar to this on my next projects!"* Another stated, *"the worksheet can be improved to produce less visual and cognitive stress when trying to follow it in a hectic testing phase"*. Several students (n=6) mentioned missing information that could be added to the worksheet to enrich its content suitable for ideation, e.g., ergonomic measurements, placement for photos/videos, division between basic and advanced task analysis, memorable comments, and space for multiple problems/issues at each step of operation. These suggestions have been collated and will be used to improve the next version of the worksheet, which will be a digital rather than printed version.

Two prominent themes were found amongst the feedback on the redesign studio as a whole: its duration and its closeness to real-world commercial practice. Among students mentioning the duration (n=13), most thought that six weeks was too short. This duration was set knowing that it would allow sufficient time to complete the work satisfactorily. However, the main issue for students was the unfamiliarity of such a tight and intensive studio. They faced difficulties in adapting to a different working style compared with longer and more relaxed projects in early years. The short duration was necessary to replicate the feel of a real-world commercial practice, which ironically was students' most appreciated aspect of the redesign studio (n=12). Two comments were particularly rewarding: *"My overall comment is really the best project I've ever had. I can't help but thank you for advancing it in such a way",* and *"It was beautiful. We had the opportunity to learn about many different products in a project."*

	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Q1. **"Using the worksheet was a useful step in my design process."**	40	54	6	0	0
Q2. **"The worksheet was easy to follow and complete."**	37	51	9	3	0
Q3. **"Part 1 of the worksheet (task analysis) helped me to systematically describe the correct product operation."**	31	46	17	6	0
Q4. **"Part 1 of the worksheet (task analysis) was helpful for recording participants' reported or observed difficulties and dissatisfactions during product use."**	51	43	6	0	0
Q5. **"Using a numerical scale (1-5) for Part 2 of the worksheet (general impressions/appraisal) made data analysis relatively easy."**	43	31	23	3	0
Q6. **"I appreciated analysing UX data, collected through the worksheet, both qualitatively and quantitatively."**	43	40	14	3	0
Q7. **"The fact that the 'Next Generation Products' design brief was close to a 'real-world' design challenge was satisfying to me."**	69	23	6	3	0
Q8. **"The duration of the 'Next Generation Products' project (6 weeks from brief to final jury) was a strength of the project."**	20	23	40	9	9
Q9. **"The 'Next Generation Products' project enhanced my understanding of UX."**	29	51	17	3	0
MEAN (%)	**40**	**40**	**15**	**4**	**1**

Figure 3. Results of post-studio survey

4 CONCLUSIONS

The redesign studio clearly helped orient students towards the practices of professional design and the rewards that can come from relatively fast-paced and evidence-driven decision making, rather than over-concentration on early stage imagination, ideation and "what if..?" questions. It also provided students with experience of being creative within a solution space that was more constrained than they were used to: change an existing product rather than innovate from a *tabula rasa*. The redesign studio mirrored professional design practices, regarding intensity (which students found challenging) and decision-making (using primary data on people's needs and desires). By progressing though the five stages of the studio, students cumulatively strengthened their understanding of the shortfalls of their owned product, reaching a point where they had confidence and evidence to ideate remedies and improvements. Along the way, students were instilled with a mature perspective of UX/UI for physical and digital solutions and got to learn about design issues across many product sectors by attending their peers' juries.

REFERENCES

[1] Joo H. A Study on Understanding of UI and UX and Understanding of Design According to User Interface Change. *International Journal of Applied Engineering Research*, 2017, 9931-9935.
[2] Norman D. A. *The Design of Everyday Things: Revised and Expanded Edition*, 2013 (Basic Books, New York).
[3] Anderson S. *Seductive Interaction Design: Creating Playful, Fun, and Effective User Experiences*, 2011 (New Riders).
[4] Hassenzahl M. The Thing and I: Understanding the Relationship between User and Product, in M. Blythe, K. Overbeeke, A. Monk, & P. Wright (Eds.), *Funology – From Usability to Enjoyment*, 2003, pp.31-42 (Kluwer Academic Publishers, Dordrecht).
[5] Rowland C. *User Experience Design for the Internet of Things: Why It's More than UI and Industrial Design,* 2015 (O'Reilly Media, Inc).
[6] Kovatcheva E. User Experience Design Models for Internet of Things. *Serdica Journal of Computing*, 2018, 65-82.
[7] United Nations (2021). Sustainable development goal 12. Available at *https://sdgs.un.org/goals/goal12.*

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

ECOLOGICAL ETHICS: TOWARDS AN EDUCATION OF TECHNO-DIVERSITY

Santiago PEREZ[1], Victor PETIT[1], Pauline PICOT[1], Lou GRIMAL[1], Claudine GILLOT[1], Nadège TROUSSIER[1] and Noel FITZPATRICK[2]
[1]InSyTE - Université de Technologie de Troyes, Troyes, France
[2]Technological University Dublin, Ireland

ABSTRACT
The sustainable development is a big challenge for the end of the century due to earth evolution linked with anthropic activities: climate change, resources depletion, health stakes and related problems will change the way we live. Engineering design activities will have to evolve to address in a different way human's needs and also new kinds of needs. The ability to change design practices will depend on the way to think the relationship between human and nature. Ethics has a specific place for that. The proposed paper deals with ecological ethics and discuss the way it can be addressed concerning technology and the way it can be taught in terms of pedagogical methods.
A first part discusses the concept of ecological ethics and proposes to avoid environmental ethics but develop an ethics of the environment. This position enables to defend to transfer the biodiversity characteristic to techno-diversity one in order to ensure adaptation and resilience, future will require for being able to keep health, comfort levels within environmental constraints. The requirement of a pragmatic approach of ethics and ecology is highlighted to be able to face and be conscious of diversity of situations. Then, a discussion on pedagogy of ecological ethics is done and shows how the link must be built with society, into pedagogical activities.

Keywords: Ecological ethics, techno-diversity, pedagogy, engineering design, technology

1 INTRODUCTION
Educators and institutions have been creating, selecting, modifying, and adapting their methods and tools to fulfil their students' needs since education began. Such process is different from institution to institution and even from educator to educator as the geopolitical context poses the limits and opportunities in very specific temporal scales. The current (and growing) global unsustainability crisis has been forcing educators, for at least the last fifty years, to rethink their pedagogical strategies to transfer their knowledge on the causes, consequences, and actions to take to overcome such crisis.
At the core of the unsustainability crisis lies a dualistic mode of thinking of the world we have inherited from past educational systems: this is the divide between humans and nature. Othering nature has turned into the instrumentalization of the natural resources to fulfil the human needs and wants. Such utilitarian perspective has already created not only physical changes to the geological spheres of the Earth, but also has created more unsustainable societies. A reflection about such division was presenting the early 1970's which allowed a change in society, and as the ecological movement grew, the reflection on environmentally sustainable values finally reached the classrooms.
Since then, ethical questions regarding our role as technologists of planet Earth have raised and have been addressed from diverse perspectives. This article describes the transition from environmental ethics to ecological ethics in a context of technology education, that is the transition from a utilitarian perspective of nature to an integrative perspective where the human-nature divide ceases to exist. We describe such transition and root for the implementation of an ecological ethics-based pedagogy to face the unsustainability challenges we face today and those we will face in the future. Using an integrative literature review we will guide the reader through essential concepts, such as "milieu" and "techno-diversity", to understand the importance of an ecological ethics-based education.
This paper is to be taken as starting point to generate a new method of learning, teaching, and practicing ecological ethics in the context of technology education, in especially of engineering design education. Taking technology education as our subject of study, this article starts presenting the method

we are using to discuss the necessary distinction between environmental ethics and ecological ethics, to later move to describe the relationship between ecological ethics and technology. The last part of the article comprehends a discussion on pedagogy of ecological ethics and its link with society and into pedagogical activities.

2 METHODOLOGIES

This article discusses the intersection of technology education and ecological ethics contributing to an integrative literature review on the conceptual and practical developments of the concept of "techno-diversity". A critical analysis is performed contrasting the ontological and epistemological positions of the most relevant English-speaking and French-speaking authors on the subject. The combination of both corpus of knowledge allows to reconcile both approaches in order to propose new perspectives on the pedagogical methods to learn, teach and practice ecological ethics in and outside the classrooms of technological higher education. The aim of this integrative review is to assess, criticize and synthesize the literature on the chosen topic with the intention to propose a new theoretical framework for learning, teaching and practicing ecological ethics in the context of technology education [1].

This paper aims at describing the initial results of several discussions among a multidisciplinary (from philosophy to mechanical engineering and computing sciences) and multigenerational (from doctoral students to well established professors and heads of university departments) team of researchers. The challenge of co-constructing this article (as it has been thought and written using multiple perspectives) demonstrates by itself the importance of generating common methods and frameworks to reflect and discuss on the "milieu" (concept developed below) from where this specific knowledge is produced.

This integrative literature review comprehends four steps: 1) the definition of the structure of the literature review, 2) the literature review itself, 3) a synthesis and a critical analysis of the literature found, and 4) a proposal to further develop the learning, teaching, and practicing of the knowledge learned from the results of the literature review.

For performing the literature review, articles in English and French language are taken into account. A preliminary identification of the main sources has been developed, from which we start to extract the keywords to look for on the different databases. The keyword analysis is particularly complex as similar concepts are expressed with different (non-translatable) words into the other chosen language (e.g.: "milieu", "environment", "technique" ...). Consequently, we put the emphasis on generating an integrative literature review rather than a systematic literature review. The initial keywords being used for such task are "ecological ethics", "technology" and "pedagogy", the three of them translatable into French and English without losing its conceptual meaning. We are exploring those concepts in the following sections, starting with a discussion to show how to move from an environmental ethics perspective to an ecological ethics one.

3 LITERATURE REVIEW

3.1. Environmental ethics

Since the pioneering article "Is There a Need for a New, an Environmental, Ethic?" by Richard Routley in 1973, the subject of study of Environmental Ethics has been growing in the English-speaking world [2]. More academic publications, conferences and scientific journals are being proposed to study the conceptual framework and its application to diverse areas of study. For those last fifty years, environmental ethics scholars developed the idea of intrinsic value of the environment in order to reconcile the divide human-nature to move towards more sustainable pathways.

The idea was to move from an anthropocentric perspective towards one that would grant intrinsic value to natural entities. In its search for intrinsic value (vs. instrumental value), environmental ethics were led to essentialise nature and extract the human from it, thus reinforcing (or at least maintaining) the divide human-nature they initially wanted to reconcile.

The Wilderness movement, a conservation practice born in North America that sees nature as an entity that should be left undisturbed and intact in order to be preserved, is an example of such efforts. Today, even the advocates of *wilderness* have now come to question this notion and mode of protection as typically dualistic, Western and macho [3]. As Philippe Descola explained in the introductory lecture to an IUCN (International Union for Conservation of Nature) meeting, the export of Western models of nature protection (*wilderness* type) and Western modes of recreation has been to the detriment of local populations as well as their environment [4].

At the same time, across the Atlantic, due to geographical and historical reasons, the same notion of wilderness did not make sense. In France there is no such thing as "paysage sans paysan" (countryside without countrymen), the landscapes are neither shaped only by natural forces nor human ones, the "paysages" are the result of the combination of both forces [5]. The dualism human-nature is less strong and tends to form a type of reflection where it is possible to talk about ecology without ever talking about "Nature" or even "environment"; instead, concepts like "culture" and "milieu" are at the centre of the ecological reflection in France. In the next section we will return to expand on the concept of "milieu" and its relationship with the ecological thinking.
It is important to remember that our argument is that the drawback of environmental ethics is not that it looks for the intrinsic value of nature, is that it advocates for a dualistic vision that puts naturalism against humanism. Such position validates the Great Divide between Nature and Culture, creating with it a separation between natural sciences and human sciences (from Serge Moscovici to Bruno Latour [6, 7, 8]) in the education systems. Based on this statement, in the next section we introduce the concept of "milieu" which is central to understand our position on ecological ethics.

3.2. Ecological ethics and technology

As written by Petit and Guillaume [8], Hicham-Stéphane Afeissa [9] divided the philosophy of ecology in two components: ecology of technology (focus on the study of the way the relations of human beings to their environment have been reshaped by technology - Anders, Jaspers, Arendt, Jonas) and ecology of nature (questioning the value to give to nature and ecological and ethical communities -Leopold, Lynn White Jr., Naess, Callicott).
"This divide, Afeissa rightly highlights, is a central distinction to understand the French tradition, which is clearly situated on the former side. In his study of the French tradition of political ecology illustrated by Jacques Ellul, Bertrand de Jouvenel, René Dumont, Serge Moscovici, André Gorz, Cornelius Castoriadis, and Felix Guattari, Kerry Whiteside points that the French debate on ecology is not framed as a strong divide between eco-centric and anthropocentric approaches; it is rather formulated as a critique of the invasion of the techno-sciences in our daily lives [10]. Despite the variety of their respective approaches, none of the French political ecology philosophers separates the question of ecology from the question of technology." [5]. On this statement, Petit warns however that it would be misleading to conclude that an ecology "without nature" would mean an ecology "for technology"; it rather means first and foremost that "Nature" and "technology" articulate each other to shape a "milieu".
The concept of "milieu" has implications different from the concept of Environment. There are two main distinctions: 1) rather than positioning on the outside, "milieu" lies between the inside and the outside"; 2) rather than referring to a shared objective experience, "milieu" refers to the unique experience of a living organism in a place. If the environment is an absolute concept, the milieu is a relative concept. If the environment refers to an external nature, the milieu designates a physical-bio-socio-technical complex. In the next section we will develop the relationship between technology and milieu.

3.3. Philosophy of the technical milieu

"The term "technical milieu" does not separate technology and life, nor the technologies of matter from the technologies of living organisms; nor the ethics of the living from industrial politics; nor the philosophy of the environment from the philosophy of technology." [5]
At the core of Simondon's ecological philosophy lies the following sentence: "learn to consider our techniques as our own children" [11]. This sentence, echoed the thought of the readers of Bernard Stiegler, who knew how to add a little bit more of complexity by adding the concept of "technique" to it, and also to the readers of Donna Haraway [12] who claimed herself: "Make kin, not babies!"; "both groups of intellectuals can be considered as ecologists as they helped deploying the technological responsibility we need to develop the understanding of the dynamics of society and the consequences of its actions" [5].
In France, there is a tradition of ecology of the "technical milieu", represented by authors that go from Gilbert Simondon [13] to Bernard Stiegler [14]. Contrary to environmental ethics, the ethics of the "technical milieu" digs into the politics of life, the politics of "milieu" aligns there with ecological ethics as a critique of the political economy (in this case, that of Bernard Stiegler leads to the contributory

economy and/or the commons). The concept of “milieu” appears as a bridge between the philosophy of technology and the philosophy of nature and positions itself as a way to reflect on the ecological ethics and its political implications. Such form of thinking political ecology has given space for rethinking what we learn and how we learn what we learn. We can follow the example of Geography, that was a pioneer, and the first to understand that there was no political ecology possible without radical pedagogy [15]. In the next section we will develop the role of pedagogy (alternative pedagogy) as a strategy towards an ecological ethics perspective for technical education.

4 THE ROLE OF PEDAGOGY

We cannot go into the history of alternative pedagogies without thinking of the role of the ecological movements in the decade of 1970. Multiple educational reforms were happening simultaneously around the globe transforming our societies. Ivan Illich is a great example of such effort, proposing along Alexander Lenger the “Radical Humanism” [16]. Such a trend openly criticized the society of consumption recently brought by the emerging neoliberal economy in Europe and North America. They were one of the first ones proposing a commitment to reconsider the ways of living, producing and consuming in order to make modern societies compatible with the limited number of natural resources available. Today, such ideas find even more weight into the sustainability studies thanks to the emergence of the Planetary Boundaries and the Doughnut Economics, using interdisciplinary scientific frameworks.

An example of a new pedagogical strategy towards ecological ethics, can be found in Italy in the decade of 1970’s. Global Tools, a multidisciplinary experimental programme of design education, founded in 1973 was seeking to invent a *new school without students to teach*, a school based on the re-appropriation of simple technologies [17]. We could call this a "school of the environment", its pedagogy was based on the self-reflection of the future designers with their surrounding environment, to further think on the impact of the materials and type of architecture to the social and ecological surroundings. What Ugo de La Pietra, one of the founders of Global Tools, called "reappropriation of the environment" is in fact a mix between eco-social and territorial design and the school of bioregionalism, that of Peter Berg or Alberto Magnaghi [18], a school which applies a "pedagogy of the milieu" in the tradition of Célestin Freinet [19].

From an institutional point of view, and to limit ourselves to a more recent period, we can say we moved from environmental education (environmental pedagogy [20]), well established in the 1970-80’s, to education for sustainable development [21], born in the 1990’s and heavily promoted in the early 2000’s by the United Nations and its Millenium Development Goals agenda. However, from 2005 onwards the notion of sustainable development started to be strongly questioned by the field of environmental education (among others), in particular by Lucie Sauvé and her colleagues from the University of Quebec in Montreal [22]. In the logic of the pedagogues to whom environmental education lays claim - Rousseau, Dewey, Freinet, Decroly, Ferrer -, it seems natural that it should take up the concepts of institutional pedagogy, as formulated by Fernand Oury, by transposing it from the classroom to the group of citizens in an active process. Citizens who take an initiative in the city in relation to their environment are a group in institutional pedagogy [23]. This group of citizens moves from the world-as-an-object perspective to the world-as-a-project perspective, according to Philippe Meirieu [24], integrating in some way the notion ecological transition.

We recognize that since the 1970s, the slogan has been the same: create an education that does not separate knowledge from life. It would thus be necessary to integrate the existential dimension of the climate crisis and to develop a pedagogy of transition capable of making students reflect on this intimate dimension of the meaning of life[1]. By combining the pedagogy of the environment and Simondon's ecological ethics, we believe we have an operational concept for a new pedagogical framework around the concept of techno-diversity.

5 SYNTHESIS AND PROPOSAL: TOWARDS TECHNO-DIVERSITY

Teaching ecological ethics is thus to teach relations and co-constructions that come from them and allow for evolution. On this account, the teaching of ecological ethics cannot be a specific class, an independent brick added to curricula without being in contradiction with the stated importance to

[1] See the promotion at HVL - Western Norway University of Applied Sciences - of the concept of "Klimadanning", climate education understood as "Bildung".

relations. Teaching ecological ethics in technological curricula means practicing ethics in technology classes. This implies to give primacy to relations between the different teachings, thus, to break down the traditional frontiers that are built between them.

Breaking down the frontier between natural and human sciences: that means to break down the separation between the human acting subject and the natural observed, studied object. To these objects are substituted the figures of individuals (resulting from individuation) and their milieux, co-constructing together. In concrete terms, to nature or environment is substituted biodiversity; indeed, biodiversity is constituted and evolving by the numerous inter-relations of living beings among themselves and with abiotic elements. From human subjects is taken away their characteristic of being an exception in the face of nature. Human beings, with their knowledge and cultures, are to be considered as well from their relations with biodiversity and also with their technical artifacts. They are to be understood as being co-constructed and in co-construction with their milieux, to which biodiversity and their technical actions and productions participate.

Breaking down the frontier between theory and practice: that implies overcoming the dualism between theoretical, universal knowledge and technical skills and know-hows. That means doing technology in the sense that its etymology suggests, as co-construction of knowledge and techniques. Pragmatically speaking, it seems to us that project-based teaching allows for these dynamics of co-construction.

Breaking down the frontier around universities: what is at stake here is the openness and sharing of knowledge and technology not just to academic actors and students but to society and in the opposite way the openness of academic knowledge and practices to other kinds of knowledge, practices, technologies. This perspective encounters approaches of participatory research and research-action.

From this view of technology, we wish to introduce the concept of “techno-diversity” alongside the concept of technology. For the same reason as why we substituted biodiversity to nature, we intend by this suggestion to focus attention on relations among technological systems but as well on relations between biodiversity and technologies, between human cultures and technologies. Once again just as the concept of biodiversity, we understand “techno-diversity” as pointing as well toward the potentials of evolutions, of transformations of technologies, of technological milieux.

From this background of French ecological philosophy and these thoughts, our research aims, through literature review, to investigate existing practices of teaching of ecological ethics in technology curricula in order to lead a distinctive analysis on them and to participate to future, obviously diversified, technological and teaching practices.

6 CONCLUSIONS

This paper contributes to an integrative literature study on ecological ethics and concludes on the importance of breaking down the dichotomy between human and nature, by developing a deeper knowledge of the concept of “milieu”, and its relevance on the transition towards techno-diverse societies. It also underlines the requirement for a more integrative and open learning spaces, where society is encouraged to co-construct and design ethical and sustainable technologies. We conclude that the concept of “techno-diversity” opens the room for new perspectives in engineering design education.

REFERENCES

[1] Torraco R. J. (2005). Writing Integrative Literature Reviews: Guidelines and Examples. *Human Resource Development Review*, *4*(3), 356–367. https://doi.org/10.1177/1534484305278283

[2] Routley R. Is There a Need for a New, an Environmental, Ethic? *Proceedings of the XVth World Congress of Philosophy* 17th to 22nd September 1973

[3] Callicott J. B. and Nelson M. P. (Eds.). (1998). The great new wilderness debate. University of Georgia Press.

[4] See Philippe Descola, Biological Diversity and Cultural Diversity, *Imagine To-Morrow's World*, Fontainebleau Symposium, Keynote Presentations, Fontainebleau 3-5 November 1998, IUCN, pp. 77-90. https://portals.iucn.org/library/sites/library/files/documents/1999-032.pdf

[5] Petit V. and Guillaume B. (2018). We have never been wild: Towards an ecology of the technical milieu. In French philosophy of technology (pp. 81-100). Springer, Cham.

[6] Moscovici S. and Marić S. (1968). Essai sur l'histoire humaine de la nature (Vol. 1977). Paris: Flammarion.

[7] Moscovici S. (1972). La société contre nature (pp. 10-18). Paris: Union générale d'éditions.

[8] Latour B. (2013). Nous n'avons jamais été modernes: essai d'anthropologie symétrique. La

découverte.
[9] Afeissa H. S. (2009). Qu'est-ce que l'écologie?.
[10] Whiteside K. H. (2002). *Divided natures: French contributions to political ecology*. Mit Press.
[11] Simondon G. (2014). *Sur la technique: (1953-1983)*. Paris cedex 14: Presses Universitaires de France.
[12] Harraway D. (2016) Staying with the Trouble. Making kin in the Chtulucene.
[13] Barthélémy J.-H. and Duhem L. (2022). *Écologie et technologie*. https://www.cairn.info/ecologie-et-technologie--9782373613193.htm?ora.z_ref=cairnSearchAutocomplete
[14] Petit V. (2021). L'écologie de Bernard Stiegler| Cahiers COSTECH.
[15] Jarosz L. (2004). Political ecology as ethical practice. *Political Geography*, *23*(7), 917-927.
[16] Illich I. D. Celebration of Awareness; A Call for Institutional Revolution, 1970.
[17] Petit V. and Bruyère N. *Global Tools (1973-1975). Design, de-projet & low-tech, isdaT* éditions, forthcoming 2022.
[18] Magnaghi A. (2020). The Territorialist Approach to Urban Bioregions. In D. Fanfani & A. Matarán Ruiz (Eds.), *Bioregional Planning and Design: Volume I: Perspectives on a Transitional Century* (pp. 33–61). Springer International Publishing. https://doi.org/10.1007/978-3-030-45870-6_3
[19] Freinet C. (1946). Le Milieu local. *Brochures d'Éducation Nouvelle Populaire*, 24.
[20] Carlot Y. (1981). Pour une pédagogie de l'environnement. *Géocarrefour*, *56*(3), 303–312. https://doi.org/10.3406/geoca.1981.3953
[21] Brégeon J., Faucheux S., Rochet C., Valantin J.-M. and Martin-Chauffier Y. (2008). *RAPPORT DU GROUPE DE TRAVAIL INTERMINISTERIEL SUR L'EDUCATION AU DEVELOPPEMENT DURABLE*. https://www.snes.edu/IMG/pdf_Rapport_Bregeon_29012008.pdf
[22] Lange J.-M. (2012). Barbara Bader et Lucie Sauvé. Éducation, environnement et développement durable: Vers une éco-citoyenneté critique. *RDST. Recherches en didactique des sciences et des technologies*, *6*, 189–191.
[23] Ferry G. (1967). Vers une pédagogie institutionnelle, A. Vasquez et O. Fernand. 1967. *Revue française de pédagogie*, *1*(1), 72–73.
[24] Meirieu P. (2001, November). *Éduquer à l'environnement: Pourquoi? Comment? DU MONDE-OBJET AU MONDE-PROJET*. UNESCO.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

A COLLABORATIVE APPROACH TO DIGITAL STORYTELLING IN HEALTHCARE SETTINGS

Sana BEHNAM ASL[1], Carolina GILL[1], Kelly UMSTEAD[1], Raunak MAHTANI[1] and Kristin P TULLY[2]
[1]College of Design, North Carolina State University, United States of America
[2]Department of Obstetrics and Gynaecology, School of Medicine, University of North Carolina, United States of America

ABSTRACT
Human-centred design in the healthcare setting can include patients' and families' perspectives when researching, designing, and developing interventions. There are multiple qualitative research methods that may be employed to collect user data. Naturalistic video recordings are a powerful means of observing and coding multiple participants and evaluating their interactions over time. However, in the healthcare space, researchers need to be especially intentional with use of video-based data, so the confidentiality of all participants is maintained. Digital storytelling can be used as an effective way to securely share the interaction and emotions directly from the videos so that the content can be disseminated with researchers, clinicians, participants, and policymakers. The goal of the digital stories is to authentically convey observed experiences to a broader audience, including as educational tools for healthcare team member training. This paper presents a collaborative approach to producing animated stories that can be used to promote discussion and action for clinical quality improvement, from our work with birthing parents, their companions, and their healthcare team members in a hospital-based postpartum unit. We describe various considerations related to digital storytelling for provocation, involving multi-disciplinary stakeholders in identifying priority scenarios, and the development process of digital stories. Considering the growing emphasis on patient-centred and equitable healthcare, our reflection may be useful to designers and researchers working with sensitive data, or healthcare educators and administrators seeking ways to build more empathy around human experiences and prompt discussions to improve systems of care.

Keywords: Design research, human-centred design in healthcare, digital storytelling, maternity

1 INTRODUCTION
Designers are increasingly active contributors in the healthcare sector. Design-based research, visualization, and prototyping methods can aid in reimagining systems of care [1],[2]. We are a team of designers and a medical anthropologist working across universities on a large, government agency funded research grant to improve systems of perinatal care. In this context, an interdisciplinary approach is important for generating new knowledge to advance understanding of stakeholder needs in the birthing facility and through postpartum discharge. The design team contributions include leadership with research approach, data collection, analysis, design, and the development of interventions. Through this collaboration, we are learning new ways of effectively conducting research. We are also exploring new applications of our skills, tools, and methods for impact. In this paper, we refer to our collaborators as the 'research partners' and refer to the designers in the multi-university team as the 'design team'.
Our research partner team has collected multi-method data including naturalistic videos of patients and families during their stay on a postnatal unit. Working with social scientists and clinicians, we have applied rigorous methods for qualitative analysis along with gaining an appreciation of the depth of information that is collected through extended observational and audio data. These videos document the raw, unfiltered emotions, reactions, and actions of what participants are experiencing over the course of their postnatal unit stay and care transition. The videos record instances of supportive care, as well as challenging encounters between patients, families, and members of the healthcare team. The recorded behaviours and soundscape provide valuable insight into experiences that are otherwise hard to document. These files could potentially be directly used for training and education of clinicians, however

there are many issues that prevent this application from being an appropriate solution [3],[4]. In the original video format, there is extensive personal identifying information. Furthermore, the length of the videos (even interactions that happen over a 5-minute window) would be too long for teaching purposes, which limited the scope of the video to coding, to identify the context and patterns. These limitations are opportunities for design. Using visualization and digital storytelling, designers can transform the content of the video and audio recordings to animated stories, to elicit empathy, and support stakeholder engagement and discussion in an appropriate and feasible manner.

In this paper, we share a collaborative approach to develop digital stories. The purpose was to provoke discussion amongst healthcare team members. We discuss details of our process with our research partners to identify priority interactions from the videos. We share how to develop digital stories that center the experiences and emotions of patients, while protecting the privacy of all participants. Additionally, we will summarize contributing factors to producing digital stories in the context of sensitive data. We believe this paper can be a resource for students and researchers who are interested in exploring digital stories as an approach to eliciting discussion around complex health-related topics, to improve care.

2 NATURALISTIC VIDEOS AND DIGITAL STORYTELLING

2.1 Naturalistic videos

There is a long-standing interest in using video ethnography and naturalistic videos as a method of observation and as a way of studying complex social and health-related settings [4],[5],[6]. Naturalistic video involves “the video recording or filming of the stream of activity of subjects or observation of real-life experiences in their natural setting, in order to experience, interpret, and represent behaviour” [7],[8]. In the setting of maternity care, Tully and colleagues have successfully conducted this type of research with postpartum families and healthcare team members, and their findings address patient safety and clinical efficiency [9],[10]. Digital storytelling builds on this line of work by illustrating the complexity in healthcare environments through highlighting behaviours, contexts, nonverbal cues or interactions, and environmental factors. The video data provide insight into the nuanced dynamics of clinical encounters, and, critically, into the emotions and reactions of patients and their companions after healthcare members are no longer in the clinical space. This information can help identify the needs and challenges of patients’ experiences, by offering examples of positive interactions between healthcare professionals and patients [11] as well as opportunities for improvement. Practically, participants could consent to naturalistic videos being used as educational material for training healthcare professionals or clinicians [3]. However, that approach would come with challenges. These videos contain sensitive and confidential information. Asking for participant consent to share with those identifiers outside of the study may limit enrolment, affect the extent of participation (turning recordings off/on), and introduce more complexity for ethical management [12]. Additionally, it can be difficult to isolate the information and convey certain aspects of the recorded experience or behaviours to the audiences in a de-identified image or other snippet without distorting the story or striping the event from the fuller context. Meanwhile, traditional formats for sharing qualitative data findings such as written reports or presentations may remove the empathic pieces and fail to convey the critical emotional components or contextual information with the viewers [13].

2.2 Digital storytelling

Digital stories are described as “short visual narratives (approximately 3- to 5-min) that combine and synthesize images, video, audio recordings of voice and music, and text to create engaging and compelling accounts of experience” [14]. This method of conveying information is gaining popularity in healthcare and is used as an educational and health promotion tool for sharing culturally relevant and respectful information and messages [15]. Digital stories and narrative-based videos have been used for various education and behaviour change related purposes around maternity care such as stress management, weight management, or promoting physical activity and healthy lifestyle [13].

2.3 Our study

Following review by the UNC Chapel Hill Biomedical Institutional Review Board (#19-1900), this study involved multiple methods of data collection including 461 hours of naturalistic videos among 15 postpartum patients and their companions in an academic medical center in the south-eastern United States. These videos averaged 31 hours (range 10 to 76) from two camera views in the participants’ postpartum unit rooms. To date, twelve hours of videos recorded from each participant prior to their discharge were analysed. The design team, along with research partners, participated in reviewing and analysing these videos to organize the vast amount of data, cluster codes, and develop further understanding of the context. The purpose of this analysis was to disseminate findings from selected interactions as part of identifying opportunities for improvement. The process of analysing and identifying the emerging themes from videos followed multiple iterative steps including reviewing and coding the videos in 5-minute increments with a behavioural taxonomy, identifying emerging themes, and creating detailed vignettes. Vignettes in this context were summarized accounts of events, participants, situations, and structures, which made it possible to refer to important points in the study of behaviours, perceptions, and attitudes in the context [16]. The vignettes were structured to address the timeframe, environmental factors, interactions between people present in the scene and the documents included memos from the design team and research partners for in-depth understanding of the participants' behaviours or the context. The primary purpose of the video data collection and coding was to generate findings to identify the patterns of behaviour and topics addressed, disaggregated by birthing parent ethnicity-race, to inform systems change and implementation for patient safety. The design team also explored opportunities to use the data for building empathy and engaging healthcare team members as experts on the subject in the education and discussion around possible areas of improvement and reflection. Hence, the design team was aiming to provide healthcare professionals with tools or options that would enable them to ask questions about patients’ experiences, share in-depth insights into the root causes of the issues such as communication problems or biased care, and offer feasible solutions to some of the existing gaps. To move from using images from videos to communicate key moments in stories, which cannot fully convey the details or emotional atmosphere of the interactions, the design team condensed the high volume of content and details into organized, digital stories (Figure 1).

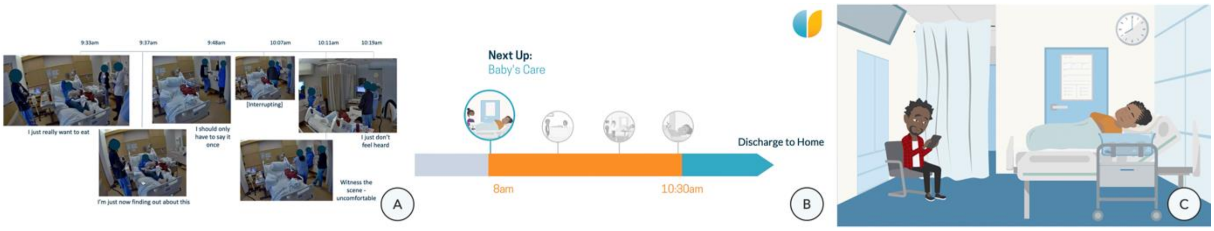


Figure 1. Use of de-identified images selected from video data (A); Use of animations with more comprehensive accounts of events from the video data (B); Digital image from the animation, with characteristics retained from the video data (C)

3 DIGITAL STORYTELLING FOR PROVOCATION

Given the rich datasets generated from naturalistic filming, we believe that digital stories are an appropriate method to convey key elements, with important contextual and emotional elements. Further, digital storytelling can be an effective method to shift power dynamics in research. Creating shareable accounts of participants’ experiences protects confidentiality and may promote the agency of stakeholders. By transforming the data into shareable visualizations, such as digital stories, participants can see that their stories are heard, verified, and represented [14], [17]. Digital storytelling can engage study participants and other stakeholders around their lived experiences. Using digital stories as a provocative and tangible artifact for discussion in this context invites people to think, question, and re-evaluate the current reality around postpartum care [18]. Provocative design challenges the status quo and stimulates discussion. In this sense, “asking questions is as important as solving a problem” [19]. As such, asking prompting questions at the end of animated stories can enable discussion around gaps in care or opportunity areas for systems improvement. Also, digital stories as provocative tools allow the ‘researcher’ to select a perspective on a scene, emphasize on an experience, or zoom in and out on specific details of a situation observed and control the narrative. Multidisciplinary, diverse teams are therefore essential for determining the appropriate focus and messaging.

4 DEVELOPING DIGITAL STORIES IN THE POSTNATAL UNIT

Our team took a collaborative approach to develop digital stories that accurately depicted examples or real situations. Clinicians and other research partners identified priority interactions from the video and audio data, for the design team to build digital stories that could elicit conversations and discussions among healthcare professionals. We reflected on several questions through the process of making each iteration of the digital stories. These were as follows:

1. How can storytelling and digital stories elicit conversation and enable healthcare professionals to engage in a discussion around system strengths and opportunity areas?
2. How can we emphasize specific dimensions of the interaction, experience, or setting to bring attention to one issue at a time?
3. How can we leverage the richness of the naturalistic videos to share stories of/from the postnatal unit while protecting participants' confidentiality?
4. What are the best practices and technical considerations for creating narratives that are engaging while the context, behaviours, and dialogue are kept intact?

To address these questions and create actionable digital stories we followed specific steps, including (1) defining the scope, (2) shaping the style, and (3) technical considerations.

4.1 Defining the scope

To identify the appropriate examples, in collaboration with our research partners, we had to decide what sections of the original videos could provide the most valuable insights from the birthing parent and companion perspectives. Together, we prioritized the content. To facilitate this process, the design team developed a worksheet that allowed the research partners to select and summarize sections of the video and note examples that they felt were worth discussing with the healthcare community around the topics of communication, language barriers, racial impact, and pain management. Using the worksheets and by referring to the vignettes, the design team and research partners collaboratively defined a specific objective for each digital story. Some of the prompts used in the worksheets for the research partners to identify effective examples from the original videos and subsequently craft a message were as follows:

- Share some details about what happens in your chosen story (include any important actions, quotes, or sounds that are most descriptive or stand out; include IDs and time window)
- What is the goal of the digital story?
- What is the main message of the digital story?
- What background information does the viewer need to know?

The design team used the information from worksheets plus the vignettes to develop the animated videos. The process remained iterative because of the level of complexity in framing the context and finding the appropriate balance with the details to include in the digital stories. In some cases, this meant simplifying the story by removing some details while maintaining our interpretation of its essence. For example, replicating the exact conversation from a scene in the video without clarifying the context could have been confusing to the viewers or affected the accuracy of the information. Additionally, providing too much information or presenting a long video could overwhelm the viewers and distract them from understanding the main points. Thus, we strove to reduce the content we determined to be tangential to enable the viewers to focus on a certain topic. Additionally, we decided to use a narrator to present a short overview of the setting and context at the beginning of the story. The narrator approach was also included at the end to introduce questions - to invite the audience to reflect and engage around the problem/experiences depicted in the digital stories.

4.2 Shaping the style

Two main considerations in shaping the visual style of the digital stories were the design of environment and maintaining concordance with characters' appearance, mannerisms, and voices. In designing the environment, we initially aimed to depict the setting in a precise manner but ultimately opted for a comparatively simplified or 'minimal' style to emphasize the characters and their interactions (Figure 2). Additionally, we wanted to ensure that the appearance and sound of characters in the digital stories appropriately represented the study participants, including with their skin tones, body shapes, and clothing styles. Similarly, for the voice-overs to use in the digital stories, we recruited our research partners who shared racial/ethnic characteristics with the story characters. We asked them to review the original footage before participating in the voice-over recording sessions, to promote their understanding of the emotional context, tone, and feeling of the conversations, and record the dialogues that were adapted from transcriptions of the audio with attention to the original event and experiences.

Figure 2. De-identified video footage (A); precise style of the environment (B); final minimalistic environment (C)

4.3 Technical considerations

Having the right tools and technologies to develop the digital stories also plays an important role in the development process. Producing high-quality digital stories can be time-intensive and the software can also be expensive. The designers leading development of the digital stories did not have prior experience in making animations or digital stories. Hence, there were two main considerations for the choice of the software: the ease of use and possibility of collaboration. We compared potential software such as Adobe Premier [20], Adobe After-Effects [20], and selected an online animation software Vyond [21]. Vyond allowed the designers to work collaboratively, had a short learning curve, and did not need learning complex editing features. This platform had a series of built-in visual styles, flexible settings and features for character design such as pre-set actions or expressions that allowed us to produce the digital stories efficiently. Also, these features helped us maintain the ethnic, cultural, and physical features of the participants. Using this platform, we were also able to create a library of visual assets which reduced the production time, particularly as we scaled our production to create multiple videos sharing common assets.

5 REFLECTION AND DISCUSSION

The process of developing digital stories to depict highlights of naturalistic videos proved to be more complex than we initially anticipated. As we moved through an iterative process, maintaining the integrity of the original story was challenging and time-consuming. We balanced being precise with documented the participant experiences with adapting for useful/effective stories as standalone artefacts. Despite the challenges, our iterative production process in collaboration with the research partners, proved to be successful in ensuring the digital stories aligned with our goal to have discussions around interactions, communication, and safety during maternity care, as part of integrated work towards our project's overarching goal of improving maternal and infant safety.

We designed these videos for the specific context of health and maternity care. However, insights from our process can be transferred to other settings where researchers work with sensitive health-related data or work towards provoking discussion around complex topics. We suggest the following guidelines that other teams may benefit from considering:

- Defining the overarching purpose, message, and storytelling prompts
- Engaging relevant stakeholders during the development process
- Analysing the data and prioritizing the most important themes
- Reducing complexity by keeping the most essential or focal elements of the story
- Understanding the resources and available technologies (video and audio)
- Defining the style to emphasize essential elements of the story
- Developing prototypes to test the storyline and visual elements
- Maintaining flexibility and remaining open to feedback
- Following an iterative process to refine the digital stories

While our goal of designing and developing these videos was to initiate discussion among healthcare professionals and providers, we also presented versions of the digital stories to the general public through exhibition opportunities – this is another avenue for us to provoke discussion and motivate action around the problems surrounding systems of postpartum care. We acknowledge there is a need for testing and evaluating the digital stories we produced, for their effectiveness as meaningful materials to facilitate discussions among healthcare team members – this would enable us to further refine our process in developing the digital stories. Considering the time-consuming production process, we anticipate additional limitations and challenges in scaling production to create digital stories representing the large range of problems and experiences in our focus area, beyond those we have addressed in the digital stories so far.

This project is supported by grant number R18HS027260 from the Agency for Healthcare Research and Quality. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

REFERENCES

[1] Partridge R. (2017). Understanding the roles of the designer in health care: A practice-based study into supporting adolescents with long-term conditions. *The Design Journal*, *20*(4),523-532.

[2] Tsekleves E. and Cooper R. (2017). Emerging trends and the way forward in design in healthcare: an expert's perspective. *The Design Journal*, *20*(sup1), S2258-S2272.

[3] Asan O. and Montague E. (2014). Using video-based observation research methods in primary care health encounters to evaluate complex interactions. *Informatics in primary care*, 21(4), 161.

[4] Iedema R., Forsyth R., Georgiou A., Braithwaite J. and Westbrook J. (2006). Video research in health. *Qualitative Research Journal*.

[5] Iedema R., Long D., Forsyth R. and Lee B. B. (2006). Visibilising clinical work: Video ethnography in the contemporary hospital. *Health Sociology Review*, *15*(2), 156-168.

[6] Asl S. B., Naeini H. S., Ensaniat L. S., Khorshidian R. and Alipour S. (2014). Injury Prevention among Construction Workers: A Case Study on Iranian Steel Bar Bending Workers. *International Journal of Industrial and Manufacturing Engineering*, 8(8), 467-470.

[7] Pink S. (2020). *Doing visual ethnography*. London: Sage.

[8] Schaeff J. H. (2009). Videotape: New techniques of observation and analysis in anthropology. *Principles of visual anthropology*, *255*.

[9] Tully K. P. and Ball H. L. (2012). Postnatal unit bassinet types when rooming-in after cesarean birth: Implications for breastfeeding and infant safety. *Journal of Human Lactation*, *28*(4):495-505.

[10] Taylor C. E., Tully K. P. and Ball H. L. (2016). Night-time on a postnatal ward: experiences of mothers, infants, and staff. In F Dykes, R Flacking (Eds). *Ethnographic Research in Maternal and Child Health*. Routledge Press: New York, NY (pp. 117-140).

[11] Bensing J. M., Verheul W. and Van Dulmen A. M. (2008). Patient anxiety in the medical encounter: a study of verbal and nonverbal communication in general practice. *Health education*.

[12] Everri M., Heitmayer M., Yamin-Slotkus P. and Lahlou S. (2020). Ethical challenges of using video for qualitative research and ethnography. *Challenges and Solutions in Ethnographic Research*, 68.

[13] Evans W. D., Harrington C., Patchen L., Andrews V., Gaminian A., Ellis L. P. and Napolitano M. A. (2019). Design of a novel digital intervention to promote healthy weight management among postpartum African American women. *Contemporary Clinical Trials Communications*, *16*, 100460.

[14] Gubrium A. (2009). Digital storytelling: An emergent method for health promotion research and practice. *Health promotion practice*, *10*(2), 186-191.

[15] Idema R., Carroll K., Collier A., Hor S., Mesman J. and Wyer M. (2010). *Video-Reflective Ethnography in Health Research and Healthcare Improvement*. Boca Raton: CRC Press.

[16] Cueva M., Kuhnley R., Revels L., Schoenberg N. E. and Dignan M. (2015). Digital storytelling: a tool for health promotion and cancer awareness in rural Alaskan communities. *International journal of circumpolar health*, *74*(1), 28781.

[17] Hughes R. (1998). Considering the vignette technique and its application to a study of drug injecting and HIV risk and safer behaviour. *Sociology of Health & Illness*, *20*(3), 381-400.

[18] Lambert J. (2006). Digital storytelling. *Capturing lives, creating community*, 2006.

[19] Ozkaramanli D. and Desmet P. (2016). Provocative design for unprovocative designers: Strategies for triggering personal dilemmas. In *2016 Design Research Society 50 Anniversary Conference* (pp. 2001-2016). The Design Research Society.

[20] Adobe. Accessed: March 12, 2022. [Online]. Available: *https://www.adobe.com/products/catalog.html*

[21] Vyond.com. Accessed: February 23, 2022. [Online]. Available: *https://www.vyond.com/*

INVESTIGATING THE USE OF AUGMENTED REALITY IN THE DESIGN FOR ADDITIVE MANUFACTURING

Gustavo MELO, Rohit RAVI, Lucas JAUER and Johannes Henrich SCHLEIFENBAUM
Chair for Digital Additive Production, RWTH Aachen University, 52074 Aachen, Germany

ABSTRACT
Additive Manufacturing (AM) has a great potential of disrupting product design and supply chains in many industries by means of its unique capabilities when compared to traditional manufacturing. A wide range of designers would like to take advantage of AM to improve their designs, but they need assistance in learning and breaking out of their conventional manufacturing mindset in the early phases of the design process. Therefore, this study explores the role of Augmented Reality (AR) as a tool for visualization of 3D models to be printed using AM. Specifically, it aims to enhance the learning experience of the existing Design Heuristics for Additive Manufacturing using Design for Additive Manufacturing (DfAM) cards which are focused on transferring early design phase-relevant AM-process independent knowledge and capabilities to both novice and experienced designers. In this study, we propose a modification of DfAM cards to include AR markers into the existing card design and hence provide a comprehensive visualization along with the information about heuristics and examples on the DfAM cards. This helps the user to understand the real-world structure of the final printed product before it is being printed. The cross-platform game engine Unity is used for developing the AR models for this research. We also investigate the advantages that Augmented Reality can provide as a visual interface. An expert review is conducted to obtain feedbacks on the developed application and the new design of the cards.

Keywords: Augmented reality, additive manufacturing, DfAM, design, visual learning

1 INTRODUCTION
AM represents a set of technologies that enable physical components to be created from virtual 3D models by building the component layer by layer until the part is complete. AM has been emerging strongly in recent years. Growth in machine sales and increased numbers of equipment manufacturers show how the AM market has been expanding [1]. AM enables the fabrication of products with highly complex design with various functionalities [2-3]. However, design engineers often think in the restrictions imposed by conventional manufacturing or link AM to unrealistic expectations [2]. The awareness of the potentials and restrictions of AM has not been effectively pushed in the minds of design engineers. Moreover, the adoption of AM in the design process often fails due to a status quo in design or limited knowledge of the responsible employees. A sustainable adoption of AM is only possible by means of complete mindset shift of designers and design engineers from conventional manufacturing towards AM [3].
Literature has dealt with education in the field of AM for almost a decade. Since AM has been of growing interest, Geraedts et al. [4] investigated the role of AM in the light of design engineering in three domains: business, research, and education. Loy [5] puts this conclusion into a different perspective, by stating that design educators face a number of different challenges in terms of AM in design education. Pei et al. [6] use a survey to investigate the impacts of early exposure with AM in engineering education and find that a “think-additive” approach early on leads to a full facilitation of the benefits of AM. Simpson et al. [7] and Prabhu et al. [8] conclude in a similar way. In the light of previous and current research, the literature has not investigated the use of immersive technology as Augmented Reality (AR) for the knowledge transfer and education in the field of Design for AM (DfAM).

Currently, DfAM cards are used as a delivery format for transferring AM knowledge. DfAM consists of a set of design methods which optimize the functional performance of the part as much as possible, but also its cost, reliability, and other product life-cycle considerations. Several techniques are used today, such as generative design, topology optimization or the creation of lattice structures.
Visual instruction is an effective pedagogy to improve student learning and performance, which encourages them towards deep learning. Spatial cognitive ability is an important indicator of how much a student benefits from visualization. Visuals in two dimensions require a higher spatial cognitive ability to comprehend, while visuals in three dimensions do not require spatial ability. Visual instruction may be particularly useful for design students due to their training in spatial ability over the years [9].
Against this background, the main objective of this paper is to answer the following research question: "Can AR be used as a tool to enhance the learning of additive manufacturing knowledge using DfAM cards?". Therefore, we aim at using Augmented Reality to upgrade the transfer of AM knowledge and to supplement design learning through 3D visualizations.

2 STATE OF THE ART

Additive manufacturing (AM), also known as 3D printing, is a transformative approach to industrial production that enables the creation of lighter, stronger parts and systems by using computer-aided-design (CAD) software or 3D object scanners to direct hardware to deposit material, layer upon layer, in precise geometric shapes. AM processes use data from a CAD file which is then, in most of the cases, converted to a standard triangle language (STL) file. During this process, the CAD software drawing is approximated by triangles and sliced, containing the information for each layer that will be printed. AM offers unique capabilities when compared to conventional manufacturing techniques, namely shape, material, hierarchical, and functional complexity. It is yet, another technological advancement made possible by the transition from analogue to digital processes. In recent decades, communications, imaging, architecture, and engineering have all undergone their own digital revolutions. Now, AM can bring digital flexibility and efficiency to manufacturing operations [11].

2.1 DfAM methods

DfAM refers to the process of creating a product design that takes advantage of the unique capabilities of AM. DfAM also adheres to the process constraints of the AM technology that will be used to manufacture the product. DfAM is defined by Gibson et al. [12] as the "synthesis of shapes, sizes, geometric mesostructures, and material compositions and microstructures to best utilize manufacturing process capabilities to achieve desired performance and other life-cycle objectives. DfAM methods can generally be categorized as one of four types: general, design guidelines, computational tools, and opportunistic. Opportunistic DfAM methods focus on informing designers about and inspiring designers to utilize the four unique capabilities of AM in their designs. These unique capabilities are namely [12]:

- Shape Complexity: it is possible to build virtually any shape.
- Material Complexity: material can be processed one point, or one layer, at a time as a single material or as a combination of materials.
- Hierarchical Complexity: features can be designed with shape complexity across multiple size scales.
- Functional Complexity: functional devices (not just individual piece-parts) can be produced in one build.

2.2 Design heuristics

Design heuristics or principles are a popular way of communicating design guidance because they are easy to use, quickly communicate the necessary information and are prevalent across a variety of design domains. Implementing design heuristics or design principles is a good approach for providing early-phase Additive Manufacturing knowledge.
A heuristic is defined as "a context-dependent directive, based on intuition, tacit knowledge, or experiential understanding, which provides design process direction to increase the chance of reaching a satisfactory but not necessarily optimal solution", whereas a principle is defined as "a fundamental rule or law, derived inductively from extensive experience and/or empirical evidence, which provides design process guidance to increase the chance of reaching a successful solution" [13]. Design heuristics and design principles are similar to each other, but heuristics typically use less empirical evidence for

derivation, are more general (i.e., higher-level), are less formal, and are usually more prescriptive as opposed to descriptive [13].

2.3 DfAM cards

DfAM methods must be delivered to the user in a format that is easy to use and understand. However, it should also fully communicate the desired information. DfAM cards, also mentioned in literature as DHAM (Design Heuristics for Additive Manufacturing) cards, were found to be an effective delivery format of AM knowledge through several literature surveys and qualitative evaluation from industry workshops [14]. DfAM cards that contain multiple modalities were developed by Blösch-Paidosh [14] and their layout is based on synthesis of 77 design heuristics. In the developed cards, there are seven different pieces of information:

1. Design Heuristic
2. Design Heuristic Number
3. Description of the Design Heuristic
4. Design Heuristic Category
5. Image of an Abstract Example
6. Image of an Example from Industry or Literature
7. Corresponding Short Description of the Real-World Example

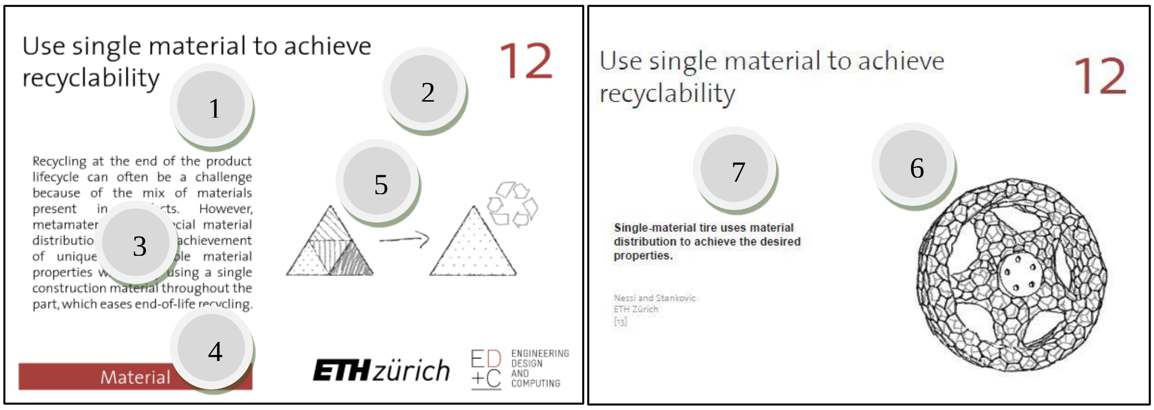


Figure 1. Front and Rear end of the DfAM card developed by Blösch-Paidosh [14]

DHAM delivery format is multi-modal because it is believed that a combination of modes, particularly the inclusion of objects, is the best way to communicate opportunistic additive manufacturing knowledge to the user and to best assist them during the creative tasks required in the early stages of the design process [14]. Text, abstract examples, concrete examples, and objects should all be used. The 2D modalities are organized as a series of cards (one for each DHAM), as using a card deck structures the information in a useful and understandable way, while also making the DHAM easy to use and learn how to use. Furthermore, an accompanying object for each DfAM card was created because it has been demonstrated that providing information in a variety of formats is beneficial, and that doing so helps structure the information in a useful and easy-to-understand manner. Figure 1 shows an example card with all the corresponding aspects labelled. The abstract example on the front of the cards keeps users from becoming fixated on a specific example, while the real-world example solutions on the back help them understand the heuristic in a design context.

2.4 Augmented Reality applications

AR applications can be marker-based, which means that the camera must detect a specific visual cue for the software to retrieve the correct information, or markerless. The most obvious distinction between marker-based AR and markerless AR is whether a marker is required, which directly determines how the relative position relationship between virtual objects and the real world is set. The most important step in developing a marker-based AR application is identifying a marker using the extracted features and superimposing virtual objects in the real environment.

Specific algorithms are required to extract features from the marker and recognize it in order to identify it. Currently there are several AR SDKs on the market that provide these types of algorithms to developers. The algorithms in the AR SDKs can detect and extract features from a marker automatically.

The relative position relationship in the development environment can be set after the virtual objects are linked to the marker (e.g., a 3D development engine or development scripts). The real position of the augmented objects can be changed in the development environment by changing the relative position relationship between the virtual AR camera (which represents the screen on which the augmented objects will be displayed), objects, and markers [15].

3 METHOD

3.1 New design of the DfAM cards

The design of the cards is now improved with the inclusion of the AR marker without manipulating the existing design. Therefore, the current heuristic card was upgraded to a foldable card with the AR marker added to the inner part. The AR marker is scanned with the help of an application which is developed in Unity Game Engine.

3.2 AR Visualization

For this research project, the AR visualization has been created using Unity. The 3D models of the design heuristics were imported to Unity and suitable image targets which displayed robust detection characteristics were chosen as the markers. Image Targets are images that can be detected and tracked by the Vuforia Engine. The Engine detects and tracks the image by comparing natural features extracted from the camera image to a known target resource database. Once the image target is detected, the Vuforia Engine will track the image and seamlessly augment the corresponding content using image tracking technology.

Vuforia Engine is an Augmented Reality software development kit (SDK). Developers can easily add advanced computer vision functionality to any application, allowing it to recognize images and objects as well as interact with real-world spaces. Vuforia Engine supports the creation of AR apps for Android, iOS, Lumin, and UWP devices. The Vuforia Developer Portal is utilized for generating license keys and for creating suitable image targets. A license key is generated using the license manager of Vuforia developer portal. This license key is then copied from the portal and pasted into the project in Unity. An Image target is created using user's Vuforia target manager portal. For this, an image with good features (rich in detail, good contrast, no repetitive patterns) is identified and then imported to Vuforia target manager. Files which give a 5-star rating are preferred for best results. A database is generated using the Vuforia target manager which is to be imported into Unity.

4 RESULTS

The application was installed on a Tablet with Android version 9.0 and was used to scan the AR markers printed on the newly developed cards to display the 3D models related to the heuristic. The new foldable design of the DfAM card is shown in the figure 2a. In the figure 2b, AR visualization for different design heuristics for Additive Manufacturing is demonstrated.

A YouTube demo video showing the AR visualiSation can be viewed under the following link: https://youtu.be/9MxIvgcQ18k.

The models were tested and evaluated by four design experts in Additive Manufacturing and Design Education field. The design experts were chosen as the candidates to obtain a professional outlook and opinion about the application, since they had experiences ranging from 3-10 years in the field of the Design of Additive manufacturing products and DFAM education. The candidates were familiar with AR experiences through gaming, interior design simulation and using AR for recreating internal parts of machines etc. The application was tested by the experts on an android tablet device with android version 9.0 and their feedbacks were assimilated. A questionnaire was prepared which focused on the feedback about ease of use & interface of the application, design of the new cards and using AR for design and for knowledge transfer.

Figure 2a. The new foldable design of the card with the exterior heuristic side (left) and interior side with AR marker (right)

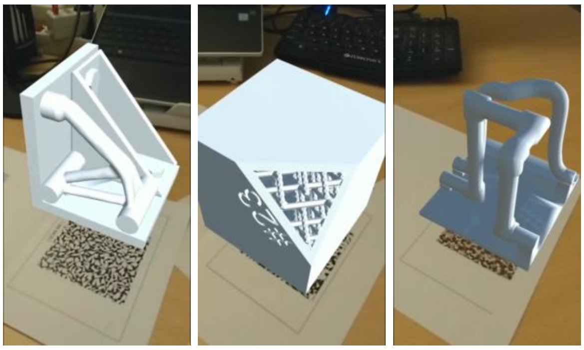


Figure 2b. Visualization via AR application of design heuristics topology optimization (left), lattice structure (middle), part consolidation (right)

The questionnaire is as follows:

1. Have you used AR apps before? If yes, could you mention details regarding the area of use.
2. Do you think AR is a useful tool for design? Can it be used to improve deign education? What are your thoughts?
3. In your opinion, what are the pros and cons of using AR as a tool to improve the learning experience in Design for AM?
4. Does this AR application help to understand the design heuristics (design principles) better? Express your opinion.
5. Based on your experience with the “AR 4 DfAM”, please evaluate the following parameters:
    - Ease of use of application
    - Interface of application
    - New design of DfAM card
6. Do you have suggestions to improve this idea or a complementary approach for making AM knowledge transfer better?

The experts had a positive outlook on the scope of AR and its applications as a demonstration tool and using it for improving design education. Regarding the use of AR for design, they were of the opinion that it can be used as a visual tool for exhibiting design and 3D models to clients. The experts found the AR visualization to be quite useful and helpful in understanding the structure of the complex 3D models and for comprehending the design principles. All candidates were satisfied with the ease-of-use and interface of the application and found the transitions from one marker to the other was smooth and seamless. They agreed that using AR for supporting design education would help in making self-learning an enjoyable experience and would be a great tool for teaching additive manufacturing principles to novices and beginners. They also provided some valuable suggestions like the idea of adding an AR marker for creating a visualization for conventional models along with the optimized additive manufacturing models, in order to make a comparative study. They also proposed to incorporate colours to highlight the optimized 3D model parts to make the visualization more appealing. The feedback and suggestions were quite insightful, and those inputs were evaluated and included into the new version of the app.

5 CONCLUSIONS

This research project aimed at enhancing the learning experience of Additive Manufacturing knowledge for novices by adding an augmented reality visualization to existing design heuristic cards. It can be described as a modification or extension to the DfAM cards where the cards are re-designed as foldable cards with the AR marker added to it. The AR visualizations were created using Unity and it was built and tested in Android 8 & 9 versions.

The AR visualization helps the user to understand the real-world structure of the final product to be printed and can be very useful for demonstration and learning purposes. Visuals play a crucial role in design education and the idea of upgrading to a visual platform from a paper-based platform were appreciated and well received by DfAM experts. Since the study was carried out with 4 candidates who were design experts, a similar way of thinking was observed from their opinions which could be different from a non-expert candidate group. Investigation with this type of group is to be carried out in the near future. Nevertheless, the current validation of the developed app provided astute observations and suggestions for improving the user experience.

This research project will be the basis of further research in developing a head mounted display visualization for enhancing DfAM knowledge transfer. Upgrading to head mounted display (for e.g., Microsoft Hololens) would hence make it a state-of-the-art technology used for DfAM knowledge transfer.

ACKNOWLEDGeMENTS

The authors would like to thank the Federal Ministry of Education and Research of Germany (BMBF) for funding the research in the project Industrialization and Digitalization of Additive Manufacturing for automobile series production (IDAM, grant number 13N15084) and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) for funding under Germany´s Excellence Strategy – EXC-2023 Internet of Production – 390621612.

REFERENCES

[1] Campbell I., Diegel O., Huff R., Kowen J. and Wohlers T. Wohlers report 2021: *3D printing and additive manufacturing state of the industry*, Wohlers Associates (2021).

[2] Schmelzle J., Kline E. V., Dickman C. J., Reutzel E. W., Jones G. and Simpson T. W. (Re) Designing for part consolidation: understanding the challenges of metal additive manufacturing, *Journal of Mechanical Design* 137 (2015).

[3] Ahuja B., Karg M. and Schmidt M. Additive manufacturing in production: challenges and opportunities, Laser 3d manufacturing II Vol. 9353 *International Society for Optics and Photonics* (2015).

[4] Geraedts J., Doubrovski E., Verlinden J. and Stellingwerff M. Three views on additive manufacturing: business, research and education, in: I. Horváth, A. Albers, M. Behrendt, and Z. Rusák, Eds (Ed.), *Ninth Int. Symp. Tools Methods Compet. Eng.*, 2012, pp. 1–15.

[5] Loy J. The future for design education: preparing the design workforce for additive manufacturing, *International Journal of Rapid Manufacturing* 5 (2015) 199–212.…

[6] Pei E., Minetola P., Iuliano L., Bassoli E. and Gatto A. Impact of additive manufacturing on engineering education–evidence from Italy, *Rapid Prototyping Journal* (2015).

[7] Simpson T. W., Williams C. B. and Hripko M. Preparing industry for additive manufacturing and its applications: Summary & recommendations from a National Science Foundation workshop, *Additive Manufacturing* 13 (2017) 166–178.

[8] Prabhu R., Miller S. R., Simpson T. W. and Meisel N. A. The Earlier the Better? Investigating the Importance of Timing on Effectiveness of Design for Additive Manufacturing Education, in: *ASME 2018 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 2018.

[9] Lau S.-K., Joshi N. & Pang M. (2021). Visual Instruction to Enhance Teaching of Technical Subject to Design Students. *International Journal of Art & Design Education*. 40. 10.1111/jade.12343.

[10] *What is Additive Manufacturing?* Available: https://www.ge.com/additive/additive-manufacturing [Accessed on February 12, 2022].

[11] Gibson I., Rosen D. and Stucker B. (2015). *Design for Additive Manufacturing. In Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing* (2nd ed., pp. 399-435). New York, New York, USA: Springer.

[12] Fu K. K., Yang M. C. and Wood K. L. (2016). Design Principles: Literature Review, Analysis, and Future Directions. *Journal of Mechanical Design*, 138(10). doi:10.1115/1.4034105.

[13] Blösch-Paidosh A. and Shea K. (2017). *Design Heuristics for Additive Manufacturing.*

[14] Cheng J., Chen K. and Chen W. (2017). *Comparison of marker-based AR and markerless AR: A case study on indoor decoration system*. 10.24928/JC3-2017/0231.

ONLINE PARTICIPATORY TOOLS IN CLASSROOM AND RESEARCH SETTINGS

Raunak MAHTANI[1], Carolina GILL[1], Kelly UMSTEAD[1], Sana BEHNAM ASL[1] and Kristin P TULLY[2]
[1]College of Design, North Carolina State University, United States of America
[2]Department of Obstetrics and Gynaecology, School of Medicine, University of North Carolina at Chapel Hill, United States of America

ABSTRACT
Collaborative engagement in research and education often involves the need for a shared workspace among participants. With improved web-based technologies, and limitations to in-person interactions presented by the COVID-19 pandemic, educators and researchers need to adapt their methods and tools to support meaningful engagement. We reflect on our experiences and iterative experiments navigating these challenges in the domains of design education and design research. As design educators, our team utilized various online platforms including video conferencing, whiteboards, spreadsheets, surveys, and polling tools, to support teaching and student collaboration. As design researchers working in the domain of maternal healthcare, we borrowed from our experiences in the classroom and applied some of these tools to our research with patient and clinician stakeholders, to support data collection and research team collaboration. In this paper, we elaborate on these experiences by drawing from examples across our teaching and research activities to share key strengths, challenges, and considerations of the online workspaces, with a particular focus on online whiteboards. We compare the two settings and reflect on barriers and facilitators of online engagement specific to these. Lastly, we suggest recommendations for designing online activities and selecting appropriate online tools based on the objective, contextual needs, and the affordances of tools and activities. Our findings may support decisions of educators, designers, and researchers in planning for online engagement.

Keywords: Participatory design, participatory research, design education, design research, technology, design for healthcare

1 INTRODUCTION AND LITERATURE REVIEW
Traditionally, activities in the domains of design education and research have largely relied on methods of in-person engagement and collaboration. The work and culture in design programmes are often built around the of a ‘studio’ space. In research, particularly in qualitative work, the focus of engagement has been in-person, with artefacts, and/or observational in the naturalistic setting of the participants. With the current technological developments of online tools and with pressing global issues such as the COVID-19 pandemic, various sectors have had to adapt their processes. Education and research are no exceptions, leading to a necessary reconceptualizing of the classroom, studio, and the research site. Both sectors have utilized online tools to support collaboration, communication, data gathering, and analysis.

1.1 Usage of online tools in education
In the education space, utilizing online tools brings various general advantages. Integrated platforms such as Moodle [1] are now prevalent in many educational settings. Educators can closely monitor student progress through online wiki platforms such as MediaWiki [2] and Google Docs [3] and are able to provide more detailed feedback than possible by non-technology supported means [4]. Yet, a nuanced picture considering the context of usage and specific attributes of the tool offers a clearer picture. Hidayanto and Setyady’s analysis of technological characteristics driving usage of collaborative tools highlights the importance of ease of use and perceived usefulness of technologies [5]. Hsu and Shiue analysed the relationship between various ‘presences’ at play in an interdisciplinary project utilizing Google applications, based on a Community of Inquiry framework, which identifies core elements of teaching presence, social presence, and cognitive presence to sustain purposeful inquiry and meaningful

collaboration [6], [7]. Hsu and Shiue's findings suggest the positive influence of social presence on cognitive presence, highlighting the impact that synchronous aspects of online communication can have on effective engagement. A study of postgraduate service and interaction design education by Lee et al. offers a further detailed understanding of technological affordances driving the quality of interactions [8]. In their study of Slack [9] as a platform in the classroom, affordances such as the ability to create multiple discussion channels, visibility of digital avatars, and the focus on the communicative exchange were connected to the conversational and flexible quality of interactions the students had.

1.2 Usage of online tools in research

Due to the COVID-19 pandemic and technological developments, researchers also have had to adapt to using online platforms, particularly for communication and data collection. Some of the reflections of researchers in this space have included using these technologies in Community Based Participatory Research (CBPR) [10], interview and document analysis study [11], and focus groups [12]. The reflections of these various researchers, coupled with Pocock et al.'s [13] methodological commentary, suggests that there are both advantages and disadvantages across all aspects of research to utilizing online tools. For instance, by virtue of utilizing online tools, access to participants may be increased for populations across geographic distances yet may be limited to participants with internet availability and skill. Considering an example of ethical issues, privacy for participants may be supported through the flexibility of online platforms, yet it may be compromised if the participants do not have access to a private physical setting in which to attend the research activities. The studies also reflect on how the researcher's role had to evolve, such as the role of the co-moderator of activities to involve addressing potential technological and logistical difficulties.

2 OUR EDUCATION AND RESEARCH EXPERIENCES

2.1 Education

Two authors are educators at North Carolina State University (NCSU), which is a large research university in the South Eastern United States. The findings of part of this paper are based on experiences in a graduate level industrial design studio course. The students in this course come from various disciplinary backgrounds and gain an experiential understanding of the design thinking process while refining fundamental skills learned in prior courses such as research, sketching, and prototyping.

The graduate industrial design studio course operated in the academic year 2020-21. It was conducted remotely, with the students and faculty interacting with each other in online environments. The course is distinct from typical university lectures as it meets for a longer duration - three to four hours per session, between two to three times a week. The course requires interaction-focused experiential work where students test, observe, experiment, or practice industrial design in a hands-on environment. The assignments for the course involved the students working both individually and in groups.

2.2 Design research

We are also researchers in the Postnatal Patient Safety Learning Lab, a multi-university research project sponsored by the Agency for Healthcare Research and Quality (R18HS027260). Our team is distributed across The University of North Carolina at Chapel Hill, The Ohio State University, and NCSU. The project aims to improve maternal and infant postpartum care through improved safety, equity and overall quality of care. Our role as researchers has involved generating new knowledge with multiple groups of stakeholders including birthing parents, companions, and healthcare professionals. We are co-developing solutions with these participants, in coordination with our research partners who are experts in domains including systems engineering, nursing, paediatrics, and implementation science.

In our research project, we have operated by virtual means in collaboration with research partners and stakeholders. Throughout our research, our goal is to better understand the experiences and perspectives of stakeholders through qualitative research methods such as interviews, and participatory co-design workshops. We have conducted activities to engage with parents, healthcare professionals and research partners, through open conversations and hands-on activities. Examples of activities have been creating reflective journey maps to help prompt sharing with depth. These activities have also involved both individual and group work for research participants.

Since the start of the Coronavirus pandemic in early 2020, we have had to adapt our processes to fit the constraints this issue brought to our work. Through this transition, we leveraged new approaches to education and collaboration by utilizing various online participatory tools to support our research and teaching. In the graduate studio course, the online tools have primarily supported synchronous and asynchronous forms of collaboration among the students and teaching team. Whereas, in our research work, the online tools have primarily supported data collection through our primary source activities, in addition to secure online data management and collaboration and communication with our research team. In this paper, we leverage our experience of both these settings to reflect on the effectiveness of the online tools across both contexts. We share key strengths, challenges, and considerations of online platforms, and make recommendations for choosing online tools based on contextual needs.

3 BENEFITS AND CHALLENGES OF USING ONLINE TOOLS

3.1 Our usage of online tools in education

In the graduate studio courses, both synchronous and asynchronous collaborative activities were supported by the usage of online participatory tools. Class sessions and one-on-one meetings occurred over the online video conferencing application Zoom [14]. We primarily used the online whiteboard tool Miro [15] as a visual workspace and repository. Over the duration of the class period, one-on-one meetings and group discussions were conducted over video conferencing and simultaneously, the virtual whiteboard served as a shared visual workspace, to communicate course goals, collect research findings and ideas, and document the process. Additionally, the virtual whiteboard supported asynchronous activities between discussions by enabling the addition of comments, documents, and links. Hence, it worked not only as a shared visual workspace but also as an asynchronous communication tool and a repository for documenting multiple aspects of the projects.

We initially set up the workspaces with a basic framework for the students to build upon, such as by segmenting the workspaces by different kinds of content, work by different students, or different phases of the projects. Assuming some students would be new to the tools, we included informative legends or keys for various functions and orientation to the workspaces. As the project continued, students adapted the workspace to their processes and needs.

In general, we found this setup to work well in the graduate studio course. The students appeared to be very comfortable with using the technology and had a quick learning curve. By having a view of their own work and that of their peers, we believe that this set up encouraged cross-peer learning and reflection on ways to improve one's work. Screenshots of the online repository of work overtime were even used directly in some student presentations to show their process.

Through synchronous collaboration, the online whiteboard enabled the students and teaching teams to have a full view of the progress of the project at one location, simplifying and centralizing management of project data. Students were able to conveniently view other students' work and offer their critiques. This led to streamlining discussions and activities during the class periods and meetings.

Between direct engagement, students were also able to use the whiteboard for asynchronous collaboration. This enabled students to keep track of not only their own progress but also that of their classmates. Students were able to experience the complete arc of each other's progress, rather than just at significant milestones as would be afforded by traditional in-person design education. Similarly, the teaching team were also able to follow students' progress in a more continuous manner. The students and the teaching team were able to offer ongoing critique through comments and links.

Yet, we noticed some drawbacks to the setup, too. The human connection among students and between students and the teaching team was negatively impacted. More recently, we are noticing that the whiteboard may not support in-person or hybrid interactions as effectively as it did with completely online experiences. Now that we are transitioning to in-person and hybrid forms of teaching in 2022, we notice that the online whiteboard is used as a form of digital repository but less as a collaboration tool.

3.2 Our usage of online tools in design research

In our research experiences, the online participatory tools primarily supported synchronous activities interspersed with some asynchronous activities, with our research partners and with stakeholders. The online tools served the purpose of collecting data, synthesizing, and organizing it, and also to support communication and alignment between participants. Here too, we utilized the video conferencing application Zoom [14] for discussion in parallel with a shared visual workspace. We used various forms of shared visual workspaces ranging from whiteboard software like Miro [15], Lucid Chart/Spark [16] and Google Jamboard [17], to adapting cloud-based versions of other productivity tools such as

Microsoft Word [18] and Google Sheets [19] into workspaces. Additionally, we used survey tools such as Qualtrics [20] and polling tools such as Poll Everywhere [21]. For asynchronous communication and secure file sharing with our research partners, we used Microsoft Teams [22]. Drawing from our experiences in the graduate studios, we set up these workspaces with informative legends or keys to orient participants and to explain how to use the software, in addition to reserving time at the beginning of the workshops to help participants access and begin using the software, with clarification as needed.
Our initial expectations were that these tools would be effective to facilitate engagement, as they largely had been in our experiences with the graduate studio. Generally, the tools enabled us to collaborate with the team across geographic locations, since research partners are located at multiple universities in the eastern United States. Stakeholders for our research such as patients and healthcare team members were also only accessible to us by virtual means, due to the constraints of the pandemic. The online tools certainly brought the benefits of access to these collaborators. Because of our interactions with our research partners being remote, we were also able to have meetings more frequently than we would have, compared with when we met largely in-person.
We encountered challenges in supporting participation due to varying levels of comfort with technology. In some situations, participants chose not to utilize a certain tool or feature to communicate their ideas. For instance, some participants chose not to utilize an online whiteboard to share their thoughts, instead opting to only verbalize. In one instance, participants were having troubles with logging into/signing up for the whiteboard software we were requesting them to use. As a result of such difficulties, we found that it also often took us longer than expected to orient participants and address any logistical difficulties. Participants also logged in using different devices such as phones in addition to computers. Initially we had not anticipated this and hence our activities were not accessible by phone.
Regarding data collection, the combination of a shared visual workspace and discussion over video call enabled the collection of a rich mixture of open and close-ended data. For example, one workshop activity involved recording stakeholder needs, along with assigning these needs into bounded categories. For such a prompt, participants were able to verbalize their thoughts with the group while creating virtual post-it notes to record their ideas – these led to the generation of open-ended data. At the same time, they placed these notes into bounded categories on the workspace representing close-ended categories – this led to the generation of close-ended data. As a result of participants recording their ideas by virtual means, we had the benefit of having a large part of our data digitized by the end of the workshops and ready for further analysis. Having a shared workspace also enabled the continuation of data collection outside of the time frame of the research activities. For instance, after completing workshops with our research partners, we were able to maintain a 'live' version of the document where attendees could add additional information after the activity or participants who were absent could also share their input.
We realized that due to issues of technological access and technology literacy, our sampling of participants may have been limited and biased by our activities being online. As mentioned, participants preferred to share ideas by various means - some sharing through virtual post-it notes, some speaking out loud or through the chat feature on the video conferencing application. We noticed it was difficult for them to do both at the same time. To compensate for this, we either had to allot more time for individual activities or scribe and take notes on the whiteboards while facilitating conversation, sharing similarities with others' experiences of additional researcher roles in online activities [11], [12]. As a result of varied levels of comfort, and various channels by which information was shared, we may also have faced an equivalent of a non-response bias, and our data may hence be biased towards the responses of some participants more than others. More so than usual, the research team had to remain vigilant to address any emerging challenges during the activities. Consistent with other researchers [11], we found ourselves using parallel channels such as text messages as a coordination 'back-channel'.
The participants' varying levels of comfort prompted us to try various tools. Expecting that participants might be more comfortable with common tools such as word processors and spreadsheets, we even adapted cloud-based versions of these to be shared whiteboard-like workspaces. This was only partially successful at addressing some of the drawbacks mentioned above. The spreadsheets added the advantages of direct organization of data for analysis in addition to digitization. Additionally, setting up formulae within the spreadsheet enabled the automatic copying of selective data across activities, facilitating continuity between individual activities. Yet, we noticed usability challenges of such a set up for some participants, similar to those experienced in prior research activities. Cloud-based word processing tools, while offering limited sophistication, were simple to use. We noticed a large proportion of participants use these easily and effectively as a shared workspace.

4 COMPARING THE SETTINGS

A comparison of the two settings and our experiences is summarized in Table 1. Our experiences of utilizing online collaborative tools are particularly focused on shared visual workspaces. We experienced using the tools in both the educational setting in graduate industrial design studio courses and in design research for healthcare systems. The differences in the two settings may have contributed to some of the variation in experiences noted above. Considering the characteristics of the participants, the students were relatively young, and we expect that being 'digital natives' they may be quick to adapt to the usage of such tools. Additionally, they may already have experienced using similar tools in other classes or projects. In comparison, we notice more of a variation of age ranges and comfort with technology across our research partners and stakeholders.

The frequency and duration of engagement may also play an important role. Since the students utilized the tools regularly over the course of their semester, they had the opportunity to refine their approach over time. Our research activities have been less frequent - once every few weeks or months; with some activities being one-off engagements. This may make it difficult for participants to adapt to the tools and processes and for us to adapt to the preferences and needs of the participants. Long term participatory research projects with more frequent interaction with stakeholders may have different, more productive experiences.

Table 1. Comparison of using online workspaces in design education and design research

	Comparing the settings	**Benefits of online workspaces**	**Challenges of online workspaces**
Design education	- Students were younger and 'digital natives' - Likely prior experiences with similar online tools - Long, frequent activities	- Asynchronous feedback sharing - Cross-peer learning - Documenting and visualizing entire process	- Human connection negatively impacted - Limited usage as repository in in-person or hybrid projects
Design research	- Participants had variability in age range and comfort with technology - Unlikely prior experiences with similar online tools - Short, infrequent activities	- Increasing access to geographically distant participants - Enabling frequent engagement - Collecting open- and close-ended data - Asynchronous data collection and automatic digitization	- Participant ease of use dependent on comfort with technology - Logistical issues and added researcher responsibilities - Access to participants may be biased by technological literacy and access

5 RECOMMENDATIONS

We find that like any human centred design process, the choice and tailoring of online participatory tools for education and research activities needs to consider multiple contextual factors. It is important to consider the people involved in the activities, and the nature of the activities and tools. We echo the approach of Lee et al. [8] and suggest that the affordances of the tools offer a useful additional perspective. Anticipating the synergy between the people, activities and tools can help educators and researchers tailor the activities and tools to be a good match for the people involved and research goals.

Regarding the people involved in the activities, it may be beneficial to inquire into their preferred modes of engagement prior to conducting the actual activity, such as during a pre-semester discussion for students or during a screening survey for research participants. Knowledge of what tools and technologies may already be used by the students or participants would also be beneficial. This can help choose tools that are most appropriate for the activities.

It is also important to critically assess the combined affordances of both the activities and the tools. For instance, if individual input in a shared visual workspace is needed prior to group discussion, the structure of the activity and the tool should promote this. The activity would need to allow for enough time for individual orientation and input. Considering the affordances of video conferencing tools, participants having time away from the video call, such as with cameras turned off while being in the larger group, may encourage meaningful individual contributions. On the other hand, if they are in a breakout room, participants may be used to engaging in discussion immediately. With the combined affordances of the video conferencing tool and shared visual workspace, participants can have a variety of ways to engage in activities. Regarding the need to enable participants to effectively express their

ideas without overloading facilitators during activities, organizers may benefit from a thoughtful balance of redundancy and constraints. Ideally there would be sufficient ways of sharing information for different types of participants while being a manageable process for facilitators.
We also suggest that organizers of such activities conduct pilot tests with the combination of tools that would be used in the final activities. Additionally, it would be helpful to provide pre-recorded or in-activity tutorials of how to use the tools involved. These measures would help to account for logistical issues such as logging in or creating accounts and getting acquainted with the tools, which may be especially relevant when dealing with multiple organizations or groups of stakeholders.
New online technologies and tools can facilitate remote collaboration in the spheres of design education and research. Continual consideration of people, activities, tools, and their associated affordances in combination can help us increasingly adapt for more effective educational and research experiences.

The research activities of the project discussed in this paper were supported by grant number R18HS027260 from the *Agency for Healthcare Research and Quality*. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

REFERENCES

[1] Moodle. Moodle. Accessed: Mar. 12, 2022. [Online]. Available: *https://moodle.org/*
[2] MediaWiki. Wikimedia Foundation. Available: *https://www.mediawiki.org*
[3] Google Docs. Google LLC. Available: *https://docs.google.com*
[4] Kai-Wai Chu S. and Kennedy D. M. Using online collaborative tools for groups to co-construct knowledge, *Online Inf. Rev.*, vol. 35, no. 4, 2011, pp. 581–597.
[5] Hidayanto A. N. and Setyady S. T. Impact of Collaborative Tools Utilization on Group Performance in University Students, Turk. *Online J. Educ. Technol.* - TOJET, vol. 13, no. 2, 2014.
[6] Hsu Y. C. and Shiue Y. M. Exploring the Influence of Using Collaborative Tools on the Community of Inquiry in an Interdisciplinary Project-Based Learning Context, EURASIA J. *Math. Sci. Technol. Educ*., 2017, vol. 14, no. 3.
[7] Garrison D. R., Anderson T. and Archer W. Critical Inquiry in a Text-Based Environment: Computer Conferencing in Higher Education, *Internet High. Educ*., vol. 2, no. 2, 1999.
[8] Lee T., Pham K., Crosby A. and Peterson J. F., Digital collaboration in design education: how online collaborative software changes the practices and places of learning, *Pedagogy Cult. Soc.*, vol. 29, no. 2, 2021, pp. 231–245.
[9] Slack. Slack Technologies. Accessed: Mar. 12, 2022. [Online]. Available: *https://slack.com/*
[10] Tamí-Maury I., Brown L., Lapham H. and Chang S. Community-based participatory research through virtual communities, J. *Commun. Healthc.*, vol. 10, no. 3, 2017, pp. 188–194.
[11] Roberts J. K., Pavlakis A. E. and Richards M. P, It’s More Complicated Than It Seems: Virtual Qualitative Research in the COVID-19 Era, *Int. J. Qual. Methods,* vol. 20, 2021.
[12] Dos Santos Marques I. C., Theiss L. M., Johnson C. Y., McLin E., Ruf B. A., Vickers S. M., Fouad, M. N., Scarinci I. C. and Chu D.I. Implementation of virtual focus groups for qualitative data collection in a global pandemic, *Am. J. Surg*., vol. 221, no. 5, 2021, pp. 918–922.
[13] Pocock T., Smith M. and Wiles J. Recommendations for Virtual Qualitative Health Research During a Pandemic, *Qual. Health Res*., vol. 31, no. 13, 2021, pp. 2403–2413.
[14] Zoom. Zoom Video Communications. Available: *https://zoom.us/*
[15] Miro. Miro. Available: *https://miro.com*
[16] Lucid Software. Lucid Software. Available: *https://lucid.co/*
[17] Google Jamboard. Google LLC. Available: *https://jamboard.google.com/*
[18] Microsoft Word. Microsoft. Available: *https://www.microsoft.com/en-us/microsoft-365/word*
[19] Google Sheets. Google LLC. Available: *https://google.com/sheets*
[20] Qualtrics XM. Qualtrics. Available: *https://www.qualtrics.com/*
[21] Poll Everywhere. Available: *https://www.polleverywhere.com*
[22] Microsoft Teams. Available: *https://www.microsoft.com/content/microsoft/bade/en-us/microsoft-teams/group-chat-software*

DESIGNING OUT UNWANTED HEALTHCARE FUTURES: A NEW FRAMEWORK FOR HEALTHCARE DESIGN INNOVATION WITH INTENT

Anna WOJDECKA, Tibor BALINT and Ashley HALL
Royal College of Art, London, United Kingdom

ABSTRACT
At the time of a global pandemic, it is becoming acutely evident that design has to intensify efforts to move beyond reactive tackling of healthcare challenges as they occur, towards a proactive approach of designing-out unwanted healthcare futures before they become a reality. As healthcare design navigates towards more distant horizons, the scale and magnitude of design challenges increase. New approaches to envisioning and negotiating preferable healthcare futures across disciplines are required in order to make that shift successful. In this paper, we discuss the application of a new trans-disciplinary approach applied within burst-mode healthcare design education of professionals from multidisciplinary backgrounds. This strategic design-led innovation approach distinguishes between desirable and undesirable futures. It employs futures scoping methods, alongside the identification of technology drivers and enablers, to understand the target landscape and to design strategic pathways toward paving design interventions. Tools, such as the four futures of Jim Dator and NASA TRLs, are used alongside collaborative mood boarding to visualise possible futures and facilitate concept generation utilising moon-shot thinking and back casting.

Keywords: Healthcare futures, designing-out unwanted futures, transdisciplinary education

1 INTRODUCTION
Design disciplines have a moral responsibility to intensify efforts to tackle future health challenges, consider potential risks and address emerging crises before they arise. Healthcare design has an ethical obligation to maximise positive impact, preferably facilitating prevention over cure. We can consider maximising design impact operating within three-dimensional space, which includes an axis of time, scale and variety of design expertise involved, which we illustrate diagrammatically below (Figure 1). The scale axis captures the changing role of design is anchored in facilitating trans disciplinarity in problem-solving, referring to Meadow's Leverage Points and the movement from designing objects to systems and models [1]. The temporal axis can refer to reactive vs. proactive design. The third 'disciplinarity' axis captures the range of expertise involved. Design for behaviour change maximises impact by utilising behavioural science expertise and frameworks to detect and pre-empt unwanted behaviour and intervene with a solution (preferable outcome) ahead of time [2]. The temporal scale is considered within a short, 'micro' fragment of the user journey and identifies particular behaviour, analyses different components, including actors, motivation, capabilities, barriers and facilitators, to propose an optimal design intervention. Design innovation in the context of health futures has the potential to maximise impact by operating analogously, but including a wider temporal component, within a macro-scale. In this way, it either observes a variety of futures and proposes solutions to design-out unwanted futures or facilitates solutions for an envisioned, 'negotiated' preferable future.

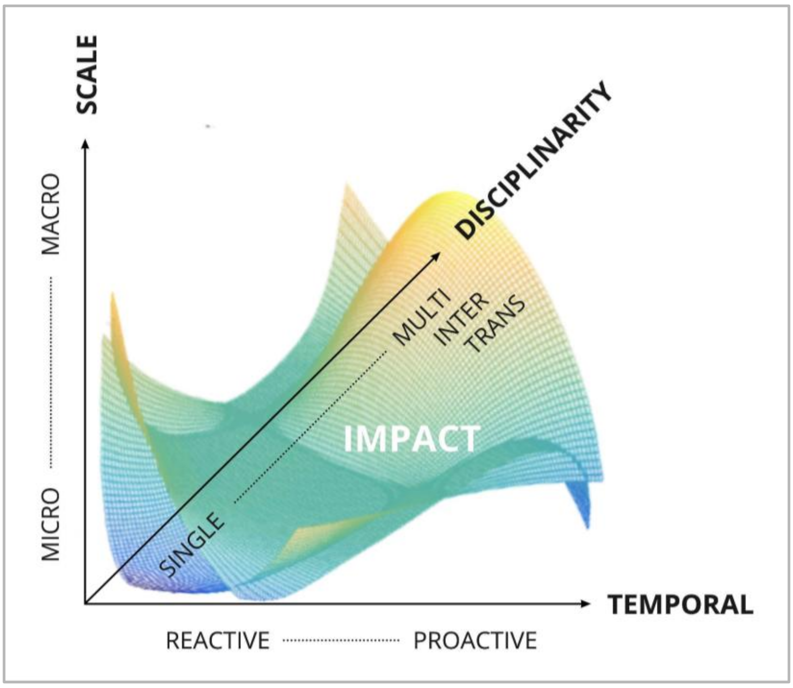


Figure 1. Three-dimensionality of maximising the design impact

The expanding body of research within the domain of future studies provides a variety of methods and tools within futures research practice and education for impacting social change [3]. Some futurists point out the need for preventing situations when *'back casting often ends only in a report'* or *'methodologies for integrating thought and action (...), such as anticipatory action-learning (...) are seldom applied and tested'* [4]. Space industry organisations, such as NASA, which undertake projects with long time horizons (measured in years and even decades), have developed tools and methods, including Technology Readiness Levels (TRLs) [5] and Technology Taxonomy, to assess technology maturation during the project development cycle [6]. Design futures research practice offers 'futuring' methods from Speculative Design to Foresight and Scenario Planning [7]. Despite the advancements in futures research, the implementation of 'proactive' design approaches to health(care) innovation still remains largely unexplored. New educational approaches to teaching future healthcare design innovation in an interdisciplinary context are required to maximise the impact on the future of health.

Health Design Innovation is a core one-week module delivered as part of the second year curriculum of the Healthcare and Design MRes and MSc courses jointly at the Royal College of Art (RCA) and Imperial College London (ICL) [8]. The module introduces different mechanisms of disruptive innovation, types of innovation, design futures, including anticipatory, speculative, prospective futures, and Design for the Unthinkable World. By the end of the module, participants are expected to be equipped with a variety of future scanning and forecasting approaches, as well as methods to negotiate and deliver Preferable Futures, outline innovation strategies and the innovation blueprint of the proposed solution. The module has been delivered both as face-to-face hands-on teaching in the academic year 2021/22 and through an online, highly interactive, multi-time zone mode in the academic year 2020/21 due to pandemic social distancing restrictions. The teaching staff included experts from healthcare design innovation, health policy and invited staff from NASA's Jet Propulsion Laboratory with long-term future project planning expertise. The student teams included a wide range of expertise, with backgrounds ranging from design, art, medical, policy, business and social sciences.

2 THE JOURNEY FROM PAST(S) TO FUTURE DESIGN INNOVATION

The first two days of the module introduce the theory of innovation and retrospective analysis of innovation types in lecture-discussion format. The themes include technology, business models, systems and processes analysed on case-study examples. This lays the groundwork for the hands-on group work over the rest of the week. Students are divided into teams of four to five participants with diverse backgrounds and engage with directed hands-on workshop activities, which are introduced by short strategic lectures. The faculty provides group mentoring, facilitating, and feedback in the form of studio walk-around tutorials and open-office sessions. The diagram below illustrates the framework of the design research process application, from health challenge identification and incorporating past insights, to proposed design solution innovation impact blueprinting (Figure 2).

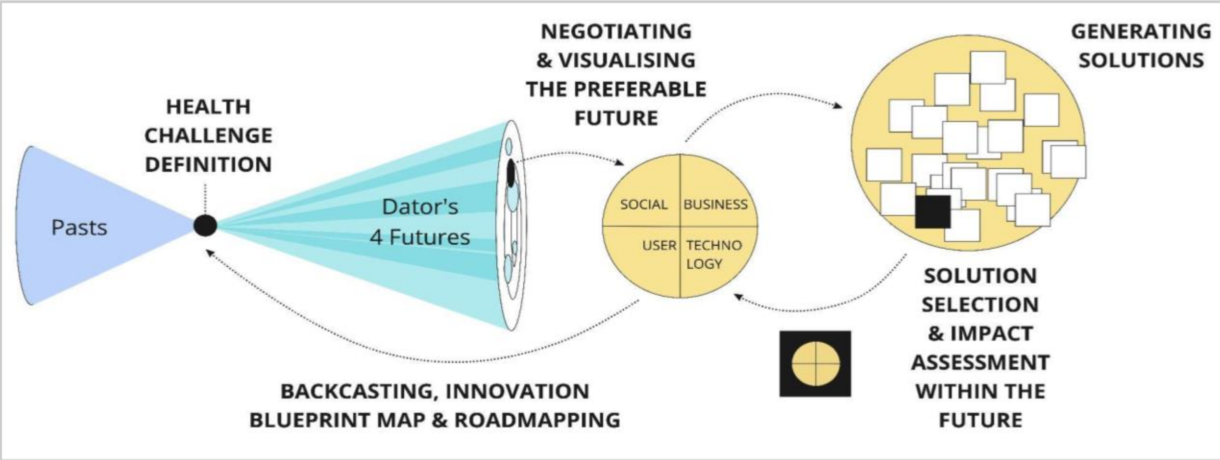


Figure 2. Modular workshop cycle from understanding the challenge and design opportunity to the design solution and impact map

3 THE PAST CONE, THE FUTURE CONE, AND THE HYPERSPACE OF NOW

During the third day, student groups defined a selected health challenge by discussing multiple pasts and futures in the context of Minkowski Spacetime Cone.

In order to outline the challenge, its dimensions and scale, the teams used multiple pasts to understand the potential relationships [9]. Four quadrants of realisation, adopted by Johnes from the Johari Window have been used by team members to gather insights, evidence, and spot potential gaps within: 'known knowns'—consequences relatively easy to predict, 'known unknowns'—such as side effects of a new treatment, 'unknown unknowns'—related to the awareness of not knowing, and 'unknown knowns'—which the team might know, but is not aware of at the time [10]. Students used medical technology horizon scanning [11] and NASA Technology Taxonomy [6] discussing potential technology roadmaps and identifying them within the future cone of possible, plausible and probable futures [12].

As a next step, the teams envisioned in detail Dator's 4 Futures—Continuation, Limits and Discipline, Decline and Collapse, Transformation—within the selected challenge area [13]. Teams used the Miro.com online collaborative whiteboard platform to detail each of the futures with visuals and diagrams, and describe within: User, Social, Economic, and Technology contexts (Figure 3).

Figure 3. Example: Visual scoping of Dator's 4 Futures. Students: Rozansky, E. Krenkler, J. McEntee, K. Kandya, S. Minkovska, S. Richter

4 NEGOTIATING THE PREFERABLE FUTURE

Day four was focused on the selection of a preferable future within the envisioned foresight landscape. With the diversity of background and expertise, negotiating common visions of what would constitute the preferable future for the team was one of the key challenges. Lohman's 'fields of vision' diagram illustrates 'individual' future cone perspectives and potential disparity of preference (Figure 4) [14].

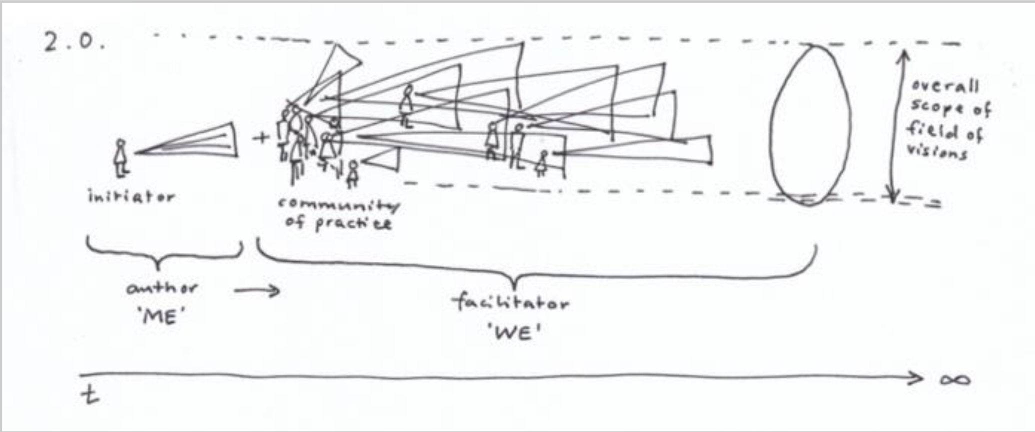


Figure 4. Fields of vision, after Julia Lohman

To facilitate the process of negotiation, teams used a number of design methods to advance the conversations and develop their concepts, including boundary objects in the form of visualisation tools and mock-ups [15]. The term 'boundary objects' originates from the field of social sciences and refers to objects that can be simultaneously (a) concrete and abstract; (b) specific and general, and (c) conventionalised and customised. Through connecting conversations, they facilitate developing novel distinctions and shared meanings between the design team members. Boundary objects overlap between worlds (or disciplines), becoming the problem space for negotiations and (design) conflict resolutions. During the design process, both the conversations and the boundary objects may evolve and could be referred to as second-order boundary objects [16][17]. Conflict resolution could be achieved through cybernetic circularity, with conversations between the participants, reaching across discipline boundaries. This approach helps to evolve an idea towards a preferred outcome. The teams worked with visuals, sticky notes, simple sketches, higher fidelity drawings to create keystone graphics, and low fidelity mock-ups to establish a shared vision of the preferred future, defining it within multiple layers: User, Social, Economic, Technology and Environment (Figure 5).

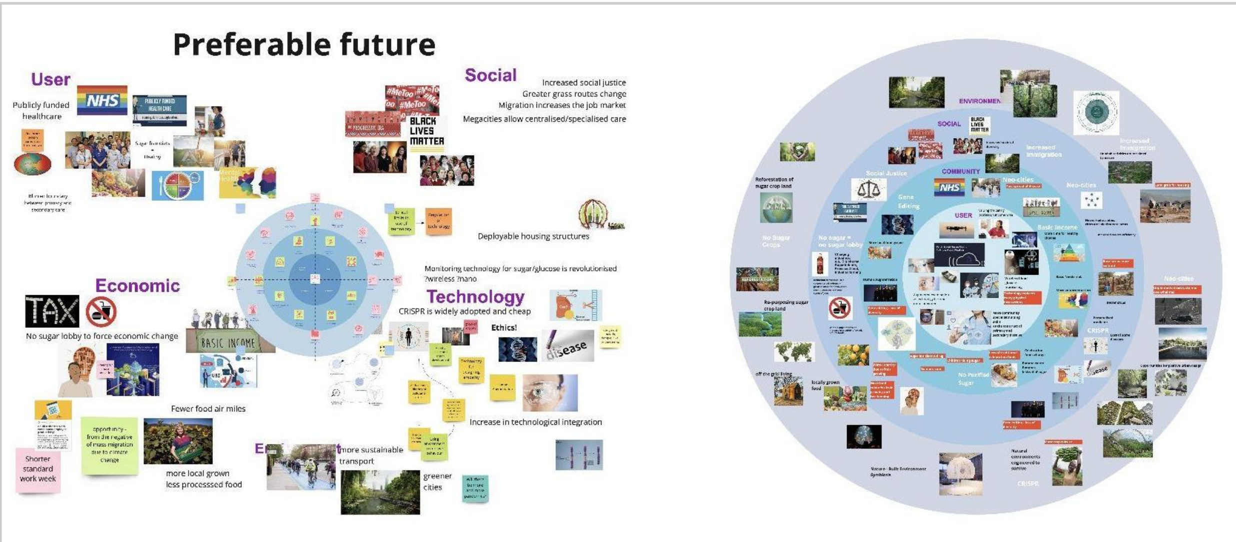


Figure 5. Preferable future layers detailing. Students: D. Rozansky, E. Krenkler, J. McEntee, K. Kandya, S. Minkovska, S. Richter

5 DESIGN INNOVATION AND IMPACT

The envisioned landscape of different futures, potential black swan events, and the defined context of the preferable future allowed teams to consider strategies to design-out unwanted futures. Each team selected an innovation strategy of either Moon-shot Thinking or Blue Sky Thinking, and/or Back casting approach.

Healthcare Design Workshop Cards were used to facilitate generating a large volume of solutions within a selected preferable future context [20]. The ideas were thematically grouped, narrowed down and examined using the disruptive innovation impact map (Figure 6) developed by the authors.

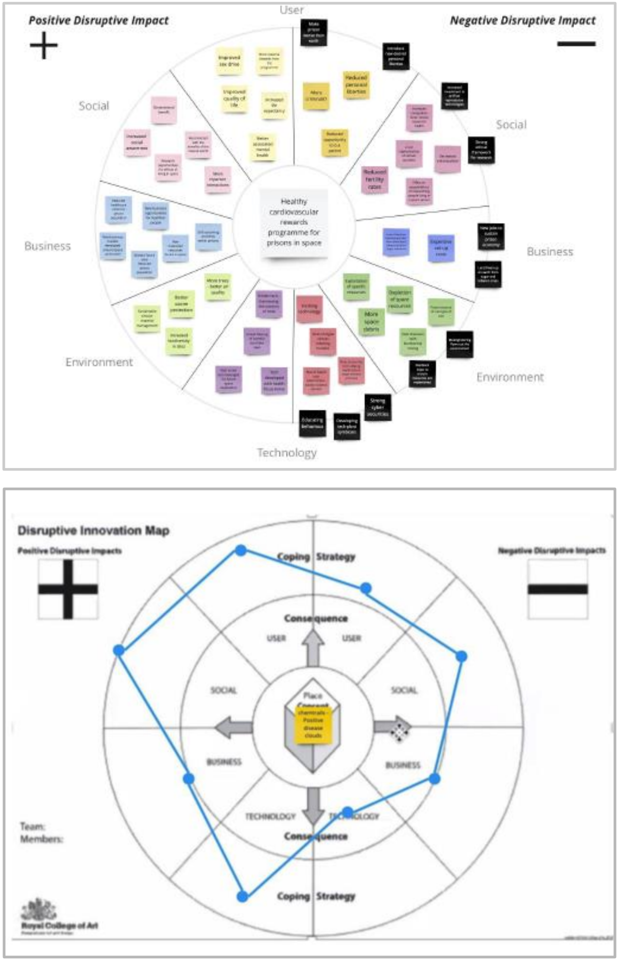


Figure 6. Innovation-impact blueprinting maps. Students: C. Luxford, K. Kandya, S. Ahuja (left), A. Mirani, B. Wall, C. Tighe, J. Chui (right).

Modular outputs were presented on the last day of the module. Teams presented the challenge analysis, the proposed solution within the context of the selected preferable future and the projected innovation impact map. The teams provided reflective analysis of the research process and methods used to negotiate preferable futures, as well as ideated solution groups and the innovation blueprinting.

6 REFLECTIONS AND INSIGHTS

The collaborative visualisation and diagramming played a key role in facilitating the module learning, both in the remote and face-to-face delivery of the module. Digital whiteboarding tools, such as the Miro.com platform, have been introduced to enable collaborative work during remote delivery of the module. This not only facilitated the successful teamwork across different locations and time zones, but also strengthened the richness of captured design research process, and has been incorporated into the face-to-face teaching model, where each team keeps a trace of the process throughout the week.

One of the key observations highlighted by the student teams was the complexity of negotiating the shared vision of a preferable health future. The role of using boundary objects in facilitating communication enabled a common understanding of matters discussed and played a key role in facilitating the discussions and productive conflict resolution. Other teams defined ‘actors’ representing stakeholders within the selected future.

The crucial element of the idea selection process was the solution evaluation using the Disruptive Innovation Map, which enabled assessing the impact of the solution as of ‘now’ and also for a projected future.

7 CONCLUSIONS

The introduced process has been enthusiastically received, and resulted in rich module outputs, especially when it comes to the process. Elements of the framework we have tested here have been the subject of discussion by the authors over several years and have a dual purpose of introducing students to a number of futures-related concepts while also indicating how these can be used together as a whole. This approach recognises a general trend we have observed in healthcare design projects away from classic design solutions towards realising that larger issues lie in the positioning of design and meta skillset orientation towards design futures. It also helps build methods and methodological fluency and confidence which we have observed later in the student's major projects. While the main aim of this approach is strategic for enhancing healthcare design capability and for navigating towards preferable futures, we also suggest there is novel value in future explorations towards products and services at a more applied level.

The disruption mapping has increased impact assessment and afforded us to appreciate follow-on innovation opportunities while the framework approach has allowed both designers, healthcare professionals and students from diverse backgrounds to rapidly gain confidence in design futures delivered through a burst-mode postgraduate education model.

REFERENCES

[1] Meadows D. H. (1999). Leverage points: Places to intervene in a system.

[2] Wojdecka A., Hall A. and Judah G. (2021). Transdisciplinary behaviour change: A burst mode approach to healthcare design education. *E&PDE 2021*, The Design Society.

[3] Dator J. (2002). Advancing futures: Futures studies in higher education. Greenwood Publishing Group.

[4] Stevenson T. (2004). Time for new social technologies? *Futures*, 36(1), 109-113.

[5] Mankins J. C. (1995). Technology readiness levels. *White Paper*, April, 6(1995), 1995.

[6] Miranda D. J. (2020). *2020 NASA Technology Taxonomy* (No. HQ-E-DAA-TN76653).

[7] Galdon F., Hall A. and Ferrarello L. (2021). Futuring and trust; A prospective approach to designing trusted futures via a comparative study among design future models. *Strategic Design Research Journal*.

[8] Hall A., Leff D., Wojdecka A., Kinross J., Thompson P. and Darzi A. 2019. Beyond the healthcare paradigm: Co-creating a new model for collaborative transdisciplinary healthcare design education, *E&PDE 2019*, University of Strathclyde, Glasgow.

[9] List D. (2004). Multiple pasts, converging presents, and alternative futures. *Futures*, 36(1), 23-43.

[10] Jones T. (2010). Future agenda: the world in 2020. *Infinite Ideas.*

[11] Brown I. T., Smale A., Verma A. and Momandwall S. (2005). Medical technology horizon scanning. *Australasian Physics & Engineering Sciences in Medicine*, 28(3), 200-203.

[12] Hancock T. and Bezold C. (1994). Possible futures, preferable futures. *The Healthcare Forum Journal.*

[13] Dator J. (2019). *Alternative futures at the Manoa School*. (pp. 37-54). Springer, Cham.

[14] Lohmann J. C. (2017). The Department of Seaweed; co-speculative design in a museum residency. *PhD thesis*, Royal College of Art.

[15] Star S. L. and Griesemer J. R. (1989). Institutional ecology, translations and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social studies of science*, 19(3), 387-420.

[16] Balint T. S. and Pangaro P. (2017). Design space for space design: Dialogs through boundary objects at the intersections of art, design, science, and engineering. *Acta Astronautica*, 134, 41-53.

[17] Balint T. S. and Lee C. H. (2019). Pillow talk—Curating delight for astronauts. *Acta Astronautica.*

[18] De Bono E. (1985). *Six Thinking Hats*. London Penguin Books.

[19] Wojdecka A., Hall A., McDonagh R., Leff D. and Kinross J. (2019) *Healthcare Design Workshop Cards: Context, People & Technology*, Royal College of Art & Imperial College London.

COLLABORATIVE LEARNING IN INTERNATIONAL INTERDISCIPLINARY TEAMS

Miroslava Nadkova PETROVA[1], Milagros Diez Canseco Castro de STEFFEN[2], Ricardo Geldres PIUMATTI[2] and César Rubén Lucho LINGÁN[2]
[1]Universidad de Monterrey, Mexico
[2]Pontificia Universidad Católica del Perú, Peru

ABSTRACT

Teamwork, often distributed across continents and cultures has become a standard in the context of Industry 4.0. To enable students to look beyond their own space, time and culture while resolving specific problems in a specific context makes them more flexible and culturally sensitive and prepares them for collaborative work in their future design practice. The paper discusses key aspects of an online collaborative project developed by students from two design careers, interior design and industrial design, located in two Latin American countries, Mexico and Peru. The study draws upon socio-cultural approaches and deliberates the different dimensions of collaborative work – cognitive, socio-relational and affective. We analysed the individual and shared goals of the collaboration, the roles that each participant played, the specific methods and tools used by the two groups, how knowledge was shared, how problems were negotiated and resolved and how students felt about it. Our main objective is to evaluate how the collaboration impacted students' learning. Firstly, we focused on students' performance, the co-created knowledge and the competences developed in the course of collaboration. Secondly, we examine the quality of the design project and correlate it to the effectiveness of the communication in the teams. Research data were collected with student surveys and self-reflection writings carried out at the end of the semester, and comparative study on the intercultural collaborative project outcomes with the outcomes of a traditional in-house team project.
The advantages of collaborative learning and the values created are summarized in conclusion.

Keywords: Collaborative learning, interdisciplinary design, intercultural collaboration

1 INTRODUCTION

Teamwork, often distributed across continents and cultures has become a standard in the context of Industry 4.0. The digital transformation profoundly changed the dynamics of the production processes and business models which imposed a shift in the workforce competencies requirements. Along with cognitive abilities, systems skills and problem-solving skills, the new technological adoption entails capabilities of collaboration, communication and adaptability [1].
The complexity of the design tasks, the need for multiple expertise and the division of labour are recognized as driving factors for the increased necessity of collaboration in the design field [2] Moreover, the shift from the traditional human-centred design approach towards co-creative practices implies that the challenges we face today can be resolved only as a team effort where researchers, designers and users participate together in the design process [3]. Different projects have been exploring the participatory capacity across design processes around the world [4,5,6].
The role of universities is vital in preparing the new generations and equipping them with the knowledge and skills demanded by the companies. Design education responds to these realities through implementing team projects where small groups of students are exposed to a situation where they "learn or attempt to learn something together" [7]. Through communication, dialogue, argumentation, negotiation, conflict resolution they jointly take decisions and solve problems. In the collaborative process, all participants are dependent on each other, share responsibilities and work together to achieve the common objective in a more efficient way [8]. As a result, students acquire collaborative skills that will be crucial for their future success as design professionals.

1.1 Collaborative online international learning

Information and communication technologies expanded the channels of collaboration for design teams and generated new opportunities enriching the ways students learn. Collaborative Online International Learning (COIL) is one of the methodologies encouraging collaborative learning between students from different countries. It expands their horizons by providing the opportunity to get acquainted with new cultural realities, thus, broadening their knowledge. Though this innovative teaching and learning paradigm originated back in 2006 [9], virtual exchange gained its momentum with the covid-19 pandemic. The methodology allowed the internationalization of both students and teachers which would be otherwise impeded by the travel restrictions. Students could participate in a virtual journey enriching their cross-cultural experiences while teachers were allowed to teach a course in a foreign university without the need to be physically present. What differentiates COIL from a typical online course is that it is specifically designed to connect students with a different cultural background and different geo-physical perspectives. The planned activities focus on the creation of shared experience and understanding, while exploring the potential of various platforms for online collaboration [10]. Students are enabled to look beyond their own space, time and culture but at the same time they resolve specific problems in a specific context thus becoming more flexible and culturally sensitive. Hence, they are better prepared for such types of collaborations in their future design practice.

According to Dillenbourg, Järvela and Fischer [10], for many educators collaborative learning is one of the best ways to achieve changes in educational citizenship. Teamwork in virtuality, has the same objective as in face-to-face settings; therefore, it can be considered a joint work of people who are trying to achieve a common goal. Virtual learning environment has already established itself as a space where innovation is present, and when collaborative learning is added, the possibilities of developing enriching learning experience of the participating teams become optimal. This is particularly valid when two or more disciplines of the same profile are involved.

2 COIL IN THE LATIN AMERICAN CONTEXT

The project in consideration in this paper brought together two Latin American universities - Universidad de Monterrey (UDEM, Mexico) and the Pontificia Universidad Católica del Perú (PUCP, Peru). From the Mexican side there were 14 students led by one professor and from the Peruvian side 33 students and three professors participated. The Mexican students were in their seventh semester in the *Interior Design* programme in the Department of Architecture and Habitat Sciences. The class where COIL was implemented was *Studio Integral*. This is the last and most advanced studio in their course of study where they develop large-scale interior design projects drawing on the knowledge built in the previous studios. The general aim is to prepare them for the elaboration of their diploma thesis. The Peruvians were students of *Industrial Design* in their sixth semester, in the Industrial Design programme at the Arts and Design Faculty. The course where the project was implemented was *Design Project 2*. This is the second course of the third year of Industrial design studies. The Industrial Design Career takes five years, and the third year is their first in specialized design studies after two years of general courses. The main objectives of the class were to prepare students for collaborative work with partners from other design specialties and fields and to practice the development of a comprehensive design project.

2.1 Planning

After establishing initial contact between the professors from the two countries, several zoom meetings were organized to choose the topic of the project, to align the existing course syllabus and objectives of the two courses, to discuss and develop the specific activities.

The COIL project was integrated as a module within each of the courses with duration of five weeks. It took place in the second half of the autumn semester in 2021, so that students could be preliminarily acquainted with the theoretical aspects, conceptual and instrumental tools necessary to elaborate the project. Adaptive reuse of an industrial heritage building was selected as a topic for the collaboration. The general objective was formulated as follows: to explore the potential for adaptive reuse of the dilapidated Peña Blanca building in Monterrey (Mexico) through evaluating its cultural significance as an industrial heritage and reinventing its values as to enhance the building and to bring it to new life through the proposal of new functions relevant to the current context. The interior design students were in charge of analysing the historical, cultural, social, artistic and economic context of the site, to estimate the values of the historical building by gaining holistic understanding of the problem of preservation and conservation of cultural heritage, to identify the potential for intervention and to generate design proposals. The industrial design students elaborated deeper the analysis of the user needs according to the proposed concept. They were expected to design the furniture and equipment, to specify the materials and manufacturing processes.

Moreover, the objectives of the COIL were formulated:

- To develop skills to work in multidisciplinary and international teams
- To encourage cross-cultural experiences and students' awareness of similarities and differences
- To strengthen the online learning mode imposed by the global quarantine through building a collaborative learning experience and establishing a cross-national dialogue
- To foster an international creative network in the field of design
- To develop skills on multiple visual platforms on and offline

2.2 The process

The first synchronous meeting included the project presentation, introduction of the students and designation of the teams. Each team was constituted of students from both countries as this is a prerequisite to achieve the goals of the collaboration. Four teams were formed consisting of 2-4 Mexican students and 6-9 Peruvian students. Since the industrial design students were a big group, they were split into three sections, each one guided by one teacher in charge. The Mexicans, who started working on the investigation phase two weeks earlier, presented the outcomes of their research to their peers and discussed the project brief, the user needs and the possible interventions in certain areas of the building. The Peruvians joined the discussion with further consideration of the human perspective in the problem solving process. Thus, the five-week experience began.

Students started to actively search connections between the user needs and values, and the current trends within the broad socioeconomic and technical context, to frame questions, discern opportunities and generate alternatives, to explore the advantages and disadvantages of the proposed ideas. The project advance was supervised by the teachers, but the group dynamics were not controlled as the students worked independently outside of the class time.

In such collaborative learning settings students not only acquire knowledge but are exposed to specific social situations where the interaction that takes place significantly impacts the learning process. Learning emerges as an interrelation of the cognitive, socio-relational and affective dimensions of the collaboration [11]. In our case, due to the different schedules of the two classes it was not possible to find a time slot to organize a synchronous meeting of the two groups, so students were expected to self-organize and work jointly on the given tasks without direct control of the process by the teachers. Thus, some of the teams that failed to take the initiative and timely meet their partners to advance on the project experienced a delay in the design process. This resulted in late submission of the deliverables, justified by the students from both countries as a fault of their partners. It is recognized that tensions often occur in collaborative work. However, these tensions are not considered as process disruptors, but rather as "a vital precursor to learning and development" [12]. When students encounter problems in the collaboration, they search for opportunities to resolve them in order to improve the situation and eventually to meet the learning goals. Considered from that perspective, collaborative teamwork significantly contributes to the development of students' social competences. After participating in an international collaborative learning experience, they acquire some generic skills related to social communication, interpersonal and social relationships, and construct interpersonal intelligence.

Collaborative work between students from different geo-locations (Peru - Mexico) allowed the creation of a space where differences in time, culture, competences, etc., took on great value, transforming all of this into competences with the capacity for mediation between equals [13].To be able to interact, different contexts or digital tools were used, and different cooperative learning techniques and communication tools were employed. Teamwork in virtual environments has in common the use of communication and interaction tools, used with pedagogical intent as elements that enrich the way of learning by doing. With these two lines and a constructive learning method, both students from the Peruvian university and students from the Mexican university went through an experience rich in values, ideas, customs and skills acquired during the semester in which the project lasted.

3 RESEARCH METHOD AND DATA COLLECTION

To evaluate how the international interdisciplinary online collaboration impacted students' learning we used a socio-cultural framework. It considers that individual learning is developed through social interactions which are dependent on the social and cultural context in which they occur [11,14].

A qualitative case study was carried out to investigate the cultural, individual and social factors that influenced the behaviour and the learning experience of the students in the specific intercultural context of the collaboration. Firstly, we focused on their performance, the co-created knowledge and the competences developed in the course of collaboration. Secondly, in order to go beyond the subjective experience of the students, we examined the quality of the design projects they delivered and correlated it to the effectiveness of the communication in the teams.

Research data were collected with student surveys and self-reflection writings carried out at the end of the collaboration. The surveys consisted of open-ended questions to encourage student's reflection on the collaborative process, including the personal and team challenges faced, the problems encountered, the behaviours adopted, and the choices made to overcome them, how the final outcome was impacted, and the most significant personal meaning of the COIL project. We consider this "reflection-in-action" as Schön [15] defines it to be of particular importance for the acquisition of knowledge. When students contemplate on the experience in a structured way, they learn how to control the process and hence improve their collaborative competences.

Furthermore, we performed comparative study on the intercultural collaborative project outcomes with the outcomes of a traditional in-house team project to confirm whether the COIL experience had a positive impact on the quality of the design.

4 DATA ANALYSIS AND DISCUSSION

The first question addressed in the research referred to the problems and challenges that the students encountered in the collaborative project development. The major problem mentioned by all participants was time-management and the delayed submission of the deliverables caused by the amount of work which had to be accomplished within tight deadlines and the big scale of the project. The students from both universities indicated the difficulties in communication and non-compliance with deadlines as the greatest challenges for teamwork. *"We had to work with two teams from Peru and not all of the team members answered our messages which made the communication very difficult,"* and *"It was difficult to work with students who did not respect due dates,"* shared the students from Mexico in the self-reflection writing. The perception of the Peruvians was similar: *"The biggest challenge we had to resolve was communicating with the students from UDEM because of our schedules. It wasn't easy, but we solved it by sending each other information through a chat on WhatsApp."*

Work in a big interdisciplinary team was also identified as a problem. This is evident from the following quote by a Peruvian student: *"I had never worked with a team with lots of members and it was difficult because there were a lot of opinions and ideas. The greatest team challenge we experienced was how to make decisions, because everyone had opinions, suggested different ideas and it was very difficult to choose a final one."* Indeed, we observed that the students were very enthusiastic in the beginning of the collaboration and proposed many ideas which were eventually rejected because the lack of time did not allow their full development. Another reason for the delayed delivery was the desire to improve the initially proposed concept: *"My group developed a new concept for the project, and that decision changed the guidelines we have been following, so that affected the schedule we have settled."*

The following two quotes describe how students tried to overcome the difficulties and to resolve the communication problems which occurred. *"We set rules to attend all team meetings, 100% honesty in our opinions, and an open mind to criticism,"* and also, *"We decided to divide the work according to the expertise of each member. This allowed us to move the work forward more quickly and to improve the quality of our proposal."*

However, despite the difficulties a general satisfaction of the final project outcomes was expressed: *"After much debate and several proposals made, we managed to resolve the problems in the best possible way, and this impacted the project outcome in a very positive way"* (student from Mexico). *"It was a great teamwork experience; everyone gave their best and really amazing proposals came out with potential to continue being developed"* (student from Peru).

When asked to describe their experience of the COIL project, among the positive comments that students wrote were that it was "a very productive collaboration," "an innovative educational experience," "an open minding experience," "a great opportunity to recognize the pros and cons of my own design process.” There were also some negative comments such as “it was very stressful,” “it was difficult,” and “the amount of work was huge.”

Among the most personally meaningful aspects of the collaboration, all students mentioned the opportunity to work with students from a different design field and a different cultural background. *“It was a very interesting project where we got to test our skills in front of a new group of colleagues and share experience with each other. We met new realities and different approaches.”* The intersection of the two knowledge domains gave the students the opportunity to learn and get inspired by each other: *“When we were sharing ideas for the concept, I felt really inspired by the ideas of my partners”*. The new skills that were obtained were also recognized as one of the advantages of the COIL. Among them were indicated: to take risks and not be afraid to experiment, to work under pressure and plan the time, to build mutual trust and appreciate the different points of view, to gain confidence in expressing and defending ideas, to be more responsible, organized and patient. Students shared that they not only learned how to distribute tasks in order to work more efficiently but also mastered a new design vocabulary to communicate their design ideas.

Besides the insights on students’ perspective on the collaboration, for us as educators it was important to ascertain to what extent COIL has contributed to the knowledge acquisition and how the quality of the design project was affected. For this purpose, we compared the project delivered as a result of the interdisciplinary intercultural collaboration with a traditional in-house team project developed the previous semester. In the case of the interior design students, a more profound and comprehensive project was delivered with a greater attention to the details, a better stylistic conformity between the furniture and the other interior components, and a more careful specification of materials. In a traditional project students focus rather on the architectural programme of the space and use ready-made furniture usually selected from available 3d models in online libraries which do not always respond fully to the defined user needs. With the collaborative project development, the product design students contributed with their knowledge about ergonomics, structures, materials and processes, so a more conscious alignment between space and product was achieved. Product design students in turn could integrate their design proposals in the interior spaces rendered by their partners. Thus, they not only validated them but had the opportunity to reinforce the socio-environmental aspects of their projects.

5 CONCLUSIONS

In conclusion, we can summarize that with the COIL project students gained experience preparing them well for the challenges which might be encountered in intercultural interdisciplinary collaborations. The participants developed intercultural competences, i.e., the relevant knowledge, skills and attitudes to relate and communicate effectively and efficiently with individuals from other cultures. In this group effort, team members from each university came with their diverse perspectives and design approaches but when working together to achieve a common goal, they learned how to share knowledge and build mutual trust to find the solutions of the problems together. Despite the communication gap which was reported by the participants as a shortcoming we consider it beneficial for their training because by dealing with it they learned how to manage the tensions of collaborative work. To avoid the occurrence of such problems in future collaborations we plan to ensure a closer supervision of the collaborative process to aid the teams deal with them in a timely manner.

We were very satisfied to observe that all students showed willingness to overcome the problems and that during the process they built confidence in their own skills as designers, in regard to both generating and communicating ideas to the others. We consider reflection as an important element of learning that promotes conscious thinking and analysis of the educational experience, so we encouraged students to rationalize how the collaboration has contributed to their personal development. *“I didn't have experience working with people from other countries and other design fields, but now I know what I have to improve in order to work effectively with colleagues I haven't met before,”* shared one of the students. This opinion, together with the overall higher quality of the projects in comparison to the traditional in-house projects testifies the successful outcomes of COIL implementation in the educational process.

REFERENCES

[1] Karacay G. *Talent Development for Industry 4.0*. In Ustundag, A. Cevikcan, E. (Eds.) Industry 4.0: Managing the Digital Transformation, 2018, pp.123-136 (Springer).

[2] Salmon G. May the Fourth be with You: Creating Education 4.0. *Journal of Learning for*

Development, 2019, Vol. 6, No.2, pp. 95-115.
[3] Goldschmidt G. The designer as a team of one. *Design Studies*, 1995, 16(2), 189-209.
[4] Sanders E. N. and Stappers P. J. Co-creation and the New Landscapes of Design. *CoDesign 4*, 2008, no. 1, pp.5–18.
[5] Hao C. Cultura: Achieving intercultural empathy through contextual user research in design. 2019 DOI: 10.4233/uuid:88322666-9cf1-4120-bbd6-4a93438bca74.
[6] Hao C. Van Boeijen A. and Stappers P. J. Cultura: A communication toolkit for designers to gain empathic insights across cultural boundaries. In L. Alberto (Ed.), *Procedente de IASDR Conference RE: Research.* 2017, pp. 497-510 Cincinnati University. https://doi.org/10.7945/C2SD5J.
[7] Marradi C. *A Design Tool-Box to Scale Social Innovations from one context to another: Unfolding the Scaling Journey of Designscapes Initiatives*. 2021. Available: http://resolver.tudelft.nl/uuid:9beaf6fd-b585-4d1c-87f8-9281176d222c [Accessed on 2022, 7 March].
[8] Dillenbourg P. What do you mean by collaborative learning? In P. Dillenbourg (Ed.) Collaborative-learning: Cognitive and Computational Approaches. 1999, pp.1-19 (Oxford: Elsevier).
[9] Emitt S. and Ruikar K. *Collaborative Design Management*, 2013 (Routledge).
[10] Rubin J. Faculty Guide for Collaborative Online International Learning Course Development. Available: http://www.ufic.ufl.edu/UAP/Forms/COIL_guide.pdf [Accessed on 2022, 1 March].
[11] Dillenbourg P., Järvelä S. and Fischer F. *The evolution of research on computer-supported collaborative learning: From design to orchestration*. In N. Balacheff et al. (Eds.), Technology-Enhanced Learning. Principles and Products 2009, pp. 3-19 (Netherlands: Springer).
[12] Baker M. Andriessen J. and Järvelä S. *Affective Learning Together: Social and Emotional Dimensions of Collaborative Learning*, 2013, pp. 1-31 (Taylor & Francis Group).
[13] Sins P. and Karlgren K. *Identifying and Overcoming Tension in Interdisciplinary Teamwork in Professional Development.* In M. Baker et al. (Eds) Affective Learning Together: Social and Emotional Dimensions of Collaborative Learning, 2013, pp. 185-205 (Taylor & Francis Group).
[14] Casanova Uribe M. O. *Aprendizaje Cooperativo en un Contexto Virtual Universitario de Comunicación Asincrónica: Un estudio sobre el proceso de interacción entre iguales a través del análisis del discurso*. 2009. (Universitat Autònoma de Barcelona).
[15] Cole M. and Engeström Y. *A cultural-historical approach to distributed cognition*. In G. Salomon (Ed.), Distributed Cognitions: Psychological and Educational Considerations, 1993. pp. 1– 46. (Cambridge University Press).
[16] Schön D. *Educating the Reflective Practitioner*. 1987 (Jossey-Bass, San Francisco, CA).

NEW FOOTING FOR SERVICE DESIGN: ROOTS OF MEANING

Severine VAN HOECKE, Lien DE SCHEPPER, Emile COGNIE and Ivo DEWIT
University of Antwerp, Faculty of Design Sciences, Department of Product Design and Development, Belgium

ABSTRACT
Innovative organisations worldwide are part of a rapidly evolving world concerning innovation, digitalisation and economic growth. Consequentially, manufacturing companies are seeing opportunities when exploring the new field of product–service systems (PSS) and are excelling in these. With regards to the liquefying advantage and valuable flexibility of servitization, there is still an under-addressed early exploration phase that primarily focuses on the mere service component. This lack of research attention might hinder organisations from developing PSS. Nonetheless, it acts as an opportunity to address servitization at an earlier development stage without compromising on radicality. The existing literature is abundant with tools and methods to optimise the PSS design process, but this paper focuses on the integrative design of PSS and proposes to continue onward from the early servitization component and service-based innovation literature. This paper redirects the spotlight on the intangible component and the impact of a meaningful user experiences in the early stages of the design process.
These contributions aim to avoid designing for a strictly product-oriented world and turn towards a human-fuelled existence, instead of floating along the current consumer-minded wave. Through radical service design, meaning will prevail and harbour our human needs and drives, compelling the excessive tangible products to take a step backwards and in doing so creating a positive ecological effect.

Keywords: Service design, design methods, radical innovation, servitization, product-service system, value, meaning

1 INTRODUCTION
In recent years, consumerism has given way to people's need for meaningful and fulfilling experiences. Designers sense the need to shift to service-focused innovations because of the shift towards a product-poor and information-rich economy, which is presently supported mainly by digitalisation. Service design has grown simultaneously with the emergence of digitalisation and has been attracting more attention. According to Penin [1], all economies are service economies. We find ourselves in a service revolution, inching away from consumerism to a service-based economy. Modern consumerism is inevitably shifting towards more meaningful solutions and raises questions about sheer technological-driven innovation. As this continues, economic growth in modern societies increasingly originates from service-based innovation.
This paper discusses the potential of radical service design in shaping the future. Radicality of service design implies letting go of existing defining borders and looking onward to a serviced-oriented future. Radicalism holds the power to make a drastic change for the better, disrupting the status-quo and inviting novelty [2].
The research will explore the radicality of service innovation that can be implemented by service providers. Aspects that will increase the effectiveness of the radical service design process will be discussed. It incorporates the necessity to design for human needs and meaning, which is achieved by prioritising valuable radical innovations on the service component. It will combine the existing conceptual literature on PSS design tools, novelty processes and philosophical frameworks to advise on how to lower thresholds when developing radical services.

2 LITERATURE REVIEW

2.1 Service's relations

Zeithalm et al. [3] describe services as "Immaterial, heterogeneous, inseparable and perishable". Services are inherently intangible because they don't only rely on objects. They can change and adapt to their context. They're de facto interactions, so production and consumption happen simultaneously, and the experience can only be remembered but not kept physically. The description is still applicable to radical services, but the following still lacks further exploration: the emphasis on interactions and relations between the different actors of the service [4].

In post-phenomenology, the object and subject are not seen as different entities [5]. Therefore, the relations, which influence the human experience of the world, are taken into account. Ihde distinguishes four types of relations: embodiment relations, hermeneutic relations, alterity relations and background relations in the context of technology. But Secomandi [6] argues that those relations between the user and the digital context can be extended to interpersonal relations in services.

In the context of interpersonal relations in services, Cipolla and Manzini [7] distinguish the 'I-It' and 'I-Thou' encounters. The former are standard services, interactions with something already known. 'I-Thou' encounters involve relationships between two persons and in a context that is not known, nor predictable. An I-Thou encounter has several possible advantages for radical services: "it is a service that improves or regenerates contexts of life, enabling and stimulating participants to collaborate with others. Relational services are able to promote a 'social learning process' towards sustainability, indicating a way of living based on sharing and collaboration, promoting the reinforcement of local social fabric and the creation of new common goods" [7]. I-Thou relationships can only be 'meta-designed': the service can only start, support and assist the interpersonal encounters.

2.2 Radical service design

Despite what was stated earlier, there is still not enough incitement in the early stages of the design process, exploration and ideation. It hinders the creation of opportunities for radical service design in the later process because the service component is still under-addressed, which compromises its radicality. Radical innovations can shake and disrupt the market with creative solutions to put today's ineffective and counterproductive structures to the test [2]. But can the effect of radical services be predicted? Radical services will impact society in the long term by intervening in the system and disrupting current structures. Such intervention in a system can be seen as a leverage point with a circular and self-sustaining characteristic. As radical services are transformational, there is the possibility they won't fit in the current system anymore. Radical disruption brings a change to the user's life, in contrast to an incremental service which builds upon the existing. The power of the radical intervention lies in its capability of letting the user *aggregate value* to the information flow at the time and place of use.

"Radical service design allows meaning to be the leading factor and harbour our human needs and drives while taking the relations and interactions of the different actors into account. Radical services are immaterial, heterogeneous, inseparable, and perishable. They challenge the socio-economical structures of today."

Suppose a *tax system where citizens choose how their taxes are being spent;* radical democracy, or a *university student selectively attending a class of choice solely to learn what he/she came for*; radical learning [18]. In addition, radical service unknowingly bonds the user with underlying factors such as *need fulfilment* and a *meaningful engagement*, which leads to a *positive emotional attachment*. Figure 1 below visualizes the previous aspects in a circular manner.

When it comes to *meaningful engagement*, designers must become aware of the real underlying reasons of *why* people consume and not *what* they consume. The attached meaning will determine if users interpret the service intervention as a substantial innovation that can change their quality of life. The whole design process starts with understanding the meaning people attach to products and services because people buy meaningful interventions and not the products themselves. Take Airbnb as an example, the online accommodation marketplace for lodging worldwide. In essence, it offers a more personal and engaging travelling experience that goes much deeper than traditional hotel booking. Lüneburg et al. [8] found that meaningfulness also depends on emotional and psychological meaning, not just the usability and utility of an innovation. But Hassenzahl [9] found that utility and usability are considered in the light of need fulfilment. Understanding 'emotional ownership' that's encompassed

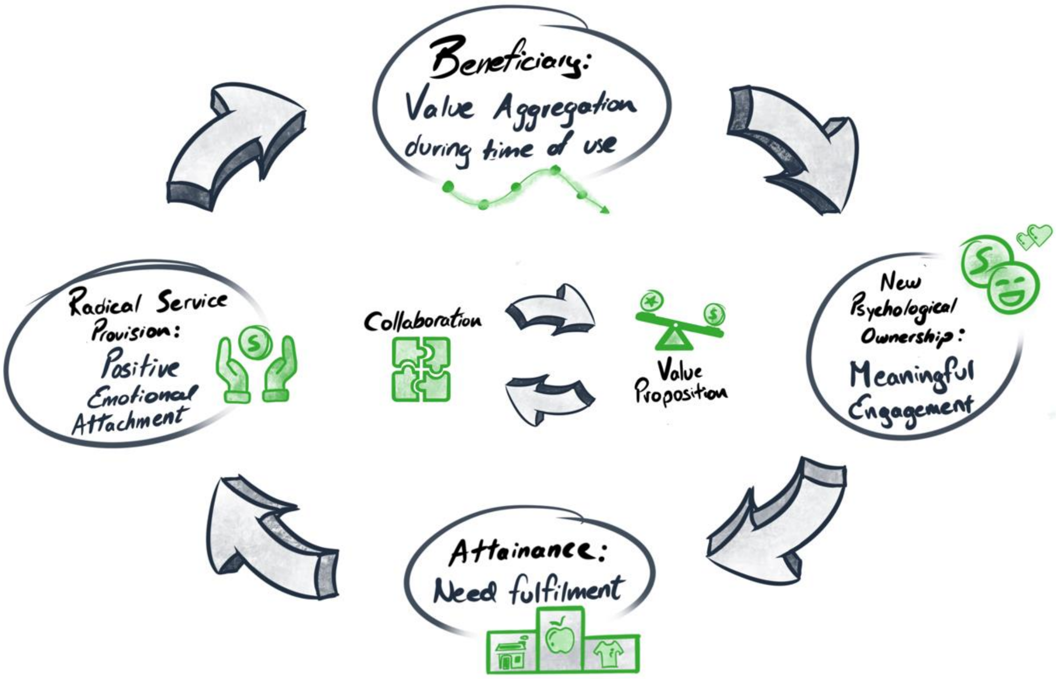


Figure 1. The four main stages of the Radical Service cycle

within the service, is of essence when understanding what value is offered and what needs are fulfilled before any meaning can be given to the service-to-be.

By *need fulfilment* is understood the 'intangible component' that serves as a mediator when creating value in the short term. Essential feelings that users seek to fulfil in life are addressed. These aren't products or services themselves that fulfil user needs, but rather the opportunity they create. The sense of fulfilment can be addressed by emotional design, which can in turn create a positive emotional bond between the product and the user [10]. The core needs must be deduced from users' habits and actions early in the design process, to appoint a uniquely long lasting & self-expanding characteristic to the service proposition. No economic or practical reward is desired by the users during usage because the engagement is already a meaningful activity to attain their emotional needs.

If the emotional needs are properly met and attained, the service can in turn create a *positive emotional attachment* with the user. Considering a customer's values can aid the designer in sustaining the meaningful engagement and create something thoroughly radical. A person's values are what they deem important in life to make it worth living, which is a subjective manner. Whereas the value of goods can be objectively measured, for instance with money. The Value Framework of den Ouden [2] describes four areas of value, which can be used to develop a radical service.

Radical services rely on developing no physical goods at all. This means the concept of value arises through *value aggregation* instead of possessing value. By decentralising physical goods, a radical service will naturally fill in this gap by allowing the beneficiary to aggregate value *during* the entire service provision. The actively involved user will now become the core value of exchange through psychological ownership instead of physical possession to make the interaction more meaningful. Today 'possession' mostly assumes physical attributes, which is tied to pride and advocacy. Since the physical aspects of a service are now limited to the bear minimum, for the user, the shift to no physical goods will cause the service to become a more meaningful and psychologically rich ownership. According to the Service-Dominant-Logic (SDL) theory [11], the user of the good itself should be the central piece instead of the product. But when the user's needs are being accounted for in the service, the need for physical ownership will become negligible because the real emotional needs will have been met through a sense of advocacy and joy. In such relational service the danger exists that the limits of 'economical rationality' will be reached [12]. People will unlikely be willing to pay for services that appear as intrinsically 'human,' e.g., during an encounter at a school gate, one parent proposes you to bring your child to school [13]. Transforming this free offered 'service' as a priced one, would jeopardise the integrity of the encounter.

2.3 The Impetus of Services

The Impetus of Services Embedded within the Radical Service scheme in Figure 1, sits the idea of collaboration and a rigid value proposition. How can a service provider steer this self-sustaining value creation without any physical object attached to it? Designers or Service providers cannot deliver value but offer only a value proposition to be aggregated by the beneficiary in the moment and the place of the value creation [4]. An authentic value proposition "explicitly addresses social responsibility and eco-effectiveness" [14]. By incorporating symbolic, emotional, functional and economical dimensions into the statement, the organisation will thrive authentically and stay close to the customer to avoid discrepancies between the business proposition and the customer perception [15]. The proposed value doesn't lie in the outcome itself, but in its self-expanding characteristic. Looking at Apple, the beacon of innovation during the early 2000's, with the launch of iTunes. Apple gave birth to a radical new way of experiencing music. iTunes grew as an easy, affordable, and legal way to become part of the growing digitalization of music. All of this, counted on artists and musicians to participate in the growing trend without customers owning a single physical CD.

Through collaboration, the tacit knowledge, which includes the meaning people attach, needs and values, of other involved parties can be included in the design. Collaboration in a multidisciplinary team is therefore essential because it is often not known who possesses the appropriate knowledge [16]. The team needs to be composed of interpreters and relevant stakeholders. Interpreters, such as artists, designers, or philosophers, can create an impact for the customers during the design process. They listen to the design discourse as a first step. By looking closely into the context, they interpret the meaning people assign to specific activities. Interpreters can even influence the meaning that people give to object and services by proposing radical but realistic ideas. They have the power to change the existing cultural paradigms and introducing new meanings [10]. Ideally, companies, institutions, or even untargeted people can further strengthen the team. However, an overly keen focus on customer preferences tends to lower the innovation ambitions and outcomes [17]. Customer involvement should therefore be restricted only to the design phase [18]. If guided by the right tools and people, they could lead to an increase in radicality.

3 CONCLUSIONS

Radical service design allows meaning to be the leading factor and harbour our human needs, drives and values while taking the relations and interactions of the different actors into account. The different kind of relations characterise the different services and serve as an inspiration source for designing different kind of services. The embodiment relations, hermeneutic relations, alterity relations and background relations are distinguished, as well as the *I-Thou* from the *I-It* encounters. They challenge the socio-economical structures of today. The *I-Thou* encounters lie hand in hand with the post-phenomenological viewpoint. Such relations are meta-designed during the start of the service and while supporting and assisting the interpersonal encounters. It further emphasises this relational behaviour between object and subject not as separate entities but rather as a human experience of the world.

Radical services are immaterial, heterogeneous, inseparable, and perishable. Looking at *Figure* 1, the service provider must lean on collaboration in a multidisciplinary team as well as a clear Value Proposition. It is necessary to reveal the tacit nature of human needs, drives, values, and the meaning people attach to products. By making use of interpreters, it is also possible to influence those.

Since in radical services the only forms of value are the user and the service itself, no physical ownership ought to be considered in this radical model. Decentralising physical goods and replacing this by remembering the experience of the service instead of an economical, physical, or practical reward. It is up to the service provider to steer the value creation in an indirect manner. The user is seen as the creator who aggregates value throughout the use of it. Designers can accomplish this by attaining the user's need fulfilment, by considering a meaningful engagement for the user from the very start and ensuring a positive emotional bond to close the cycle. Furthermore, stakeholder collaboration during the early stages of development should help state a clear value proposition. The latter should encompass how value will be aggregated, by whom and to whom.

Further Research The paper touches upon the effect of radical services. But to be able to predict this, it is necessary to pinpoint and test the parameters of radical services. The elaboration during early process steps that dig for value and the emphasis on meaningful engagement are beneficial steps when creating services that cater to need fulfilment. The extent to which it would produce a radical solution is left unanswered. This paper suggested the fundamentally embedded parameters of immateriality,

heterogeneity, inseparability, perishability complemented by the integration of meaning people attach to services, their need fulfilment, and their values. The kind of relational encounter could be an indicator of the degree of radicalness of a service. Although in the case of the latter a clear definition or radicalness indicator could be developed. Similarly, it isn't indicated which parameters carry more weight.
It would be interesting if based on the literature framework different kind of blueprints for radical services could be formed and tested. Likewise, the success of a more systematic and step-by-step guidance for radical service development could be a valuable starting point for further research. This way it will also become clear if the statements made in this paper will remain valid even if a more detailed approach existed. Is a visual cycle, as was given in Figure 1, useful when being implemented in a 'real world' context? Would a co-creation toolkit for the collaborative process help move the design process forward in the right direction? Would it focus on the important aspects of gathering essential information to exercise a maximum influence on existing cultures? Would a complimentary model on push-strategies over pull-strategies still highlight the four crucial stages as mentioned earlier?
The impact of integration of meaning, need fulfilment, positive attachment, and the effect of psychological ownership of non-physical goods still needs to be researched. Although these have been identified as four main stages of a radical entity, their effectiveness and dependency still need to be researched. When it comes to the effectiveness of one of the stages or the Radical Service cycle in its whole, there is still room for an exploration on the short- and long-term effects of radical services themselves. How and why a radical deployment would cause a long-lasting change for the better and reinforce itself thanks to its self-expanding characteristic. In other words, a loop with a sustainably reinforcing quality. Alternatively, the deployment of a novel service can also reach a simple instant gratification without any self-sustaining quality.
Lastly, the extent to which a radical service effectively reinforces the social fabric of society needs to be further assessed. Since the radical solution is purely intangible and does not propose any physical attribute attached to the service provision, it relies on a relational character. This relational aspect is almost non-measurable and hard to define. Up to what point the service maintains its relational character before reaching an economical rationality, is closely related to the research touched upon in this paper. The extent to which the radical service can keep its relational character is still unclear.

RELEVANCE FOR DESIGN EDUCATION

This paper incites to reflect on the stages of an innovative service of a radical nature. With a collaborative approach, this paper challenges service design educators to question the fulfilment of needs and the meaning for the user.

REFERENCES

[1] Penin L. (2018). *An introduction to service design: Designing the invisible.* Bloomsbury Publishing Plc. https://doi.org/10.1080/14606925.2019.1615677.
[2] den Ouden E. (2012). *Innovation design: Creating value for people, organizations and society.* Springer. https://doi.org/10.1007/978-1-4471-2268-5
[3] Zeithalm V. A., Parasuramon A. and Berry L. L. (1985). *Problems and strategies in Services Marketing*. Vol. 49 No. 2, pp. 33-46. Journal of Marketing. https://doi.org/10.2307/1251563.
[4] Morelli N., de Götzen A. and Simeone L. (2020). *Service design capabilities* (1st ed.). Springer, Cham. https://doi.org/10.1007/978-3-030-56282-3.
[5] Ihde D. (1990). *Technology and the lifeworld: From garden to earth.* Indiana University Press. https://iupress.org/9780253205605/technology-and-the-lifeworld/.
[6] Secomandi F. (2012*). Interface matters: Post phenomenological perspectives on service design.* [Doctoral thesis, Technische Universiteit Delft]. TU Delft research repository. https://doi.org/10.4233/uuid:57e33f9a-b634-4cb2-bad0-8c5b35f7ae65.
[7] Cipolla C. and Manzini E. (2009). *Relational services*. 22(1), pp.45-50. Knowledge, Technology & Policy. https://doi.org/10.1007/s12130-009-9066-z.
[8] Lüneburg L.-M., Papp E. and Krzywinski J. (2020). *The potential of wearable demonstrators introducing innovative technologies.* Proceedings of the Design Society: DESIGN Conference, 1, 2029–2038. https://doi.org/10.1017/dsd.2020.306.
[9] Hassenzahl M. (2010). *Experience design: Technology for all the right reasons*. Morgan & Claypool, San Rafael, CA. https://doi.org/10.2200/S00261ED1V01Y201003HCI008.

[10] Verganti R. (2009). *Design driven innovation: Changing the rules of competition by radically innovating what things mean.* Harvard Business Press.
[11] Zsigmond T., Zsigmondová A. and Machova R. (2021). *From goods-dominant logic to service-dominant logic.* SHS Web of Conferences, 120, 02015. https://doi.org/10.1051/shsconf/202112002015.
[12] Gorz A. (1989). *Critique of Economic Reason*. Verso. London.
[13] Mason P. (2016). *Postkapitalisme, De Bezige Bij.* Amsterdam.
[14] O'Cass A. and Sok P. (2015). *An exploratory study into managing value creation in tourism service firms: Understanding value creation phases at the intersection of the tourism service firm and their customers.* Tourism Management, 51. https://doi.org/10.1016/j.tourman.2015.05.024.
[15] Polanyi M. (1996). *The tacit dimension*. New York: Doubleday anchor. https://press.uchicago.edu/ucp/books/book/chicago/T/bo6035368.html.
[16] Goduscheit C. R. and Faullant R. (2018). *Paths towards radical service innovation in manufacturing companies - A service-dominant logic perspective.* Journal of Product Innovation Management, 35. https://doi.org/10.1111/jpim.12461.
[17] Melton H. and Hartline M. (2015). *Customer and employee co-creation of radical service innovations.* Journal of Services Marketing, 29, 112–123. https://doi.org/10.1108/JSM-02-2014-0048.
[18] Meadows D. (1999). *Leverage Points: places to intervene in a system*. pp. 13. The Sustainability Institute.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

VARIOUS FORMS OF EXECUTING PEER REVIEWS IN CIVIL ENGINEERING EDUCATION

Anette HEIMDAL and Ingrid LANDE
University of Agder, Norway

ABSTRACT
This paper investigates the students' perceived outcomes of different types of peer review. The purpose is to evaluate the students' learning outcomes through surveys after attending the various peer review sessions. The motivation for using peer reviews for the engineering students is to engage the students as presenters and opponents. This could improve the students' ability to be critical of their work and to give and receive feedback. The three different peer review concepts investigated in this paper are i) supervised peer review with one or more university employees, ii) unsupervised peer review where the students will execute the session on their own, and iii) written peer review where the students will be organised in pairs with another group and only give and receive written feedback.
The results from the surveys can identify the learning outcomes and other dividends from the different ways of using peer review as a part of the supervising on the academic work. The findings could help improve the ways of supervising students in their academic work, and also whether the different ways of executing the peer reviews differ much in the students' learning outcomes.

Keywords: Peer review, civil engineering, survey, supervision

1 INTRODUCTION
There is evidence that peer review could have significant benefits for both students and university staff members in higher education. Mulder et al. [1] concluded that facilitating student peer review could help university staff members to provide more detailed and timed feedback to students. This was especially true in large classes, which is a common occurrence in higher education. A further finding was that participating in student peer review helps students to gain a deeper understanding of course material and assessment requirements. However, students often doubt the credibility of their peer's feedback. Zacharias' [2] findings were that students value the feedback from teachers high, and are insecure about the feedback from peers. Not only do the students doubt the credibility of the feedback provided by their peers, but according to Cheng et al. [3], the students also lack confidence in their abilities to critique the work of others. One of the conclusions of Mulder et al. [1] was that implementing peer review in higher education could help students develop important skills of self-assessment.
This paper will be a continuation of the paper from *the International Conference on Engineering and Product Design Education* in 2020: "Investigations on the use of student peer review to improve supervision of capstone courses in the civil engineering education" [4]. This paper concluded that the students had high expectations of the outcome of participating in peer reviews, but that the perceived outcome was even higher. It was also found that peer review is a valuable tool for students. However, the research had supervised peer review with four university employees present at all the sessions. Even though this resulted in a more efficient way of supervising many bachelor and master's students at the same time, the students in [4] had the same supervisors and were working on the same research project. Therefore, the purpose of this paper is to invite all the students writing their bachelor and master's thesis in civil engineering and only have the persons responsible for the courses present at the peer reviews. Thus, this will result in more work for the university staff. By investigating the students' feedback on three different ways of conducting peer review we hope to answer the following key question:

- How do students evaluate different executions of peer reviews, and how useful do they rate the feedback?

2 CASES

The students participating in this investigation on peer reviews are in their final semester in the bachelor programme or master's programme in civil and structural engineering at the University of Agder in Norway. The capstone course for the bachelor programme is 20 ECTS and 30 ECTS for the master's programme. The semester started 5^{th} January 2022 and the students have until May 2022 to finish their projects. The bachelor students are writing in groups consisting of 3-4 students, while the master's students can write alone or in groups of 2-3 students. An overview of the total number of students writing their bachelor and master's thesis is given in Table 1. Most students chose a project in cooperation with the local industry, meaning that the students have one supervisor from the industry and one supervisor from the university. The projects result in a thesis following an IMRaD (Introduction, Methods, Results and Discussion) template and an oral defence. Both the bachelor and master's students use the same template.

At the beginning of the semester the students had a start-up workshop where general information about writing a thesis was given, and an explanation of the template. The scheme of the peer review was given during this workshop, where the students had to sign up for all three peer reviews on the workshop held at the beginning of the semester. A total of 22 bachelor students and 9 master's students signed up to participate in the peer review sessions (Table 1). The peer reviews covered topics from different chapters from the template. The students have experience with using the template in previous courses. They have also had supervised peer review previously in their study and know the purpose and process of peer reviews. Hence, the students received these peer reviews as additional guidance on their academic work.

Table 1. Overview of participants in the study

Study programme	Total number of students registered	Participating in peer review
BSc	54	22
MSc	41	9

2.1 Execution of peer review

The three different peer review concepts are i) supervised peer review with one or more university employees, ii) unsupervised peer review where the students will execute the session on their own, and iii) written peer review where the students will be organized in pairs with another group and only give and receive written feedback. The first peer review topic was the *research question and project plan*, the second peer review was about *methods*, and the last peer review concerned their *theoretical background*. The bachelor and master's students had separate peer review sessions.

Overview of presenters and opponents was given to the students 2-3 days ahead of the peer reviews along with information about the sessions. The students were contacted via e-mail 2-3 days before the peer review. The following information was given:

- Contact information to the participants
- Schedule with presenters and opponents including the title of their thesis
- The topic of the peer review
- Purpose of the peer review
- Expectations and guidelines for the presenters and opponents

2.2 Supervised peer review

The feedback in the supervised peer review was given orally by the opponent, peers, and lecturer. Even though the university had opened after the pandemic, we considered it more including for everyone to conduct it digitally using *Zoom*. The opponents received the presentations before the session to prepare feedback in advance.

All participants were present throughout the session. The presenters had 15 minutes to present their research questions and progress plan. The opponent started giving feedback, followed by feedback from other peers and the lecturer.

The topic of the supervised peer review was the research question and the progress plan for their projects. The research question and the progress plan must be approved at the beginning of February. This is a requirement for examination [5, 6].

2.3 Unsupervised peer review

Unsupervised peer review was also conducted using Zoom. The lecturers started the session but left after the introduction. The unsupervised peer review was conducted in the same way supervised peer review but without lecturers present. The topic of the unsupervised peer review was methods. According to National Guidelines for engineering studies [7], the students should be able to use relevant methods for research and development work. Hence, this topic was chosen for the unsupervised peer review.

2.4 Written peer review

The students sent their work to their other peers by e-mail. This was limited to three pages to reduce the workload. The opponents had one week to give written feedback before sending it to the lecturers for final feedback. Written feedback was given as comments in the Word or pdf document. The total timeline of the written peer review was two weeks.

The topic for the written peer review was the theoretical background. A scientific theory section should be included in a thesis [7] and the students should be able to anchor their work in research [5].

3 METHODS

Students were asked to answer one survey after each peer review session. After the supervised peer review sessions, a joint survey was sent to the bachelor and master's students. This contained five multiple-choice questions and one free-text comment option. This was distributed on the 25th January and was available for the students until the next peer review sessions on the 8th February. The second survey was distributed on the 8th February after the unsupervised peer review sessions and contained 8 questions where one was a free-text comment option. To be able to see the difference between the bachelor and master's students two identical surveys were sent: one for the bachelor students and one for the master's students. The same was done after the written peer review. This final survey consisted of a total of 11 multiple choice questions and one free-text comment option. These surveys were distributed 10th March and closed on the 14th March and had one activation. If the students answered that they did not participate in the written peer review an extra question would appear asking why they did not participate. All surveys were distributed by E-mail and made with SurveyXact.

The students were asked to evaluate on a scale of 1 to 5 where 1 meant very poorly, unsatisfied, useless and 5 meant well, very satisfied, and very useful, on questions concerning their preparations, presentation of their work, feedback, and overall satisfaction. The five multiple-choice questions from the first survey were identical to the next surveys. These were analysed by calculating an average and the standard deviation. The standard deviation was calculated to show the variation in the students' opinions.

4 RESULTS AND DISCUSSION

An overview of the surveys is shown in Table 2 below, containing information about education degree, distribution date, number of questions and response rate. The first survey was sent to both bachelor and master's students. Regarding unsupervised peer review and written peer review, we decided to send different surveys. Consequently, we could see if there is any difference between the students with different educational degrees.

Table 2. Data about the surveys

	Education degree	Date	No. of questions	Response rate
Supervised peer review	BSc and MSc	25-Jan-22	6	68%
Unsupervised peer review	BSc	8-Feb-22	8	64%
	MSc	8-Feb-22	8	67%
Written peer review	BSc	10-Mar-22	12	45%
	MSc	10-Mar-22	12	56%

Students rate their preparedness as relatively high. In response to "How well prepared were you for the peer review?", the bachelor students rated their preparedness consequently higher than the master's students on all three peer reviews (Table 3). It is worth mentioning the standard deviation on the written peer review for the master's students. This is owed to severe differences in answers; with two students rating 1 very poorly prepared and two students rating 5 well prepared. A possible explanation for these results could be in line with Gielen et al. [8] observed advantages from the peer review session. Firstly, when participating in peer reviews the students would spend more time on their work, which can improve the quality of the work. Secondly, the risk of embarrassment from peers could also pressure the students to perform better. Furthermore, when the students were asked how much time they spent on preparing the three pages for the written peer review, the bachelor students would spend more time than the master's students. Interestingly though, the bachelor students would spend less time giving feedback to others than the master's students.

Table 3. Average results from the surveys with standard deviation in parenthesis

	Supervised peer review	Unsupervised peer review		Written peer review	
	BSc & MSc	BSc	MSc	BSc	MSc
How well prepared were you for the peer review?	3.81 (0.60)	3.86 (1.17)	3.50 (0.84)	3.89 (0.78)	3.00 (2.31)
How well did you present your work?	4.19 (0.60)	3.29 (1.20)	4.17 (0.75)	4.00 (1.00)	3.67 (1.15)
How useful was the feedback from peers?	4.00 (1.00)	2.36 (0.84)	4.00 (0.00)	2.78 (1.09)	4.00 (1.00)
How useful was the feedback from the university staff?	4.76 (0.44)	-	-	4.89 (0.33)	4.33 (1.15)
How satisfied are you with the peer review?	4.24 (0.54)	2.64 (1.22)	4.00 (0.63)	3.67 (0.71)	4.00 (1.15)

It is apparent from Table 3 that the students found the feedback from the university staff more useful than the feedback from peers. These results are consistent with data obtained in "Teacher and student attitudes toward teacher feedback" [2]. Students often tend to blindly trust the feedback from the teachers and assume that it is the correct way of solving a problem.

The most striking result to emerge from Table 3 is the low scores from the bachelor students on unsupervised peer review. This discrepancy could be attributed to the lack of confidence in their ability to critique the work of their peers in line with the findings of Cheng et al. [3]. The students approached the authors after the unsupervised peer review with several questions they wanted to be answered. The same thing happened to Zacharias [2]; when the students were told to comment on each other's work they would often ask the teacher to verify if the comments were true. In the free-text comment option, one student wrote: 'I think it would work better with the university staff members present who knows the formalities of the thesis. A lot of my peers threw out opinions which sometimes turned out to be wrong. This confuses us and makes us insecure on how to execute our work correctly.' This was further corroborated by another student: 'It was hard to know if the feedback from our peers was good. It was a lot of assumptions from my peers which is difficult to relate to. However, an all-right peer review.' These results are consistent with those of Mulder et al. [1] findings which showed that one-third of the interviewed students worried that they did not have adequate experience and they were also concerned that their reviewers were not experienced enough. The master's students, however, seemed to find all the different peer reviews useful and were also satisfied with the unsupervised peer review. This could confirm the insecurities of the bachelor students and prove that master's students are more self-driven and independent in their work.

However, the scores from the supervised peer review are rated quite high on all five questions, including the feedback from peers. In the free-text comment option, there are no comments about the lack of competence in their peer. One of the comments was: 'Peer review gives good guidance in your task, and a lot of the discussions regard all of us. There is probably a correlation between participation, preparedness, and results. I would like to see more students participate in the peer reviews.' It seems to us that having university staff members present could remove some of the insecurity in feedback.

According to Van Berg et al. [9], one role of the teacher in the peer review process is to facilitate an arena where the students feel safe in assessing the work of their fellow students. This, in turn, could explain the differences between the supervised and unsupervised peer review sessions.

5 CONCLUSIONS

This paper investigated the students' feedback on three different ways of conducting peer review, and sought to answer the question:

- How do students evaluate different executions of peer reviews, and how useful do they rate the feedback?

The students evaluated the supervised peer review as very useful. However, the score from the unsupervised peer review varied between the bachelor students and the master's students. The master's students rated this equally to the supervised peer review, while the bachelor students had trouble conducting this peer review. They had doubts regarding their peers' feedback and needed validation afterwards from the teachers. Furthermore, the students rated the feedback given by university members as very useful which could indicate that they trust this feedback more than their peers' feedback. On the other hand, it seems like the educational degree plays a role in the evaluation scores. The master's students seem to find all the three different conduction of peer review useful, managed to give constructive feedback to their peers and were also satisfied with the peer reviews.

Although the current study is based on a small sample of participants, the findings suggest that the bachelor students could need a closer follow-up from the university staff, because of the lack of trust in their peer's feedback. Overall, the students rated the conduction of the peer reviews as useful but came with strong recommendations in the surveys that supervisors or teachers should be present at all peer reviews to avoid confusion and mixed feedback.

6 FURTHER RESEARCH

Further research should be carried out to establish if the written peer review would improve if the feedback also was explained orally. Van Berg et al. [9] investigated the use of written and oral feedback in higher education, finding that to obtain the most complete feedback a combination of both feedback types is essential, where the written feedback can be orally explained and discussed. Another aspect would also be to research the students' experiences and learning outcomes when giving feedback and reviewing others' work. Gaynor studied the quality of written peer feedback, the importance of assessments and student perceptions [10], concluding that the students perceive reviewing and giving feedback to their fellow students as more useful than receiving feedback on their work, as well as believing that it improved their understanding of the assignment.

REFERENCES

[1] Mulder R., Baik C., Naylor R. and Pearce J. How does student peer review influence perceptions, engagement and academic outcomes? A case study, *Assessment & Evaluation in Higher Education,* vol. 39, no. 6, pp. 657-677, 2014.

[2] Zacharias N. T. Teacher and student attitudes toward teacher feedback, *RELC journal,* vol. 38, no. 1, pp. 38-52, 2007.

[3] Cheng W. and Warren M. Having second thoughts: Student perceptions before and after a peer assessment exercise, *Studies in Higher Education,* vol. 22, no. 2, pp. 233-239, 1997.

[4] Heimdal A., Thorstensen R. T. and Svennevig P. Investigations on the Use of Student Peer Review to Improve Supervision of Capstone Courses in the Civil Engineering Education, in *DS 104: Proceedings of the 22nd International Conference on Engineering and Product Design Education (E&PDE 2020), VIA Design, VIA University in Herning, Denmark. 10th-11th September 2020*, 2020.

[5] University of Agder. Bachelor Thesis, Civil Engineering. *https://uia.no/en/studieplaner/topic/BYG300-G* (accessed Februray, 2022).

[6] University of Agder. Master's Thesis. *https://uia.no/en/studieplaner/topic/BYG508-G* (accessed Februrary, 2022).

[7] *Forskrift om rammeplan for ingeniørutdanning*, 2018.

[8] Gielen S., Tops L., Dochy F., Onghena P. and Smeets S. A comparative study of peer and teacher feedback and of various peer feedback forms in a secondary school writing curriculum, *British*

Educational Research Journal, vol. 36, no. 1, pp. 143-162, 2010, doi: 10.1080/01411920902894070.
[9] Van den Berg I., Admiraal W. and Pilot A. Designing student peer assessment in higher education: Analysis of written and oral peer feedback, *Teaching in higher education,* vol. 11, no. 2, pp. 135-147, 2006.
[10] Gaynor J. W. Peer review in the classroom: Student perceptions, peer feedback quality and the role of assessment, *Assessment & Evaluation in Higher Education,* vol. 45, no. 5, pp. 758-775, 2020.

PEDAGOGY OF PROCESS: INTERDISCIPLINARY CASE STUDIES FROM AN IRISH UNIVERSITY

Orfhlaith Mairead NI BHRIAIN[1], Louise Bridget KIERNAN[2], Bernard HARTIGAN[3], Eoin WHITE[4], Hannah FAHY[5] and Kathleen TURNER[6]
[1,5,6]Irish World Academy of Music and Dance, University of Limerick
[2,3,4]School of Design, University of Limerick

ABSTRACT
The aim of this research was to pilot a multi-disciplinary approach to creative pedagogy through collaboration between students and faculty from performing arts and product design. Creative pedagogy of process is a pedagogical approach that draws on the interaction and engagement of faculty and students across a range of disciplines and involves ethnographic research methods combined with reflective practice and a user centred design approach. This approach develops transversal competencies, common across creative domains and provides a rich learning environment for students and faculty alike. This paper examines the challenges and opportunities presented by a collaboration of this nature. Both performing Arts and Product Design are studio-based disciplines and have clear commonalities and points of convergence.
The impetus for this collaborative endeavour emerged from several discussions between faculty members relating to the importance of facilitating creativity in the third level studio. Lecturers in performance practice and product design noted similarities between pedagogical approaches in both realms to foster a learning environment where trial and error and process- based learning with reflexivity were key components. We shared common traits despite the perceived chasm between artistic and scientific research methods and output metrics.
We progressed our enquiry through establishing undergraduate peer learning projects. We sought to identify the opportunities and challenges presented by this interdisciplinary collaboration.

Keywords: Product design, performing arts, interdisciplinary collaboration

1 INTRODUCTION
This was an inter-disciplinary collaboration between staff and students across a range of disciplines involving ethnographic research methods combined with reflective practice and a user centred design approach. Both Product Design and Performing Arts are studio-based [1] and have clear comparisons. Lecturers in performance practice and product design noted similarities between pedagogical approaches in both realms to foster a learning environment where trial and error and process-based learning with reflexivity were key components. It was noted that our pedagogical philosophies had many common traits despite the perceived chasm between artistic and scientific research methods and output metrics. Therefore, the purpose of this study was threefold. In the first instance we sought to create a shared space for peer learning where students from performing arts and product design could engage in real world studio settings the goal of which was to draw on users' expertise to inform the design process and to give the performers active agency in the process in collaboration with their peers. Secondly, we sought to use reflexivity on the part of students and teachers through journaling and process books to investigate the points of convergence and divergence between how we assess creative processes by marrying multi-disciplinary teaching to cross-pollinate skillsets therefore enhancing outcomes. Finally, we wanted to build sustainable links across disciplines where students and faculty collaborations could be embedded in a modular structure.

Figure 1. Student collaboration

2 METHODOLOGIES

We progressed our investigation and enquiry through establishing undergraduate peer learning projects at final year project level. This process allows students to demonstrate the range of skills honed throughout their degree and apply them in an industry-related manner through working with multi-disciplinary stakeholders. We sought to identify the opportunities and challenges presented by this interdisciplinary collaboration between faculty and tutors. Some interesting issues emerged regarding the assessment of the creative process, both for design students and performers. We utilised a range of research techniques to inform our case studies. This mixed-methods approach allowed for engagement by students and faculty and provided data that was relevant to all cohorts. The performing arts students were active agents in the design of products that could enhance their performance longevity and the design students had access to peers who would also be clients.

Table 1. *Methodological stages*

Informal Discussions among faculty	Faculty and students collaborate within undergraduate modular structure	Interfacuty staff and student collaboration at undergraduate and postgraduate level	Case Studies	Revision, reflection, representation of ideas Response Potential Postgraduate projects	Further revision, reflection reponse and representation of working prototypes

Teamwork and collaboration are fundamental to the core methodological approaches used in product design and extending our creative approach across other faculties further enhanced this experience. The partners in the cross disciplinary collaboration benefit from contact with each partner's network, which brings more diverse thinking and offers further potential for new projects. Furthermore, the potential shared pedagogical philosophies and approaches used by members can enrich student and teacher engagement. Our shared pedagogical approaches were explored through the development of specific projects, bringing together students from two university faculties, namely Product Design and Performing Arts. Two of these projects are outlined in the case studies below.

3 CASE STUDY 1 THE IRISH DANCING SHOE: A PRELIMINARY INVESTIGATION

3.1 Establishing the project

In 2017, an interdisciplinary learning environment was established through an initial study, which was carried out by 4th year Product Design and Technology students with undergraduate Irish dance students at the university. The aim was to investigate the issues with the shoe in terms of performance requirements, aesthetics, injury prevention and usability. Research was conducted with dancers, dance teachers and physiotherapists. Design students attended dance classes with dancers and observed them executing a variety of dance movements wearing their heavy shoes. Design students also tried on the shoes and experienced walking and moving in them. Design students were also introduced to the various rituals engaged in by dancers before putting on their shoes. These included, gauze wrapping on the feet, a range of blister pads and podiatry products and a general acceptance of discomfort. A number of issues were highlighted: injury, extended periods of recuperation and issues in life. The dancing shoe was found to be a contributory factor to many of the injuries identified. Based on the traditional brogue, this shoe has had little development since its introduction and provides limited support for today's performance requirements.

3.2 The Process

Designers and dancers met together at a studio session where dancers demonstrated the range of steps they took to mitigate blisters and discomfort. They also demonstrated a variety of dance movements and highlighted where additional flexibility and support was important in terms of footwear. Focus groups and interviews were conducted with dance participants following this session to gather their perspectives.

Initial conversations allowed for multiple areas of interest and flaws to be highlighted and identified specific places to focus on in the later stages of the project. Dancers outlined the regular rituals and processes undertaken to prevent blistering and lower leg injury. These included applying plasters, gauze and tape and various products to cushion the toes and heels and minimise discomfort. There was a consensus that shoes were generally uncomfortable until broken in and that pain was a part of the process.

This type of focus group allowed for open dialogue and discussions and gave students an opportunity to opine on a host of topics. It was loosely structured, and participants spoke openly. Students took notes but they did not record the session as they were striving for a natural ambience. In hindsight, had we

video recorded this session, we could potentially have gathered more detailed data. However, the process from the point of view of the participants may not have achieved the same level of open discussion.
Interviews were also conducted with experienced tutors and performers of Irish dance. These included a chartered physiotherapist with significant experience as an elite competitor and professional performer of Irish dance. Tutors spoke about the range of products currently on the market. The conversation with the physiotherapist gave an insight into the most common types of injury and indicated at what point in the dancers' career they were most likely to occur. It also gave the students access to the technical language and terminology used to discuss dance injuries.

3.3 The student experience

Students enjoyed collaborating with their peers and appreciated the opportunity to participate in focus groups. This was highlighted by the design students in their process book reflection:

> *'In speaking to a group, it allowed us to focus on specific areas and necessities to bring into idea generation, what the needs and wants are, and what preferences were for each dancer. Also, by getting a group discussion, we were able to get a larger range of opinion'.*

One of the design students with no previous experience of dance tried to wear the shoes to get an embodied experience of how this felt. She was taken aback by the lack of comfort and support. This is evidenced by the following entry in the process book:

> *'While attempting the toe stands, she noted how difficult the move was. While being supported by two dancers to aid her balance, it was possible, but highly uncomfortable. With high pressure on the toes, this was something that Suzanne found to be sore even in just a stationary position'.*

3.4 Outputs

The design students documented their creative process in a process book which guided them throughout the project, but which also allowed the dancers to see the progression from beginning to end. The dancers attended the end of year presentations and exhibition of work by the design students and saw the prototypes which were designed as a result of the collaboration. This project has been further developed and it now being advanced as a PhD study. This indicates the opportunity for real world studio design collaboration and peer learning in a university setting. Students were given the opportunity to meet, discuss ideas, reflect and become active agents in their own learning. This engagement was recorded in the student process book. Through conference presentations and written publications, dissemination of ideas and potential projects is ongoing.

4 CASE STUDY 2: AN ACCESSIBLE WAY FOR VOCALISTS TO PROGRESS VOCAL HABILITATION AND HYGIENE

4.1 Process

In 2019, an interdisciplinary learning environment was established, as a fourth-year product design student set out to investigate how design could support the training of singers. Subsequently, a meeting was arranged between the investigating student, their research supervisor in design, and the course director of the BA Voice programme at the Irish World Academy of Music and Dance. This meeting highlighted areas within the vocal training process with potential to be supported by design, and the concept of designing an accessible means of progressing vocal habituation and vocal hygiene emerged as a focal point. The initial discussion developed into a final year project, and the design student engaged BA Voice students and faculty during the research and testing of the concept.
The rationale for designing a tool to support healthy vocal habituation stemmed from the initial discussion where aspects of vocal training were discussed. Semi occluded vocal tract (SOVT) exercises [2], were highlighted as important for singers to regularly incorporate into their vocal routine. These SOVT exercises are generally included in vocal warm up and cool down routines [3]. Vocalising in this way has been widely discussed as beneficial for singers and voice users [4]. SOVT exercises are regularly employed in clinical voice therapy and voice rehabilitation contexts [5], [6]. Many methods exist for SOVT exercises, including the use of a straw or purpose designed tool. There are a number of existing products on the market for SOVT exercises, but a gap was identified for the design of a product that would generate feedback, offer multiple functions and include a means of improving and tracking progress. With a narrowed focus, a clear rationale emerged to further the potential of the project within the parameters of a final year project in product design. Engagement with singing teachers during this

project presented opportunities to articulate and identify areas of potential for innovative design. Initial discussions with the research student prompted a questioning of common issues, along with the brainstorming of possible solutions. Key themes arose as areas of interest with potential to merge into a concept for a physical product.

4.2 The student experience

Students were initially apprehensive about participating in the process, but they reassured each other and grew in confidence over the course of the study. One of the issues was that the design student was a final year student, and the vocalists were a first-year cohort just acclimatising to the third level experience. In hindsight, it would perhaps, have been more beneficial to pair groups that were closer in age or level. However, the student interviews were carried out in pairs to offset some of these challenges.

4.3 Output

Between voice lessons, it is difficult for voice teachers to ascertain student progress or adherence to any prescribed exercise routine. It was suggested that a product could motivate singing students to develop and adhere to a practice routine, encouraging awareness, personal responsibility and demonstrating daily progress. This feature could encourage accountability to self and others e.g., their vocal peers or coach. Ideas about tracking progress and providing feedback were discussed. While the development of an application alongside the physical tool presented a number of opportunities for quantifiable feedback, a concern arose from the teacher perspective around the limitations or misinterpretation of aspects of this. Functions of the application that were thought to be feasible were the facilitation of SOVT exercises through the physical tool, feedback for the user on breath output and pressure, and the measurement of pitch through the application.

5 DISCUSSIONS

The case studies outlined are demonstrative of the merits of creative interdisciplinary teaching. Following Biggs' [7] model of constructive alignment, teaching is at its most effective when it encourages a move from 'surface' to 'deep learning' for students; that is a move beyond the acquisition and application of knowledge to a conceptual shift. As Biggs states, "we see the world differently" as a result of our learning (p. 60) and this is made possible by establishing clear objectives, enhancing student motivation, providing tasks that offer deep engagement, and collaborative opportunities to learn (pp. 60-61). Bain proposes confronting students with "intriguing, beautiful or important problems" to promote active and deep learning and skills in critical engagement [8]. These characteristics are demonstrable in the projects undertaken in this case, and they can be further developed through additional creative modelling in the areas of curriculum design, particularly with regard to feedback and peer review methods. Feedback between students and staff was consistently used in the creative projects outlined, by establishing an ongoing dialogue to track the development of each design solution. The skills gained in this dialogic approach could be furthered by embedding reflexive feedback into each project from the outset, thereby creating opportunities for students to "develop the capacity to monitor and evaluate their own learning" [9]. This could be achieved through tools such as reflective journaling, peer group discussions or a shared blog space, where students reflect on their personal development throughout the creative process as well as the successful development of the creative product. Students should also be encouraged to review and respond to their peer's reflections, learning from each other as a consequence. These reflective tools also benefit staff by providing space for a "learner-focused approach", enabling teachers to be responsive to student needs as the project develops, by critically reflecting on their progress in relation to the intended learning outcomes [10]. Therefore, a pedagogical model with creativity at its centre offers a myriad of possibilities for development for all involved. By establishing a collaborative culture of learning where students and teachers / facilitators are co-creators in the learning process, knowledge exchange is made possible between staff and students both across and within disciplines.

6 CONCLUSIONS

These case studies presented challenges and opportunities. In the first instance, without fully developed working prototypes, it was difficult to understand how effective the concepts would be. However, the process broadened the scope of understanding and informed design concepts. Understanding the limitations of the design concepts would be examined at later stages of the project.

Involving students in the project encouraged more awareness and attention to their individual artistic practices. It also demonstrated the possibilities of interdisciplinary collaboration, encouraging 'deep learning' through a dialogic and process-based approach to teaching. Furthermore, by initiating this process at undergraduate level and creating peer learning opportunities, it was possible to tease out some design ideas in an exploratory manner and develop ideas which could be developed further at postgraduate level. Eventually, once working prototypes were developed this could lead to invention disclosures, a possibility for patents and potential sign off and licensing opportunities with local businesses. These case studies demonstrate that a creative pedagogical approach can equip students with a broad range of transferrable skills and learning outcomes, that can serve them well beyond the life of the individual assignment or project.

REFERENCES

[1] Kjesrud R. D. 2021. Studio-based Learning: Pedagogy and Practices.

[2] Titze I. (2006). Voice Training and Therapy with a Semi-Occluded Vocal Tract: Rationale and Scientific Underpinnings, *Journal of Speech, Language, and Hearing Research,* 49(2), 448-459.

[3] Ragan K. (2018). The Efficacy of Vocal Cool-down Exercises, *Journal of Singing,* 74(5), 521-526.

[4] Maxfield L., Titze I., Hunter E. and Kapsner-Smith M. (2015). Intraoral pressures produced by thirteen semi-occluded vocal tract gestures, *Logopedics Phoniatrics Vocology*, 40(2),86-92.

[5] Simberg S. and Laine A. (2007). The resonance tube method in voice therapy; description and practical implementations, *Logopedics, phoniatrics, vocology*, 32, 165-170.

[6] Kapsner-Smith M., Hunter E., Kirkham K., Cox K. and Titze I. (2015). A Randomised Controlled Trial of Two Semi-Occluded Vocal Tract Voice Therapy Protocols, *Journal of Speech, Language and Hearing Research*, 58(3), 535-549.

[7] Biggs J. (1999). What the student does: teaching for enhanced learning, *Higher Education Research and Development*, 18:1, pp. 57-75.

[8] Bean J. (2011). *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*. Hoboken: John Wiley & Sons, Incorporated.

[9] Winstone N. and Carless D. (2020). *Designing Effective Feedback Processes in Higher Education: A Learning Focused Approach.* London: Routledge.

[10] Fry H., Ketteridge S. and Marshall S. (eds.) (2015). *A Handbook for Teaching and Learning in Higher Education (4th Edition).* London: Routledge.

TIMES OF CODE RED - LEARNING SUSTAINABILITY BY SYSTEMIC DESIGN

Kristin Støren WIGUM
Oslo Metropolitan University, Norway

ABSTRACT
This paper describes master's students' experiences of working with systemic design techniques for sustainability and how this may produce feelings of self-efficacy. Systemic design can be described as a combination of systems theory and design practice. Systemic design was developed to offer designers the tools necessary to handle the complexity of the long-term goals, such as the UN set for in its latest Intergovernmental Panel on Climate Change calls for action 2022 [1]. The students participating in this study who work with systemic design methods, are also introduced to methods of co-creation and interdisciplinary and individual self-management. This is intended not only to enable them to perform systemic design for sustainability but also to stimulate feelings of mastery. That is, educational planning is designed to facilitate the emergence of self-confidence, even though the students operate in and design for a high degree of complexity. The underlying pedagogy is thus synthesized with the goal for students to understand the following: 1) "I will never be able to understand the entire system(s)"; however, 2) "I can relax because I will not design alone. Design for urgency and resilience must be done by many stakeholders in cooperation, and systemic design is conducted using many tools that make it possible for me as a student to handle and facilitate such interdisciplinary projects"; and this synthesis of methods suggests that 3) "I can look to new care models and tools that increase awareness of self-management and that can be used to facilitate co-processes and meetings with teams and networks."

Keywords: Systems theory, design for sustainability, disruptive values, transdisciplinary approaches, self-leadership

1 INTRODUCTION
Design for sustainability was implemented in industrial and engineering design education in the mid 90's. Technical, material and life cycle-oriented approaches, as well as future scenario methodology and conceptual design, were introduced to students in certain courses. Enthusiastic scientists and eco-philosophers opened students' mindsets and brought new understanding to designers' thinking and toolboxes. Systems thinking and theory were already a part of the syllabus in "eco-design," like Meadows, Meadows, Randers and Behrens III revealed the system dynamics of our industrial society to the world as early as 1972, with their first edition of *Limits to Growth* [2]. However, at this moment, there was still time for change reducing the climate gas emissions to a less critical level. Designers could imagine new designs and stories for the future, and engineers could explore technology in all dimensions. This was not seen as a time for urgent action. Most politicians and industries and the general population were occupied with their certain sectors and interests rather than the root causes leading to global ecological crisis. It was difficult to believe that Earth has limits concerning material consumption and emissions.
In 2021, the last of six reports from the UN Intergovernmental Panel on Climate Change (IPCC) was published, which coded red for humanity [1b]. This means that climate change is already here, and there is a need for a clear planned action reducing the amount of climate gases in the atmosphere. The global population is facing severe changes in climate that will cause permanent transformation of ecological systems and balances. The UN Paris Agreement is probably our best global tool so far, working towards a common goal. The UN Sustainability Development Goals (SDGs), too, present strategies for securing social, ecological and economic sustainability. The timeframe for a major change of direction is now set to 2030. Through the Paris agreement, global society has agreed on a common goal to reach net-zero climate gas emissions by 2050. Our global population is expected to increase to 9.75 billion by then.

Degrowth, slowing down the speed of human physical expansion and reducing our ecological footprint are therefore seen as unavoidable strategies for meeting this overarching goal [3].

2 THE NEED FOR NEW COMPETENCE AND WAYS OF LEARNING

Currently, students are expected to handle the challenges of the future. Their education should help establish their understanding of the situation and, at the same time, support their enthusiasm and eagerness to contribute to society and the problems it is facing [4]. The new report for action from IPCC (April 2022) encourages the global community to work in alignment with three time perspectives, short-, mid- and long-term, moving “from urgent to timely action”, and “from climate risk to climate resilient development”. More than any previous IPCC reports, this one pinpoints systemic design approaches and underlines the importance of understanding and recognizing the interdependence and interconnection of social, ecological and economical resources for the fight against climate change and for adaptation and future resilient development. The paradigm of sustainability should overtake industrialized society [5]. Because of system delays reducing, this transformation must be introduced for large-scale implementations by 2025 [1].

Thus, teaching design for sustainability in code red times is challenging, not least learning and absorbing this research and responding to calls for action. The traditional designer’s role is not aligned with the uncertainty of the future and the clear need for a paradigm shift in industry and society. Students are entering the education arena as participants in a dialogue for change. The answers to their questions are found in the research and practice of the future, the field of climate research is continuously discovering new relations and behaviours on the planet. The skills taught in design education are therefore equally related to self-leadership, empathy, systems theory and thinking as they are to design in cooperation with many stakeholders for social and community needs rather than in response to growing market demands. Communication and relationship-building are of primary importance, as reflected in the UN SDG #17, Partnerships for the goals.

2.1 Moving from fragmented goals to interconnection and system dynamics

The theme of sustainability has been slowly fragmented and adapted to our sectoral silo thinking. The municipalities of Norway approach the 17 UN SDGs willingly, but their plans clearly show their traditional analytical procedure of choosing the most “relevant” goals and defining new, more detailed goals for every SDG, ending with a daunting number of goals to bring into action [7]. Consequently, municipalities and private companies find it difficult to implement strategies for sustainability [7]. The sustainability paradigm [5] applies an opposing approach. This approach connects as example, the SDG goals and oneself to the work of development with a holistic understanding by exploring the relations between details and primary goals, guided by systemic thinking and the principles of ecology [8]. This approach must be combined with an understanding of unsustainable practices [9] [10] and system traps [6], pinpointing today’s unsustainable practices. Systemic design promotes a holistic approach based on analyses and awareness of feedback loops and system dynamics over time. Nature, as the base for knowledge, is central, and the relationships and interdependencies of elements such as species and local demography with resources of all kinds define the foundations of eco-literacy and sustainability. What hinders these relations from existing in a resilient, regenerative state is defined as sustainability principles [9] [10]. **Error! Reference source not found.** shows the components of knowledge and competence used to build the courses and workshops used to teach sustainable design approaches at OsloMet 2021.

In a redefined Master’s curriculum named Design in Complexity (OsloMet, 2019), design students are trained in these processes and in understanding the difference between scientific knowledge and political goals for sustainability, such as the fact that the UN SDGs are a global democratically adopted strategy. As an example, it not defined as a part of the SDG goals to reach for a new economic model for sustainability in the SDG goal #8. Decent work and economic growth, although researchers in this field pinpoint the need for such. The students are provided with a general design methodology that may also be used by teams of non-designers. This methodology draws on system thinking and practical approaches to mapping and analysing systems. The importance of introducing students to specific ecological and social sustainability principles is that concrete strategies may guide the search for and lead to leverage points in systems, as well as new concepts for interventions [6]. As a profession and way of thinking, design embraces the development and implementation of non-material interventions, as well as how material solutions perform and are anchored in or integrated for use in certain contexts.

Students are introduced to the four levels of design: 1.0 traditional design, 2.0 product service systems, 3.0 organizational transition design and 4.0 transition for social change [11]. This makes them aware of the interrelations between all levels, regardless of the point at which the design process is entered. Connecting the generation of ideas and their influence on behaviour, services, physical elements and infrastructure, to all four levels, may increase system influence (i.e., reaching more and higher leverage points) and thus result in greater impact on sustainability. The constant movement and changes in systems are the result of time and system dynamics [2] [6]. Systemic understanding and awareness therefore requires the personal ability to remain in uncertainty. The students are thus introduced to leadership both of oneself and of a team.

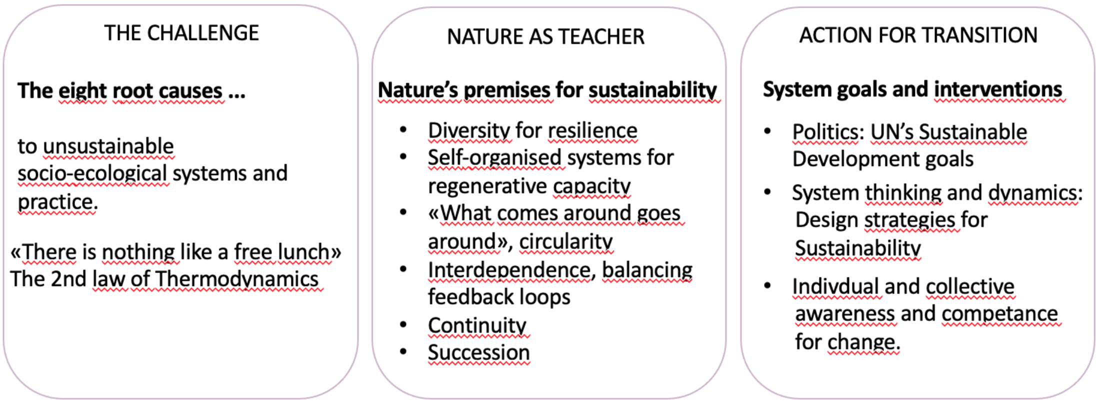


Figure 1. The key elements of teaching sustainable design approaches: root causes of the unsustainable status quo, how nature creates resilience and regenerative systems, and actions humans may take for transition of practice

3 METHODOLOGY

3.1 Learning to identify and develop interventions with high leverage

The UN SDGs underline the importance of "including all" in aiming to achieve the goals [1b]. Designers and design students may take the role of catalysts in their practice, connecting stakeholders through a visual and systemic language that brings understanding of new relations and intersectoral interventions. The students are exposed to a diversity of stakeholders, which are brought into play through a set of pedagogical and systemic approaches. In the time of code red, workshops and other pedagogical experiences should cause the proliferation of activities and actions for change. New mental models that develop courage and lead to inspiration for new collaborations are critical for enabling innovation and the inclusion of all. Table 1 presents practical approaches for students and stakeholders to experience systemic and ecological literacy, as well as self-efficacy.

Table 1. Teaching sustainability in different arenas for practical involvement and collective understanding of systems

Learning context	**Pedagogical approaches**	**Goals and procedures**
System play	Student group is challenged by different games, such as the triangle game or the more advanced beer game, experience the complexity imposed by simple rules. The students experiment collectively with the structure and behaviour of systems.	Building system-literacy: the students experiment collectively, practically (with their own body) and mentally the structure and behaviour of systems. The students intervene in the play by suggesting new rules, and dialogue between sessions reveals individual and collective experiences of the system.
Workday at an organic community-supported farm	Students have bodily experience of ecological systems, life cycles and interdependencies.	Building eco-literacy and increased understanding of food production, bio economy and strategies for social sustainability: discussions after completing work in the fields link physical work and ecological life cycles to the

		understanding of economic systems, efficiency and production of quantitative and qualitative values in a system.
Public system and service design	Students engage in “real-life” communication and organizational and social systems analyses.	Public institutions are forced to implement strategies and action plans to reach the UN’s SDGs. The students experience the hindrance or promotion of social sustainability.
Product service systems for businesses and start-ups	Students practice empathy for difficulties and possibilities in “real-life” business development.	The students come in direct contact with stakeholders with influential power. The students experience how a systemic perspective exposes new possibilities, as well as traps, and the difficulty of intervening to remove obstacles to ecological sustainability. .
One-day workshop of drawing exercises revealing the internal process of theory U [12]	Students explore a deeper level of concentration and contact with personal qualities and obstacles in letting go, remaining with uncertainty and be confident in decision-making.	Strengthening the feeling of self-efficacy: the students receive training in understanding inner processes and “changes in gear” for decision-making. [5]
Creating a common meal experience	The international student group is challenged to create a meal with a dish from their own countries, sharing their skills in preparing and cooking.	Experiencing diversity in culture, communication, and teamwork: the students engage in social sustainability practice, relational capacity building and understanding the role of food on a personal level in daily life as well as in an international context.

3.2 Pedagogics for systems thinking and understanding

A dilemma in learning sustainable design approaches is the need for some degree of systems understanding to actually perform interventions on a level sufficient to produce transformation and change. However, a method of training students in “systems literacy” is engaging in systems play (Table 1). The experience of being physically part of a system communicates the concept of systems knowledge to the participants in only a few minutes. In addition, inviting the students to engage in farm work to improve their understanding of ecological and social sustainability, resilience and regenerative systems gave direct feedback of involvement and enthusiasm for learning. Figure 2 below indicates how eco literacy is the primary goal of the course and emerges in pedagogy through systems literacy and is brought into play through communication and creativity.

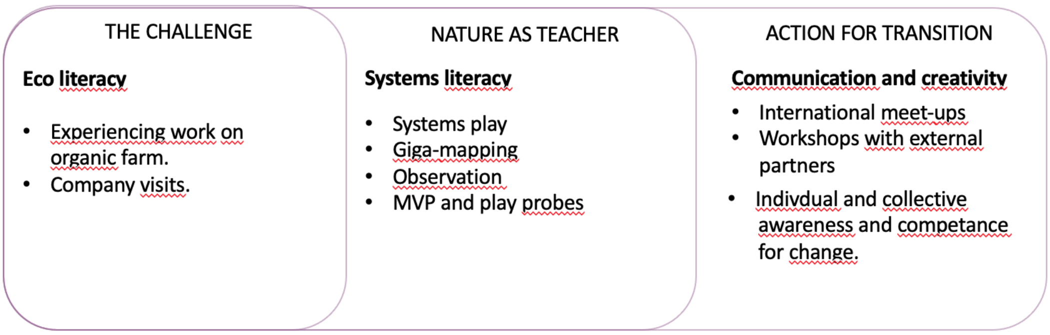


Figure 2. Teaching for a new paradigm requires tools engaging the head, hand and heart in holistic understanding and approaches

The design process is known to include a “chaos-phase,” the phase between analyses and the generation of new concepts for interventions and choices regarding final direction. In systemic design for sustainability, this phase may seem overwhelming. The complexity of defining the boundaries, values and goals of systems in relation to typical design thinking, which details user needs and wants, may cause the stagnation of decision-making and progress in student projects. In an educational context, these feelings of stagnation and overwhelming experiences are valuable for creating awareness of the necessity for care. Care is defined here as seeing and acting in a way that nourishes the relations between oneself and the distinct surrounding layers of people, society and nature [14]. Johan Rockstrôm and his colleagues [15] point to the need for a closer human connection to the biosphere and understanding of planetary boundaries to protect them. A healthy planet is the main goal to support all goals of SDG; however, strategies for reaching this goal must include caring, seeing and acting in ways that embrace the whole, oneself as an individual and the collective as all, and relation to nature. Reaching for inner sources of creativity, as well as the ability to switch between relaxation and point of action, strengthens self-management and self-care. Through nine-minute line drawing exercises and other simple physical approaches to drawing, the students start their practice and make contact with their inner compass for direction in overwhelming moments of systems mapping and the notion of "chaos" in the design process, and concentration in contact with creative thinking and new perspectives emerging[12].

3.3 Communication as intervention and process management

The search for designers' contribution in times of code red clearly shows that design is a tool for joint problem solving, inviting interdisciplinary cooperation and practice. Concepts for continuous learning courses and workshops are also developed through international cooperation (so far, between three universities at OsloMet [2020–2022]). The students are exposed to cultures from around the world and other disciplines that may contribute to the central knowledge of the systems being mapped. The field of systemic design evolves in these contexts, and its methods become more resilient, enabling non-designers to enter the scene of development and innovation. The key to this emergence of resilience is communication as a theoretical concept and as a practice. Bringing a rich set of communication tools and theories to the table and becoming aware of the complex mix of mental models and perspectives represented in an interdisciplinary group is crucial to the development and process of implentation. The participants (here, students) learn to be humble in expression and aware of the layers of communication present in both systems and individuals [16].

4 EXPERIENCES, ANALYSES AND EVALUATION

Students' evaluations so far show that they are motivated by practical workshops, inspiring lectures, mastering specific tools and group work. Systems theory and new knowledge of sustainability, as well as methods of designing for sustainable behaviour, are mentioned as eye-openers that strengthen the students' belief that their profession as designers can make a difference.

In terms of further development of the pedagogical tools and context of learning, on the one hand, the systemic approach is demanding, and most participants in the student course express that there was too little time for in-depth study concerning sustainability, as systems theory dominates. On the other hand, the students find it a relief to understand that it is impossible to know an open system in its entirety and its behaviour. Understanding the given limits to own understanding of "the whole," is as important as understanding the possibilities of influence.

When student teams function well, individual learning is high. However, students also evaluate time for individual reflection highly, as well as time for reading and exploring the material on their own and working in groups. The learning environment should nourish individual inner capacity and concentration, as well as inspiration from the outer world's input and relational building. The students point to a wish to emphasize the practical use of tools and the understanding of systemic design, sustainability, and self-management.

5 CONCLUSION

This paper concludes that teaching systemic design in relation to design for sustainability reveals to students at least three important competences that strengthen their self-confidence as designers in times of code red: 1) "I will never be able to understand entire systems"; however, 2) "I can relax because I will not design alone. Design for urgency and resilience must be done by many stakeholders in cooperation, and systemic design is conducted using many tools that make it possible for me as a student to handle and facilitate such interdisciplinary projects"; and this synthesis of methods suggests that 3) "I can look to new care models and tools that increase awareness of self-management and that can be used to facilitate co-processes and meetings with teams and networks."

6 FURTHER DEVELOPMENT

At some point, the disciplines of importance introduced to design students must be limited. Rather than gaining their own knowledge in all fields, students can be supported by a network that includes other experts on their teams. The students' experiences so far, however, indicate the need for deeper skills in communication, understanding social complexity and social interventions [16]. The inner development of self-efficacy is a previous blind spot within the subject design for sustainability and requires attention and concrete tools for students and practitioners working in the complexity of times of code red. *The inner development goals* are an international initiative [17] addressing five inner goals that are promoted as fundamental in the work towards the SDGs. This initiative may be one of many that explores and supports the diversity of personalities and motivations supporting the vision of including all in the transition to sustainable futures.

ACKNOWLEDGEMENT

Prof. Tore Gulden and colleagues at OsloMet Department of Product Design, Siv Helene Stangeland who is co-founder of Helen & Hard Architecture, Ninni Sødahl from Vækstcenteret, and colleagues at L'ecole de design Nantes Atlantique and systemic design at HTW-Berlin.

REFERENCES

[1] IPCC. Available: Climate-change-2022.Mitigation-of-climatechange. *https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf*. [Accessed on 23.05.2022], April 2022.

[1b] IPCC, Climate-change2022.Impacts-adaptation-and-vulnerability. Available: *https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf*. [Accessed on 23.02.2022], 2021.

[2] Meadows D. H., Meadows D. L. and Randers J. *Limits to growth*. 1972 (Potomac Associates-Universe Books).

[3] Hueseman M. H. The limits of technological solutions to sustainable development. p.21-3, 2003 *Clean Technology Environment Policy* 5.

[4] Rittel H. and Webber M. Dilemmas in a general theory of planning. *Integrating Knowledge and Practice to Advance Human Dignity*, 1973, 4(2), 155-69.

[5] Hildebrandt S. and Stubberup M. *The 17 UN sustainability goals, Human Systems Sustainability– on Health New theories addressing solutions.*

[6] Meadows D. H. and Wright D. *Thinking in Systems: A Primer,* 2009 (Earthscan, London).

[7] The Norwegian Association of Local and Regional Authorities (KS). *Measuring the SDGs.* Available, English streaming, Norwegian text: *https://www.ks.no/fagomrader/barekraftsmalene/alle-maler--barekraft-men-hva-maler-vi-egentlig/.* [Accessed on 23.05.2022] 2022.

[8] Commoner B. *The Closing Circle, nature, man, and technology.*1971.(Random House Inc)

[9] Robert, K.-H., et al. *Sustainability handbook*. 2019. (Studentlitteratur AB).

[10] Broman G. I. and Robert K.-H. 2015. A Framework for Strategic Sustainable Development. *Journal of Cleaner Production* 140 (2017) 17e31.

[11] Jones P. Systemic Design: Design for Complex Social and Sociotechnical Systems. *In: Handbook of Systems Sciences*. (Project: Systemic Design Research Agenda) 2020.

[12] Scarmer C. O. *Theory U: Leading from the Future as It Emerges*. 2016 (Berrett-Koehler).

[13] Stroh D. P. *Systems Thinking for social change.* 2015 (Chelsea Green Publishing Co).

[14] Macy J. and Brown M. Y. *Coming Back to Life: The Guide to the Work that Reconnects*, 2014 (New Society Publishers).

[15] Rockström J., Beringer T., Hole D., Griscom B., Mascia M. B., Folke C. and Creutzig F. *Opinion: We need biosphere stewardship that protects carbon sinks and builds resilience.* 2021 **(**PNAS DOI: https://doi.org/10.1073/pnas.2115218118).

[16] Bateson G. *Steps to an Ecology of Mind*, 2000/1972 (University of Chicago Press, Chicago).

[17] *The inner development goals*. Available: https://www.innerdevelopmentgoals.org/ [Accessed on 22.05.2022].

A SLIGHT RETURN: DEVELOPING AN AUGMENTED DESIGN STUDIO PEDAGOGY

Jon SPRUCE and Sarah MORIARTY
Manchester Metropolitan University, United Kingdom

ABSTRACT
The reorientation to remote teaching due to the impact of COVID-19 restrictions proved to be both challenging and compromising, particularly in the context of delivering practice-based design education. Central to the challenges faced by many design tutors was the loss of the design studio as a focal point for engagement and learning. As an established signature pedagogy of design education, the studio provides an environment for mediated, sticky, social and habitual exchanges in supporting teaching and learning on campus. However, delivering teaching remotely through a period of enforced separation also proved that through adversity comes new insights, with the accelerated use of emergent technologies to support distributed working revealing new behaviours and opportunities for learning to take place. In response to COVID-19 restrictions, the digital whiteboard and collaboration platform Miro was widely adopted within the UK creative industries and universities alike to facilitate remote engagement. Through the period of November 2020 to May 2021 the authors utilised Miro to create an analogue to the physical design studio environment, providing an easily accessible collaborative space for remote sharing of thoughts and ideas. However, as many institutions now begin to reorient back to campus-based delivery it is evident that some of the pragmatic approaches adopted through necessity can hold lasting value beyond crisis modes of teaching. This paper utilises the key findings from a study of remote delivery experiences conducted by the authors in June 2021 to establish clear benefits for the continued application of the Miro on-line platform within a *return to* campus-based delivery.

Keywords: Design pedagogy, augmented learning, communities of practice, design studio, sticky curriculum

1 INTRODUCTION
A key impact of the COVID-19 pandemic across Higher Education was the accelerated use of emergent technologies, particularly those that supported distributed working to support remote learning. Whilst much has been written about the potential for such technologies to support learning [1,2,3] it's adoption within UK Art and Design education has generally focussed on a blended approach via the use of established Virtual Learning Environments (VLE's) such as Canvas, Blackboard, Moodle, etc, rather than a completely digital approach as necessitated due to COVID-19 restrictions. The enforced move to remote teaching delivery brought many challenges to studio-based courses and the traditional modes of delivery that are often associated with UK Art Schools. Central to this was the loss of the design studio as a focal point for engagement and learning. The design studio, as described by Shreeve et al [4] is a space of shared, prolonged, communal activity where the process of making is visible and a focus for comment and debate. Despite the financial pressures on many UK institutions over recent years, communal learning environments have usually been maintained in some form, continuing to offer staff and students a studio-based ethos for teaching and learning [3]. As such "the studio is not just a space marked studio; it represents a way of thinking and learning" [5] and despite institutional pressures, the ethos of studio learning culture remains a strong ambition for many tutors and students. The popularity of the design studio can be considered through four lenses. Firstly, as a mediating artefact in the student learning experience that informs the content and delivery of teaching and influences the approaches undertaken by students. Secondly, as an essential part of creating the sticky curriculum [1] in providing a draw for students to return to and engage in activities together or to see something of collective interest and co-constructed with students. Thirdly, as a social place of exchange for ideas, integration, and synthesis [3] with opportunities for formal and informal peer learning that are dynamic, iterative and

experimental [6]. Fourthly, as a signature pedagogy of creative arts education affording "pervasive, routine and habitual" [7] engagement for students within their learning experience.

Across these four perspectives we can recognise that the studio creates the capacity for a structured, communal, habitual learning process that encourages and scaffolds students' capacity to challenge, experiment and grow. The challenge presented by the COVID-19 pandemic was how to translate some of these aspects of the physical studio into a completely digital environment. Within the context of a UK undergraduate Product Design programme, the online collaborative platform (Miro) was used to create an ad-hoc digital studio environment in response to an inability to teach in person due to the COVID-19 pandemic. Miro was chosen in preference to other on-line platforms such as Padlet or Mural due to its accessibility for large numbers of participants, compatibility with MS Teams and emergent widespread use within professional design practice over the period of the pandemic. Miro provided an easily accessible collaborative whiteboard space for remote sharing of thoughts and ideas.

2 REFLECTIONS UPON REMOTE DELIVERY

Following the 2020/21 academic year the authors conducted a study to reflect upon the rapid shift to on-line delivery, considering the ways in which Miro had been utilised to both mirror and transform the concept of the studio. Reflecting on five projects that utilised Miro between November 2020 and April 2021. Miro was used as a platform to structure teaching delivery, share creative content and as an environment to generate dialogue amongst students. The projects delivered across 1st and 2nd year undergraduate product design programme followed a common delivery pattern, each comprising phases of research, ideation, and presentation of final outcomes, however the utilisation of Miro in each project was different. Table 1 summaries the characteristic exchanges on Miro across the different projects.

Table 1. Characteristic exchanges

Exchange Type	**Exchange Details**
Icebreaker/Sandbox:	Tutor led activities introducing students to Miro software but also to the processes of sharing and commenting on peer work.
Individual Pin-up/Crit:	Opportunities to share work and elicit feedback from tutors and peers.
Group Pin-up/Crit:	Opportunities to share work and elicit feedback from the 'client', tutors and peers.
Individual Workshop Activity:	Highly structured design-process driven activity, delivered to the whole group but completed individually with feedback from peers.
Shared Workshop Activity:	Highly structured design-process driven activity, delivered to and completed by small groups with feedback from peers.
Individual Tutorials:	1-2-1 dialogue with students, discussing progress and planning forward actions.
Group Tutorial/Seminar:	Dialogue with students to discuss overall progress. Sessions were generally hosted on MS Teams, but students would often utilise their own private group Miro boards to show progress.
Instructional Exchange:	Delivery of the weekly primer activities. These were each located on the Miro board within a defined space for the activity and presented at the launch of each session.
Tutor-led discussions with student groups:	Posing questions and eliciting responses in moderated exchanges to prompt peer review, externalise viewpoints and promote self-reflection.
Asynchronous Exchange:	Via post-it notes placed onto student's work outside of taught sessions and via peer-to-peer exchanges, posting comments on each other's work.

Analysis of all the activity in Miro established that the platform offered significant benefits in use, both in the absence of, and potentially in parallel with, co-located working. Within each project the Miro spaces quickly created rich, shared, visual repositories that reflected different journeys through the design process, affording new opportunities for participatory engagement overcame barriers of permanence and accessibility that would be hard to recreate in a modern physical studio environment. In brief, the full study [8] revealed three core findings.

Visualise the Process to Create a Mediated Social Space: The capacity to visualise design processes and dynamically navigate through projects within the digital Miro space proved to be transformative in supporting the delivery of remote teaching. Visualisation of design processes enabled the creation of digital scaffolds within which we were able to construct workshops, experiment with modes of thinking and index design methods, and in the process generated a greater sense of awareness of their own learning journeys.

Foster Habit and Routine to Make it Communal: Students working both independently and collaboratively within remote communities of practice reflected the social aspects of physical studio participation, drawn to a common place that holds attraction. Changing the nature of their digital engagement from sharing a screen to sharing a space perhaps emerged through a growing sense of routine and habitual use, in line with Shulman's identification that working out the rules of engagement creates the time, and confidence to experiment within the digital space [7]. Similarly, the asynchronous use that was evident in several of the projects suggests that the flexibility to access and share content beyond taught lessons emerged as a very positive mode of exchange not always afforded by physical studio environments.

Enable Autonomy and Ownership to Make it Sticky: Student autonomy, ownership and experimentation within the Miro spaces developed over each project as their familiarity with the platform grew. Utilising the elasticity of the digital space and its ability to bring together different media into a shared, accessible environment mimicked the use of physical studio space, wherein the arrangement and application of space is adaptable to the required need. Thus, creating the liminal spaces for ideas sharing and discussion to develop as an environment for sticky exchanges between students, tutors and their subject.

3 RETURNING TO CAMPUS

Following the lifting of COVID-19 restrictions during summer 2021 many UK universities began planning a return to campus-based delivery for the new academic year. The identification of mirroring characteristics within the digital studio environment revealed a potential to be utilised either when campus-based teaching is required to be delivered remotely or as part of a blended delivery. Therefore, the opportunity to utilise the beneficial experiences of remote delivery to create symbiotic relationships between platforms such as Miro and the physical design studio environment offered an exciting next step in reimagining the campus-based learning experience. In-correspondence with the key benefits revealed through the previous study a targeted use of digital spaces alongside campus-based delivery was planned. Continuing to offer a digital analogue to the physical design studio environment focused on providing these things:

- Visualising the design process to support learning and navigation.
- Providing autonomy for students to develop their own working practices.
- Enhancing synchronous and asynchronous opportunities for peer and tutorial dialogue.
- Aiding self-reflection.

Table 2 details the augmented campus-based projects delivered between Sept 2021 and March 2022, describing the targeted use of Miro boards within each project.

Table 2. Augmented campus-based projects

Projects: 6 weeks duration	**Level/Year (numbers)**	**When**	**Miro exchanges augmenting campus-based activities**
Introductory 2D & 3D project activities	Year 1 (27)	Sept-Oct 2021	Miro used to capture events and create community space for new cohort; share best practice from student outputs; introduce unit/programme/assessment.
Principles & Approaches to Product Design	Year 1 (27)	Nov-Dec 2021	Miro used to map/visualise design process steps; to visually link new content to build depth of thinking in design process; to structure and make transparent assessment structure and portfolio output.
Speculative Design	Year 1 (27)	Jan-March 2022	Miro used for shared knowledge building and a platform for structured workshop delivery.

Product Design Innovation	Year 2 (22)	Sept -Oct 2021	Miro used to map/visualise the process of design through the production of work, connecting methods & activities to stages within the process
Understanding Context RSA Design Awards	Year 2 (24)	Jan-March 2022	Miro used as a collaborative research space; briefs and content resource; portfolio planning for competition submission; sharing of presentation techniques and outputs.
All projects followed a broadly common delivery format, comprising of lectures, taught studio activities, face to face tutorials, engagement with construction workshops and 3D printing.			

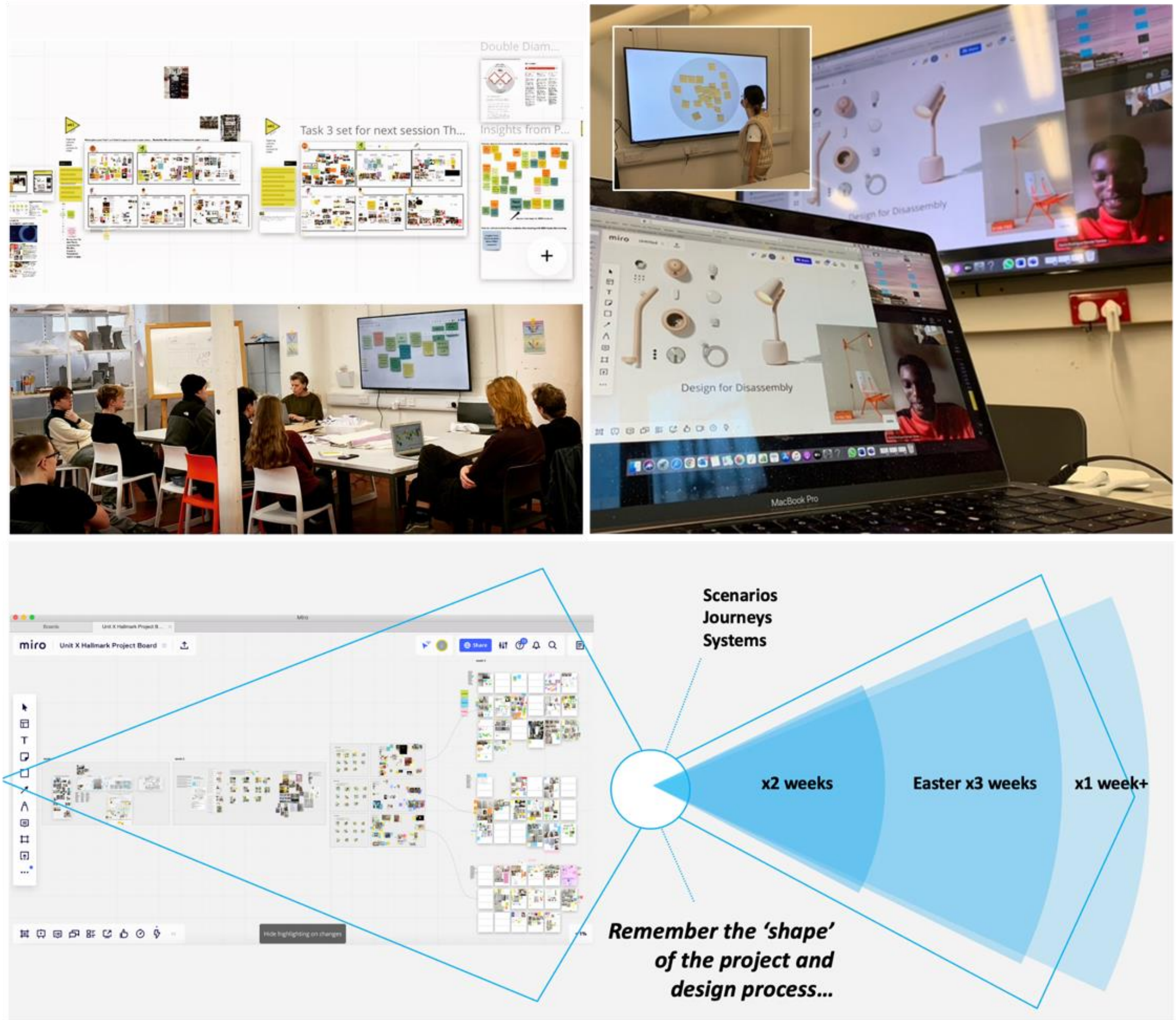


Figure 1. Images highlighting augmented delivery of projects

4 STUDENT FEEDBACK

Following delivery, all 51 students engaged with the projects were asked to reflect upon their experiences of using Miro on-line spaces alongside campus-based delivery. Questionaries were administered via the Mentimeter on-line voting platform of which 27 anonymised responses were recorded. Specifically, students were asked to consider: the relevance and usefulness (or not) of using Miro alongside campus delivery; if they enjoyed using Miro boards, engaging in group boards or constructing their own; to describe the benefits Miro adds to their learning, such as aiding self-reflection. The feedback questions were designed in correspondence with the author's 2021study findings and were intended to help establish their ongoing relevance in the context of campus-based delivery. The student responses were reviewed and thematically analysed to identify commonalities. In order to articulate the responses coherently a representative selection of direct quotations have been included in the questions and feedback summary below.

Question 1 asked if Miro project boards were still useful in supporting a better understanding of the design process, connecting design methods and navigation of the process visually?

Responses to this were overwhelmingly positive, comments included that “it helps to show the project broken down to better understand each part” and that “it helps show the steps of the project as we go along, and I like how it is accessible at any time.” Further comments added that “It allows us to maintain and develop a visual representation of our journey and it makes a nice temporary archive, convenient to go back for information we store on it.” The ability to use Miro boards as quick and easy reference points was highlighted frequently within the feedback comments, such as “I really enjoyed the blend physical/virtual learning that Miro provides. The online space allows me to instantly refer to or add to my work.” The comments here suggest that Miro continues to support the understanding of the design process and enables students to navigate through each stage of a project as an effective visual reference.

Question 2 asked if Miro continues to provide useful autonomy and ownership for students to construct project work and developing their own working practices?

A number of comments to this question referred to personal approaches being adopted, such as “Miro for me helps in the ideation and development of projects for product design. Being able to lay out all your research in a digital format and collate everything really helps to explore ideas and progress them further.” and “I’ve created my own separate Miro space for many of the projects because it’s a space where I can organise and rationalise my thoughts and insights. I also add images of the Miro boards to my final submission boards because of this.” These comments describe an enhanced ownership and understanding of their process and outputs, being able to communicate their individual practice through seeing their process as a whole, as well as individual ‘portfolio’ boards.

Question 3 asked if Miro provides meaningful opportunities for peer and tutorial dialogue?

Many students commented on value of “seeing what others are doing alongside your own for inspiration.” In addition, that “Miro was incredibly easy to use and very effective when sharing and communicating ideas with the rest of the class” so that “Multiple people can collaborate with each other on the same board by adding ‘post its’.” It was also recognised that “it is what other professionals said they use, when they have come in for talks” and that “Miro boards are a great way to share learning and they are also good for keeping track of work - e.g., organisation.” Further comments highlighted that “it benefits our learning and also helps us visualise different key lessons or lectures.” This feedback highlights an appreciation of seeing peers’ work during a project. It also suggests that key points from lectures are being revisited. Being able to relate to visiting professionals who describe also working on Miro suggests that using this ‘industry standard’ platform builds confidence in the students’ employability skills.

Question 4 asked if Miro is a useful aid for self-reflection?

Comments here highlighted a holistic view of Miro, such as how “It is best used when reflecting on projects” and that “When submitting final portfolios, the Miro boards are great to refer back to." “Miro has significantly contributed to my learning by providing a space where I can organise and collate my thoughts. I like that it’s a virtual space, meaning that those insights are saved in the space, so I can also add notes or refer back.” Being able to revisit Miro project boards during projects suggests that students are reflecting upon their work and work of peers as a part of their practice.

5 DISCUSSION & CONCLUDING REMARKS

Analysis of student feedback questionaries suggested that the ongoing use of digital tools such as Miro continues to be valuable in contributing positively to learning experiences within the context of campus-based teaching. Three key benefits have emerged from the student feedback. Firstly, the visualisation of the design process as a whole ‘project picture’ enables students to see clear connections between project content and allows the sorting of content to help define design directions. Secondly, the ability to construct and review their own practice by sharing work in progress throughout and across projects facilitates a deeper level reflective dialogue. As their practice is now much more visible, not just at presentation points, students can be seen ‘live’ (via cursors) reviewing their work and that of their peers throughout projects. Thirdly, the relationship to professional practice is of high importance to the students. Therefore, using Miro as a sharing platform and live link with external industries throughout projects creates a professional mode of practice in which the students can build identity and feel confident in a space where their outputs can be seen by industry partners at any time. Though it is evident through the delivery of projects included in this study that not all students fully engaged in using the Miro platform alongside their campus-based activities, no negative feedback was received regarding its use. Though it is evident that embedding Miro into every project has created various editing and ownership issues as the number of boards has grown over time. The auditing and longer-term stewardship of boards will need to be addressed as part of a core delivery model.

While the return to campus-based delivery across many universities has been welcomed by staff and students alike, the experiences of remote delivery and the accelerated use of distributed working technologies has driven an examination of established norms. In considering future design pedagogies that support the mediated, sticky, social and habitual exchanges essential to delivering design education, it is evident that platforms such as Miro can continue to be a highly valuable resource in supporting and *we believe* enhancing physical studio-based delivery. It is hoped that this topic resonates with EPDE Conference delegates as we seek to establish collaborative partnerships to further explore research towards the development of future design pedagogies.

REFERENCES

[1] Orr S. and Shreeve A. Art and Design Pedagogy in Higher Education: Knowledge, Values and Ambiguity in the Creative Curriculum, 2018, Routledge, Taylor & Francis Group.

[2] Deakin F. and Webb C. Discovering the Post-Digital Art School, 2016, Fred and Company, London. *http://ualresearchonline.arts.ac.uk/10295/.*

[3] Tovey M. Design Pedagogy: *Developments in Art and Design Education*, 2015, Taylor & Francis Group, London.

[4] Shreeve A., Sims E. and Trowler P. A kind of Exchange: learning from art and design teaching. *Higher Education Research & Development*, 2010, 29 (2), 125-138. *http://dx.doi.org/10.1080/07294360903384269*

[5] Spruce J. Examining the Role of The Studio Environment Within Design Education. *International Conference on Engineering & Product Design Education*. Newcastle, 2007, pp.331-336.

[6] Marshalsey L. and Sclater M. Together but Apart: Creating and Supporting Online Learning Communities in an Era of Distributed Studio Education. Int J Art Des Educ, 2020, 39, pp.826-840. https://doi.org/10.1111/jade.12331.

[7] Shulman L. S. Pedagogies of uncertainty. *Liberal Education*, 2005, 91(2). From *http://www.aacu.org/liberaleducation/le-sp05/le-sp05feature2.cfm.*

[8] Spruce J., Thomas P. and Moriarty S. From Sharing Screens to Sharing Spaces. *Design and Technology Education: An International Journal*, 2021, 26, (4), pp.96-111. Available at: https://ojs.lboro.ac.uk/DATE/article/view/2990.

APPLICATION GAP: UNEVEN GENDER PARTICIPATION IN INDUSTRIAL DESIGN INTERNSHIPS

Betsy BARNHART
University of Kansas, United States of America

ABSTRACT
Female Industrial Design (ID) students are not joining the ID work force at the same rate as their male peers. There are equal numbers of males and females studying ID, however, women make up only 31% of the industry. The author hypothesizes that internship participation has a snowball effect on student success and ultimately in their ability to join the ID work force at the same rate as their male peers. With student application rates during the first and second year of the programme leading to a higher rate of application and acceptance to internships in their 3rd and 4th years of study. This paper presents a research study conducted over two years at the University of Kansas showing the application rates of male and female identifying students from their 2nd through 4th year of study, their perceptions of portfolio readiness, and how internship application and placement rates affect employment rates post-graduation. Student surveys and semi-structured interviews were conducted with 2nd 3rd, and 4th year students 2 months post-graduation to understand the application rates, how students perceived the importance of applying to internships, how their perception of their portfolios affected their application rates and the effect internships had in entering industrial design practice. Interviews were conducted with industrial design managers from eight companies with competitive internships. This initial investigation at the University of Kansas is a model for further investigations at other institutions and professional practice.

Keywords: Industrial design, diversity in design, gender, design education

1 INTRODUCTION
A goal of Industrial Design (ID) education is to prepare students for placement in professional practice regardless of gender. However, while there are an equal number of male and females enrolled in ID programmes [1], only 31% of women are moving into the ID profession [2]. While other similar disciplines, such as architecture and engineering, are investigating gender disparities in their fields, ID has produced very little research in gender equity. Through understanding where the gender gap is perpetuated in academia and in industry, we can begin to address equity in ID pedagogy, ensuring we meet the needs of all students and increase female participation in professional practice.

2 BACKGROUNDS: LITERATURE REVIEW
Women are currently not moving forward from education into ID practice [2], which is problematic for a field fuelled by innovation[3]. Homogeneous teams have been shown to be less innovative and hold back critical thinking [4]. Diversity brings in a range of ideas and life experiences, while hiring managers are often looking for a candidate who would be a good cultural fit, which often means someone who looks like them, has a similar life experience, and skillsets [5]. This leads to hiring candidates who will not challenge the norm or bring differences of opinion, leaving out a critical part of the creative process of divergence [6, 7, 8].
Researchers have been investigating why women are not applying to design jobs, in the 1980's Bruce noticed there was a lack of women applying for jobs in industrial design [3]. She speculated that terms in application materials such as (industrial, mechanical, technical, manufacturing") have masculine tones and contribute to male dominate atmospheres in the profession [3]. Women often feel the need to prove themselves in our field, they feel they are not taken seriously and must work harder than those around them [9]. However, there are a lack of women in design management positions [10] so regardless

of how much they work, women are not seeing their peers in leadership. When women are in leadership positions it helps other women stay motivated and encouraged to continue in the profession [9].
Internships are a valuable pathway for students to enter full time employment in professional practice. Students who have internships are perceived as being ready to enter the workforce, with students receiving 14% more offers if they have internships than those who do not [11]. There is a lack of research investigating if there are gender disparities in application or placement rates in industrial design internships. This research investigates the gap of women progressing into the field of industrial design and how it relates to student internship rates. I hypothesize that female students are not applying at the same rate as their male counterparts and the lack of gender diversity in the field may be contributing to the disparity.

3 RESEARCH METHODS

The lack of data and previous literature regarding males entering the field of ID at a greater rate than their female counterparts led to the following two assessments. The first was to investigate if males and females were applying to internships at the same rate early in their education, during their 2nd and 3rd year. The second was how many males and females were participating in ID internships at each year of their education. To study this, over a two-year period 2nd, 3rd and graduating 4th year students (n=106) participated in a survey asking the following questions: the number of internships students applied to, if they participated in an internship, their perceptions of their industrial design portfolios, and confidence levels in their work. Informal, semi-structured interviews (n=18) were conducted with 6 students from the 2nd, 3rd and 4th year at the University of Kansas, equal numbers of self-identifying male and female students were interviewed. These qualitative interviews were conducted to understand the scenarios in which students were or were not applying for internships and synthesis with quotes for understanding what students are experiencing while considering participating in internships and jobs. Students' positive and negative experiences, as well as barriers to participating in internships were recorded. Interviews were conducted with (n=8) industrial design hiring managers from a variety of industrial design specialties including (n=5) product design, (n=2) UX/UI, (n=1) Colour Materials and Finish (CMF) design, with a gender breakdown of (n=7) males and (n=2) female in the authors country of origin. The findings from these quantitative and qualitative investigations show disparity in confidence levels in men and women's portfolios, how this perception effects application rates to internships, and the impact this has on employment post-graduation.

4 FINDINGS

The research reflects the unproven anecdotal notion that in industrial design academia male students are applying to and receiving more undergraduate internships than their female counterparts, which leads to a higher placement rate of employment. This was shown through the surveys and interviews with students and employers.

4.1 Application and placement rates

The survey of student's application rate for internships, to see if there was differentiation in application rates by year and gender proved what students and professionals had perceived. At the University of Kansas gender is a factor in internship application rates, 45% of 2nd year females applied to internships, with 9% of female 2nd years receiving an internship between their 2nd and 3rd year. 67% of male second years applied to internships with 38% of male 2nd years receiving an internship between their 2nd and 3rd year. These trends continued into the 3rd year. More female students had internships than in the 2nd year, however, the rate of internships for the male students continued to improve as well, continuing the gender disparity. A total of (n=16) out of (n=32) or 50% of 3rd year students had internships at some point between their spring semester of 3rd year and spring semester of 4th year, with 30% of the females participating in internships and 63% of the males.
After assessing the data further, the author found that applying to internships during the Sophomore year was beneficial, 85% of 2nd year students with summer internships received internships during or after their 3rd year, showing those who received internships were much more likely to be successful in finding a competitive internship later in their education.
The survey of students two months after graduation assessed if students gained full time employment or an internship in industrial design. A greater percentage of men found internships or employment than women, 69% of men and 50% of women.

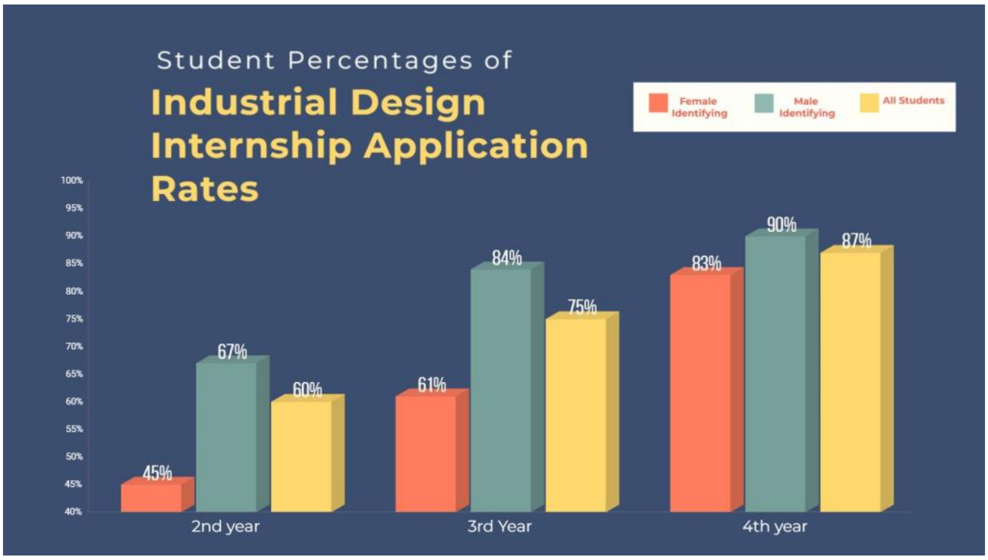


Figure 1. Internship & employment application rates

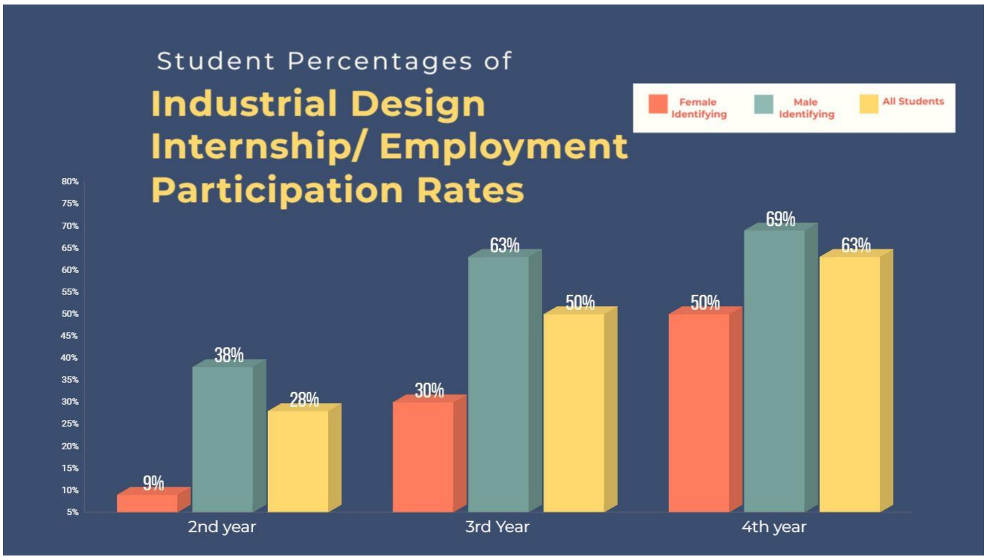


Figure 2. Internship & employment participation rates

4.2 Gender disparities

The interviews and surveys found that student's confidence in their portfolios related to how many internships or positions they applied to. In these interviews when asked why they did or did not apply to internships women were more likely to mention others telling them not to apply, that their work needed to be more polished, making them feel more unconfident and unsure. The three 2nd year females were told they were not ready to apply by upperclassmen, while one of the three 2nd year males were told the same, none of the students who were told their work was not ready applied to any positions. There was a consistent concern among all of the students of submitting applications and having reviewers remembering the students work if it wasn't good enough and being judged in the future, this also contributed to students not applying to internships. Students felt more comfortable applying to positions when members in their social group were actively applying. 3rd year students felt more comfortable applying after seeing their peers apply and seeing more of their peers' portfolios. Interestingly, a majority of students (72%) did not use their portfolio created in their 3rd year portfolio course but did see a benefit to having the course offered because it helped them prepare their resume and they used the areas covered in their portfolios they created outside of class.

Social media caused considerable stress, students compared themselves to the work posted on sites such as Behance and Instagram, where highly polished sketching skills and Keyshot renderings are often showcased. More male students than female students find sketching and Keyshot as engaging as other

skillsets and female students were less likely to resonate with those sites or feel as though their work belonged. Female students were more interested in a broader range of skillsets, which include sketching and Keyshot, but also include research UX/UI, Colour Materials and Finish, and soft goods design.
Financial constraints were also an issue for students, a majority of the students at the University of Kansas live off campus and pay for rent during the summer. Students then have to pay for housing at two locations, even with a paid internship the housing costs are high enough to be a barrier to being able to participate in an internship at another location. This exacerbates financial inequities, wealthier students with outside support are able to participate while less wealthy students are not. Students who participate in athletics are also unable to participate in internships, many of whom have scholarships funding their education and have obligations outside of school throughout the academic year and the summer.
After graduation women were more likely to find positions in a broader range of the industrial design field than their male peers, including exhibit design, soft goods design, colour, materials & finish design, UX/UI, and design research. Their portfolios overall tended to have a larger range of product categories, which (according to feedback in professional portfolio reviews) made professionals less likely to see them as being successful in whatever category the professional worked in. The female students who were interviewed were aware that having a broader range of work was seen negatively by some portfolio reviewers. Women closed the gap for fewer internships in their second and third year to some extent, but still were less likely to find employment in ID than males in their cohort.

Figure 3. Application perceptions

4.3 Industrial design managers

Interviews with design managers revealed that teams have more success hiring women when the interview teams are multi-faceted and have some diversity already in the studio. Design managers from hard goods product design gave feedback that women's portfolios will sometimes have a broader range of work including graphics, UX/UI, or soft goods, which they interpreted as the candidate would not be a good fit for their workflow, even if their hardgoods design skills including sketching, CAD, and iterative prototyping were strong. It was difficult to find women design managers to interview, for example in our region there are only male design managers. All the hard goods design managers interviewed stated there were around 20% female applicants for open positions, while UX/UI and research reported an equal number of applicants and CMF had 70% female applicants.

5 DISCUSSIONS

Reviewing the data and the interviews, it is apparent that women do not see themselves fitting in with the field of industrial design as strongly as their male counterparts. There were consistent references to their portfolios not looking "ID enough" and discounting the work they had done even though it fits inside of industrial design practice. This contributes to a lack of confidence in applying and assuming they will not be taken seriously if they do. Social media perpetuates these feelings by consistently showcasing a narrow view of industrial design focused on a specific style of sketching and high-quality photo like renderings in Keyshot. This brings to question how faculties speak about industrial design work and value in early studios, the areas of industrial design that students may not perceive as valuable are the growing industrial design areas of research, UX/UI, and colour materials and finish (CMF).

Employers should also look at the entire body of work if they are interested in hiring a diverse industrial design group, if the candidate has strong hard goods product design skills and also shows interests in other areas of industrial design that should not diminish their ability to succeed in a position. To promote gender equity in the field schools should consider mandating all students apply for internships their second year and look to provide scholarships for summer housing in locations away from campus. Even if students are unable to participate in the internships, students consistently stated how applying for internships made them more confident in their portfolio and motivated them to update their work, so it was more competitive. When these updates began during their second year their portfolios were more refined by their final year in comparison to their peers who only started applying during their final year in the programme. This would decrease the current barriers to entry.

6 CONCLUSIONS

This study showed that starting the application process for industrial design internships during the second year greatly impacts the success of the student. Even if they aren't accepted for internships their second year they are more likely to apply to more internships further down the line, but not applying at all assures not having critical internship experience. Professionals are looking for sophisticated professional work from graduating seniors, without extra work from internships it is hard to be competitive. Currently professionals who are hiring are looking for cultural fit and for designers who will need minimal training. Cultural fit can often lead to hiring practices with a bias towards individuals who resemble the hiring manager or team in both personality, skillsets, culture, sex, and race. There is merit in continuing this investigation forward in:

- Expanding to other areas of the country, collecting data from other academic institutions and Industrial Design firms
- Expanding into other categories of Industrial Design, specifically the demographic makeup of UX/UI and design research
- Assessing portfolios submitted to open positions
- Reviewing portfolios for bias based on gender and or race

Having a quantifiable understanding of where there is a lack of pedagogical equity will assist in addressing the gender gap in professional practice.

REFERENCES

[1] Coroflot, (2021) *Design Salary Guide United States.*
[2] IDSA, (2021) 2021 *Membership Findings Report.*
[3] Bruce M. A Missing Link: Women and Industrial Design. *Design Studies*, 1985, 6(3), 150-156.
[4] Scott Page, The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools and Societies, Princeton University Press, 200.
[5] Schneider B., Smith D. B., Taylor S. and Fleenor J. (1998). Personality and organizations: A test of the homogeneity of personality hypothesis. *Journal of Applied Psychology, 83*(3), 462–470.
[6] Dezsö C. L. and Ross D. G. Does Female Representation in Top Management Improve Firm Performance: A Panel Data Investigation, *Strategic Management Journal*, vol. 33, no. 9, September 2012, pp. 1072-1089.
[7] London Business School, Innovative Potential: Men and Women in Teams, 2007.
[8] Desvaux G., Devillard-Hoellinger S and Meaney M. C. (McKinsey & Company), Business Case for Women, *The McKinsey Quarterly,* September 2008. (The analysis derived from a survey of 115,000 employees at 231 private and public companies around the world. The nine dimensions of organizations are leadership, direction, accountability, coordination and control, innovation, external orientation, capability, motivation, work environment and values.)
[9] McMahon M. and Kiernan L. (2017). Sisters are doing it for themselves? Exploring Gender in Irish Product Design Education. In *DS 88: Proceedings of the 19th International Conference on Engineering and Product Design Education (E&PDE17), Building Community: Design Education for a Sustainable Future,* Oslo, Norway, 7 & 8 September 2017.
[10] *Design Council UK*. The Design Economy: The State of Design In the UK. Feb. 2018.
[11] Nunley J. M., Pugh A., Romero N. and Seals R. A. College major, internship experience, and employment opportunities: Estimates from a résumé audit, *Labour Economics*, Volume 38, January 2016, pp. 37-46.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

AN INTEGRATED APPROACH TO STEM AND SUSTAINABILITY EDUCATION WITHIN THE NEW ZEALAND CONTEXT

Euan COUTTS, Alice YORKE and Teaghan MOWER
University of Canterbury, New Zealand

ABSTRACT
There is a need for science, technology, engineering and mathematics (STEM) skills to prepare young people for a rapidly changing future. However, it has been argued that it is not enough to only teach STEM in isolation; pressing global concerns call for sustainability to be of the highest priority and an integral part of learning. One way to integrate STEM and sustainability concepts is through hands-on activities that reflect real-world problems and contextualise students' learning. This study examined the learning that occurred when a group of 49 primary school students aged between 9 and 13 undertook an engineering design challenge within a New Zealand classroom context. Four key findings emerged: first, the primary level students participating did not have a sound understanding of sustainability; second, participants were able to apply and relate their learning to a real-life context; third, the participating students preferred activities that were hands-on and practical in nature and finally, an integrated approach enabled the students to be engaged and enjoy themselves while learning. The research presented is not intended to present a novel approach for teaching STEM topics, nor be a critique of the New Zealand Curriculum, rather it highlights the application of a STEM programme integrated with sustainability in a specific context within New Zealand.

Keywords: Education, STEM, primary education, sustainability

1 INTRODUCTION & CONTEXT
Demand for science, technology, engineering and maths (STEM) skills are expected to increase over the next 20 years. The need to have technically literate professionals who can think critically and creatively is key to solving the complex problems at present and in the future [1]. But how are we to produce STEM and sustainability-literate, critical thinking, creative problem solvers who are acutely aware of the social, economic and environmental implications of their solutions? This research considers the role of education as a tool to improve STEM and sustainability education for primary school aged students in an Aotearoa, New Zealand (NZ) context.

Declining STEM results among NZ's young people demonstrate a need for renewed focus and attention to STEM-based education. The latest Trends in International Mathematics and Science Study (TIMSS)[2] reported that NZ students' science and maths achievement is significantly lower than Australia, England and the United States. Similar observations are made by the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) [3]. The TIMMS and PISA reports indicate an opportunity to improve STEM skills and understanding in primary school students. It is difficult to be declarative about NZ students' understanding of sustainability, as it is not a prescriptively assessed subject within the NZ curriculum as a distinct element.

Nearly 17% of the NZ population identify as Māori [4]; the indigenous population. Māori culture and knowledge is unique to NZ [5], where the Māori worldview has been, and continues to be, integral to society. Where materialism, dualism and anthropocentric views often serve as the dominant view on the human-environment relationship in western societies [6], Māori views focus on reciprocity and interdependency between people and planet, stemming from their origin narrative. This worldview introduces the idea of *whakapapa* (genealogy) and provide Māori with *tikanga* (right ways of doing things), whereby humankind and the planet shares the same *mauri* (life essence) rather than ruling over the land, humans are inherently related to the earth and are expected to guard over it through a principle called *kaitiakitanga* (guardianship) [7, 8]. The concept of *kaitiakitanga* promotes sustainability and intergenerational equity, endeavouring to ensure that all parts of the ecosystem are in “as good or better state than when they were found” [8]. It is pertinent, given the importance of Māori culture to NZ that such beliefs, values and practices, particularly those that relate to sustainability, are upheld. This cultural landscape of NZ further supports the notion of emphasising sustainability learning in education.

Research suggests that the earlier students are exposed to STEM based concepts, the greater engagement and increased motivation they foster towards these subjects [9]. In a review carried out by Tytler et al. [10] the different factors that get students into the STEM pipeline from primary school to secondary school were explored. This included students’ attitudes towards the subjects, specifically their interest and self-efficacy. These factors were found to be influenced by teachers and the methods of teaching, as well as their socioeconomic backgrounds, and expected future pathways. The focus on attitudes is a prevalent topic in available literature [11, 12] particularly dealing with negative attitudes that can manifest early on towards STEM subjects. Accordingly, this body of work focusses on primary school based students as early engagement to these concepts have been shown to be vital. The English-medium New Zealand classroom is guided by the New Zealand curriculum which is amongst the most flexible and ambiguous in the world [13]. When compared to curricula such as the Cambridge International Curriculum or International Baccalaureate which are prescribed and methodical in nature, the New Zealand curriculum places a high priority on ‘student-centred pedagogies, flexible skills derived from generic core competencies, and inquiry-based learning’ [14]. Revised and released in 2007, the current New Zealand curriculum highlights the core learning objectives for each subject in the ‘back end’ of the curriculum (English, the Arts, Health and Physical Education, Languages, Mathematics and Statistics, Science, Social Sciences and Technology). The approaches to teaching those objectives as well as the values and purpose of the curriculum is detailed in the ‘front end’ of the curriculum. This front end is particularly unique in its inclusion of five key competencies, a vision statement, a set of principles and values and a section on effective pedagogy [13]. Teachers are given the flexibility to address learnings in key subject areas using this front end to design and deliver content and assessments. The aim is to develop well-rounded, confident, connected, actively involved, lifelong learners. While this allows teachers and other learning professionals a large amount of scope and autonomy when it comes to what and how they teach, it can also generate confusion and frustration pertaining to the way they teach it as each school relies on the curriculum as a framework as opposed to a set of instructions [15]. Debate abounds as to the efficacy of this approach, but literature also supports the flexibility of the curriculum allowing for a unique and novel approach to teaching that allows students to be a part of the learning and engage with theoretical and academic concepts on a deeper level [16]. McDowell & Hipkins [17] found schools that incorporate both the back and front ends of the curriculum simultaneously seemed to generate more engagement in students than those who focussed on a traditional teacher-centred pedagogy. This was achieved by implemented project-based learning, student-led inquiry; personalised learning; play-based learning; team teaching; flexible use of time and space; and multilevel/age classes or groups. However, there are split opinions with some schools remaining ‘traditional’, keeping each area of the curriculum separate, citing a variety of reasons including timetabling issues, superficial subject coverage and a lack of cohesion between the different dimensions of the school inhibiting integration of subject matter. Overall though it has been argued that the prevailing integration provides students with opportunities to build meaningful relationships between learning areas and improved engagement. That said only just under half of teachers agreed or strongly agreed that student learning outcomes are better.

2 INTEGRATING STEM AND SUSTAINABILITY

The principle behind integrating STEM education is to connect real-world problems through a comprehensive class unit that combines some or all of the STEM disciplines [18]. This is to allow connected learning for students which is meaningful and relevant [18]. A multitude of studies highlight this multidisciplinary integration by facilitating design-based activities that make connections to real-life problems [19]. Creating a cohesive integrated STEM lesson is difficult due to the challenging nature of these concepts for students in primary school. However, there are successful examples that link environmental problems as the context for a design experiment. The success of a design-based challenge is captured in the lesson plan proposed by Moore et al. [18]. The benefit of this type of lesson plan is the integrated nature of teaching the content through a given context, which provides the students an opportunity to present their design to the class and learn from the discussion. The application of a STEM and sustainability-based programme can be considered a success based on student engagement [10] be it behavioural engagement, emotional engagement and cognitive engagement as discussed by Van Uden et al. [19].

The contextual literature has pointed to STEM education being particularly pertinent for NZ primary aged students. Given the indigenous history and the underlying Māori worldview, integrating STEM and sustainability knowledge, is unique and relevant to the NZ context. This, partnered with the flexibility of the New Zealand curriculum, leads to an opportunity: utilising the NZ curriculum to teach STEM concepts in a way that integrates sustainability, community and project-based learning. The research was guided by four main questions:

1. How important do students perceive sustainability to be and how comfortable are they defining what it means?
2. How do students apply science concepts to an engineering design activity?
3. What are the students' preferred ways to learn?
4. How enjoyable is an integrated science, engineering and sustainability activity for primary school students in a classroom context?

3 METHODOLOGIES

The research sought to identify whether young people responded well to a hands-on challenge that integrated principles of engineering, science and sustainability in a formalised setting. Several primary school age appropriate engineering design challenges were considered and ultimately an egg drop challenge was selected. Students were tasked with a design and build activity to keep a raw chicken egg intact when dropped from a height. The activity was selected because it is a widely known and trialled activity that allows for the integration of science concepts through an engineering design process. This challenge was adapted to be founded on waste reduction and closed loop designs that is relevant in a New Zealand context. The study was carried out at a local primary school in two senior classes *Raupō* (year 5 and 6, aged between 9 and 11 years old, 24 participants) and *Totara* (year 7 and 8, aged between 11 to 13 years old, 21 participants).

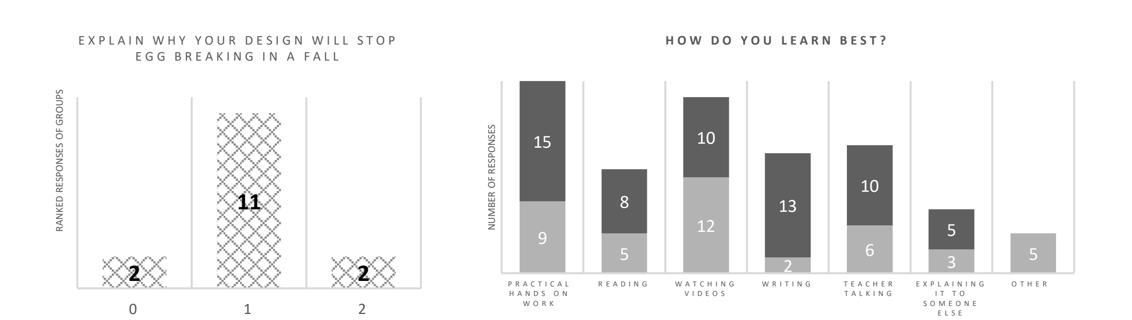
The research is descriptive in nature; accordingly, the primary form of data collection was two surveys involving Likert scales and open choice questions which could be ranked. As Likert scale survey methods are susceptible to self-reporting bias [19] the open questions were also analysed using content analysis by coding the responses to identify how well the STEM and sustainability content was understood. In-class observations were also used to provide a reference check for how well students were relating to the STEM and sustainability concepts. Audio recordings were also used for the researcher's reference to ensure the class discussions were transcribed correctly.

The research was conducted in three sessions. The first was an information-based session; setting the scene and establishing assent and consent for students who wished to participate. As young people were involved, the study was conducted following extensive review by university ethics committee with appropriate permissions and consent sought from participants and their guardians. Two further sessions were designed using the "Good Engineering Unit" conceptual framework outlined by Moore et al. [18]. These sessions involved researchers setting the context through presentations in the format of "fun facts". Environmental sustainability was discussed with a focus on waste produced in NZ including discussing materials and their lifecycles. This progressed to integrating science concepts; forces, gravity and drag were explored via discussion and illustrative demonstrations. Once these sessions were completed the design and build challenge was undertaken: the students organised themselves into groups of two to four students and used provided recycled materials to construct a device that protected an egg when dropped from a 2-storey structure. The third session began with a presentation of the final designs with each group presenting their device for discussion where students could justify their choices and relate their explanation to the theoretical concepts introduced in the second session. At the end of these sessions' participants were asked to complete the short questionnaires.

4 RESULTS & DISCUSSION

The egg drop challenge appeared to be an enjoyable hands-on learning activity that was able to integrate STEM and sustainability teaching practically. Utilising the principles of the lesson plan by Moore et al., [18] the participants were able to contextualise the science and sustainability concepts that were explained to them before applying them to a challenge that produced tangible outcomes (i.e. the egg either cracked or survived). Presenting their solutions to the challenge, discussions were used to cement understanding of concepts.

When considering how important students perceive sustainability to be and how comfortable are they defining what it means; it would appear to be evident that the students felt that sustainability was important but didn't necessarily have confidence regarding what the term means specifically. The participants' response to the survey question "I think sustainability is important" was majority positive. This response is promising that sustainability amongst younger generations is perceived to be important. Although it raised two strands of thinking; does the strength in their response to sustainability being important translate to them being more engaged in sustainability issues, and therefore make more environmentally conscious decisions? Or was it simply because they thought it was the answer we wanted to hear? The results in Figure 2 indicate it may be the latter as when asked if "comfortable explaining what sustainability is" most gave a disagree or neutral response with very few indicating that they felt comfortable they could do so. This lack of understanding for the term was confirmed in the open-ended question, "do you think your design is sustainable?". From the content analysis rankings over half of the group responses were given a 0 for this question, this reflected a response which had no attempt at explanation or an unrelated explanation. No groups provided a response referencing how their design could utilise the cradle-to-cradle design approach and what made the materials used in their design sustainable (or not), which would have ranked higher. When considering how students apply the science concepts to the engineering design activity; this question is addressed by the ranked question results documented in Figure 5. This open-ended question resulted in a great variety of responses which were ranked using content analysis. Rankings were from 0 to 2 and were based on the inclusion or relation of a design feature to relevant scientific or other theoretical information taught either earlier in the session or in the session prior. Most groups stated information about a theoretical concept but did not link these to their design. Two groups, however, did relate design features to one or more theoretical concepts covered in the previous sessions with justification achieving a higher rank. These results would appear to suggest the students did have a grasp of science and engineering concepts in the context of the task.



Figures 1, 2, 3, 4 & 5 (Clockwise from top left): results of surveys and ranked questions (light grey indicates year 7&8, dark grey indicates year 5&6 and pattern indicates mixed groups)

However, the most notable application of science concepts to the engineering activity was through the class discussion. The participants were able to explain their design intent with respect to the learned scientific principles and were open to criticism offered by peers. To the extent of unprompted justifications of their design choices or taking the feedback on board for changes they would make if they had to do it again. The success of the class discussion was unexpected as initially researchers had reservations about how well the respondents would take discussions of their designs. In practice the class discussion was constructive, giving students the opportunity to justify their designs and provided another opportunity to expand on the class discussion and reiterate key scientific principles. The respondents illustrated cognitive engagement in the class predictions of whether the design would protect the egg or not. For example, participants justified that the egg would survive as the design had a parachute with a bigger surface area to increase drag and slow down the descent.

When considering what are students preferred ways to learn; this is addressed by the results demonstrated in Figure 4. Collectively, the most popular learning option for “Practical hands-on work" followed closely by “Watching videos” at 52%. Ranked third and fourth was “Teacher talking” and “Writing”. The least popular learning option was “Other” with 12% of the total votes. As this was an open-ended option, it is not entirely unexpected that it did not generate many responses amongst the numerous options available. The second least popular option selected was “Explaining it to someone else”. However, from recordings it is evident that many did enjoy this in discussions, indicating that there is perhaps difficulty in the degree of self-awareness or reflection and indeed that there may be flaws with the wording and or nature of the survey itself. The younger participants (those in year 5 and 6) prefer hands-on work when in the classroom, while the year 7 and 8 participants preferred watching videos. Collectively these were the top two choices amongst the entire cohort. The biggest variation between the age group of participants was their response to “Writing”, this was ranked third for year 5 and 6 participants, compared to last for years 7 and 8. These responses indicate a variation between the two cohorts. Conclusions drawn from these findings could point towards adapting the styles of teaching to better suit students as they get older. However, these results are a snapshot and do not show whether the year 5 and 6 participants would change their preferences, as they get older, in the same trend as the year 7 and 8 participants. It could instead be preferences that are retained as the participants get older.

When considering what are students preferred ways to learn; this final question was answered through survey response as well as recorded observations. The survey questions that specifically asked their thoughts on the challenge returned majority positive responses; these have not been plotted as chart as they were overwhelming positive with all participants indicating that they enjoyed the challenge. Additionally, when asked “would like to do more science and engineering activities” this was again a majority positive response. While this could indicate an improvement it is difficult to separate out these observations from general enthusiasm for a challenge which felt fun, although the fact it felt fun to the students is in itself a positive indication for incorporating this type of activity in STEM and sustainability education at a primary level.

Observation indicated students were behaviourally engaged, Participants were actively involved in the lesson and on task which meets the definition by Van Uden et al. [19]. The participants listened to teachings, were all involved in planning and constructing their designs, as well as discussing and presenting. To an extent this also shows emotional engagement, as the participants were giving us their full attention and from our observation seemed to be enjoying themselves. Particularly in the testing session, the students were very excited to see if their eggs landed safely. Further research into the extent of student engagement in an integrated engineering design activity in comparison to typical classwork would need to be done in a longitudinal study with a much larger sample size to draw more conclusive results. In such a larger scale study it would also be pertinent follow up over longer timelines to determine any influence on further education and career pathways.

5 CONCLUSIONS

This research aimed to identify whether an integrated STEM and sustainability programme would work in a New Zealand context. Based on a qualitative analysis of primary school students through an egg drop challenge, it can be concluded that integrating STEM and sustainability through a hands-on engineering design challenge is effective in driving engagement and enthusiasm. However, further research is required to definitively state that in a wider New Zealand context the same conclusion could be reached and determine the generalisability of the work. It would be useful for a further study to explore the extent of knowledge New Zealand primary level students have about sustainability. This research is limited by its focus on a small sample size from within one geographic community, but the methods could be applied more generally in a large scale study. New Zealand schools are varied (e.g., traditional pedagogical methods, lower decile, Māori medium or rural schools for example) and consequently adapt the curriculum to meet their community’s needs. In order to properly capture this a longitudinal, multi-school study would be required to determine whether an integrated programme of

STEM and sustainability could work in a wider New Zealand context. While acknowledging the above, the results would appear to indicate that first, the students participating did not have a sound understanding of sustainability. Second, participants were able to apply and relate their learning to a real-life context facilitated through a constructive class discussion. Third, the participating students preferred activities that were hands-on and practical in nature. Finally, an integrated approach enabled the students to be engaged and enjoy themselves while learning with behavioural, emotional, and cognitive engagement.

REFERENCES

[1] Voogt J. and Roblin N. P. A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies, *Journal of Curriculum Studies,* vol. 44, no. 3, pp. 299-321, 2012/06/01 2012, doi: 10.1080/00220272.2012.668938.

[2] Mullis I. V., Martin M. O., Foy P., Kelly D. L. and Fishbein B. TIMSS 2019 international results in mathematics and science, *Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/international-results,* 2020.

[3] Schleicher A. Insights and interpretations, *Pisa 2018,* vol. 10, 2018.

[4] Zealand S. N. Māori population estimates: At 30 June 2020. *https://www.stats.govt.nz/information-releases/maori-population-estimates-at-30-june-2020* (accessed March, 2022).

[5] Rameka L. A Māori perspective of being and belonging, *Contemporary Issues in Early Childhood,* vol. 19, no. 4, pp. 367-378, 2018.

[6] Van Opstal M. and Hugé J. Knowledge for sustainable development: a worldviews perspective, *Environment, Development and sustainability,* vol. 15, no. 3, pp. 687-709, 2013.

[7] Timoti P., Lyverv, Matamua R., Jones C. J. and Tahi B. L. A representation of a Tuawhenua worldview guides environmental conservation, *Ecology and Society,* vol. 22, no. 4, 2017.

[8] Kennedy A.-M., McGouran C. and Kemper J. A. Alternative paradigms for sustainability: The Māori worldview, *European Journal of Marketing,* 2020.

[9] Chambers N., Kashefpakdel E. T., Rehill J. and Percy C. Drawing the future: Exploring the career aspirations of primary school children from around the world, *London: Education and Employers,* 2018.

[10] Tytler R., Osborne J., Williams G., Tytler K. and Cripps Clark J. Opening up pathways: Engagement in STEM across the primary-secondary school transition, *Canberra: Australian Department of Education, Employment and Workplace Relations*, 2008.

[11] Counsell S. L. and Geiken R. Improving STEM teaching practices with R&P: increasing the full range of young children's STEM outcomes, *Journal of Early Childhood Teacher Education,* vol. 40, no. 4, pp. 352-381, 2019.

[12] Aladé F., Lauricella A., Kumar Y. and Wartella E. Who's modeling STEM for kids? A character analysis of children's STEM-focused television in the US, *Journal of Children and Media,* vol. 15, no. 3, pp. 338-357, 2021.

[13] M. O. Education. The New Zealand Curriculum. https://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum (accessed March, 2022).

[14] Wood B. E. and Sheehan M. Dislodging knowledge? The New Zealand curriculum in the 21 st Century, *Pacific-Asian Education Journal,* vol. 24, no. 1, 2012.

[15] Hipkins R. More complex than skills: Rethinking the relationship between key competencies and curriculum content, in *International Conference on Education and Development of Civic Competencies, Seoul. Retrieved from http://www.nzcer.org.nz/system/files/more-complex-than-skills_0.pdf,* 2010.

[16] Cowie B. et al. Curriculum implementation exploratory studies, 2009.

[17] McDowall S. and Hipkins R. *Curriculum Integration: What Is Happening in New Zealand Schools?* ERIC, 2019.

[18] Moore T. J., Guzey S. S. and Brown A. Greenhouse design: An engineering unit, *Science Scope,* vol. 37, no. 7, p. 51, 2014.

[19] Van Uden J. M., Ritzen H. and Pieters J. M. Engaging students: The role of teacher beliefs and interpersonal teacher behavior in fostering student engagement in vocational education, *Teaching and Teacher Education,* vol. 37, pp. 21-32, 2014.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

TEAM BASED PROJECTS FOR MASTERS DEGREE THESIS IN DESIGN EDUCATION

Yong SE KIM
University of Turku, Finland

ABSTRACT
Design students would learn by many team-based design projects. But in a typical master level graduate programmes in design, most of thesis projects are done by individual design students. A desirable project-type masters degree option would be such that two students conduct a collaborative project, sponsored by industry, for the duration of one year. As an approach to satisfy the dual requirements of desirable team-based design projects with industry sponsors and individual evaluation for degree conferral, collaborative thesis design projects can include individual tasks within the overall project objectives. In this paper, how team-based design projects for thesis project of masters degree can be conducted is discussed through an illustrative project where a project team conducted a collaborative design project for a year and team members had their individual components.

Keywords: Project-based learning, team-based projects, design education, master-level graduate education

1 INTRODUCTION
Project-based learning and learning by doing are typical approaches in design education [1]. Design tasks are often conducted through collaboration of design team members. In design education, an important aspect is team-based projects [2]. Throughout the curriculum in a typical masters degree education, students would learn by many team-based design projects. But the culmination of the degree conferring is the thesis project in a typical master level graduate programmes in design. Due to the nature of evaluation of degree candidate, most thesis projects are done by individual design students. On the other hand, it is critical that such a thesis project should involve proper industry relevance. It is important that design projects involve industry collaboration at a level that industry partners are sincere in their collaborative help in design education. Thus, it is very desirable that industry partners sponsor thesis projects with their problems of interest.

A desirable project-type masters degree option would be such that two students conduct a collaborative project, sponsored by industry, for the duration of one year and they prepare project reports and defend their projects through presentations. These projects deal with design projects with strong industry relevance and their breaths and depths are ensured by the two-person team aspect and the two-semester long duration. Yet, the degree candidates are required to write individual thesis to satisfy typical degree conferring requirements at the university level. Also, design team members may need to be evaluated individually while they conduct the design projects as teams. As an approach to satisfy the dual requirements of desirable team-based design projects with industry sponsors and individual evaluation for degree conferral, collaborative thesis design projects can include individual tasks within the overall project objectives.

In this paper, how team-based design projects for thesis projects of masters degree can be conducted is discussed through an illustrative project where the project team conducted collaborative design project for a year and team members collaboratively and collectively designed a product-service system (PSS) [3] for a manufacturing company and they also have their individual components in the PSS design. The paper also discusses remaining issues in conducting team-based design projects for degree conferral. For example, the student team of two students produced three reports typically, two individual theses and a project report. Inevitably, these reports contain many common contents to properly describe what they have conducted. Sometimes, the students and instructors could be criticised that these theses have overlapping contents by those who do not consider the detailed context and the educational intent of this kind of project-based design education.

In the remaining parts of the paper, a curriculum where industry-sponsored design projects were used for master thesis projects is briefly explained so that how the design education was done overall. Then an illustrative project is presented with project overview and design tasks conducted individually by two students. The paper is concluded with discussions and conclusion where some other project-based masters degree design educations are compared and how this type of design education can be enhanced while industry-relevance and team-based design issues can be fully accommodated within the situation of degree conferral requirements of typical master-level education systems with theses.

2 GRADUATE PROGRAMME OF SERVICE DESIGN

Industry requires a new special kind of experts in service design and servitisation to lead innovations in manufacturing, healthcare and social innovation. Based on new design methodology developed for PSSs and the software systems with such a methodology embedded, an interdisciplinary graduate programme had been launched in Sungkyunkwan University [4].

The curriculum of the master degree programme is composed of the following 5 layers as shown in Figure 1: (1) *Integrated Design Foundation* with Human Thinking, Human Living, and Human Environment & Integrated Design, (2) *Service Design Core* with Service Design Processes 1 and 2, (3) *Service Design Social Sciences* with Service Management, Service Communication, and Service Cognition, (4) *Service Design Applications* with Product-Service Systems Design, Healthcare Service Design and Social Innovation Service Design, and (5) *Project or Research Options* with Global Collaborative Project or Service Design Research options.

This programme had been supported by the Ministry of Education, in the programme of Specialized Professional Graduate Education, as an innovative graduate education initiative. The unique nature of this programme is that its masters degree education based on project-based learning. The programme offers the project-type masters degree option where two students conduct a collaborative project, sponsored by industry, for the duration of one year and they prepare reports and defend their projects through presentations. These projects deal with service design projects with strong industry relevance and their depths and breaths are ensured by the two-person team aspect and the two-semester long duration. The projects that are related to master theses are conducted in conjunction with those courses of rounded boxes, e.g., Collaborative Design and one of *Service Design Applications* courses.

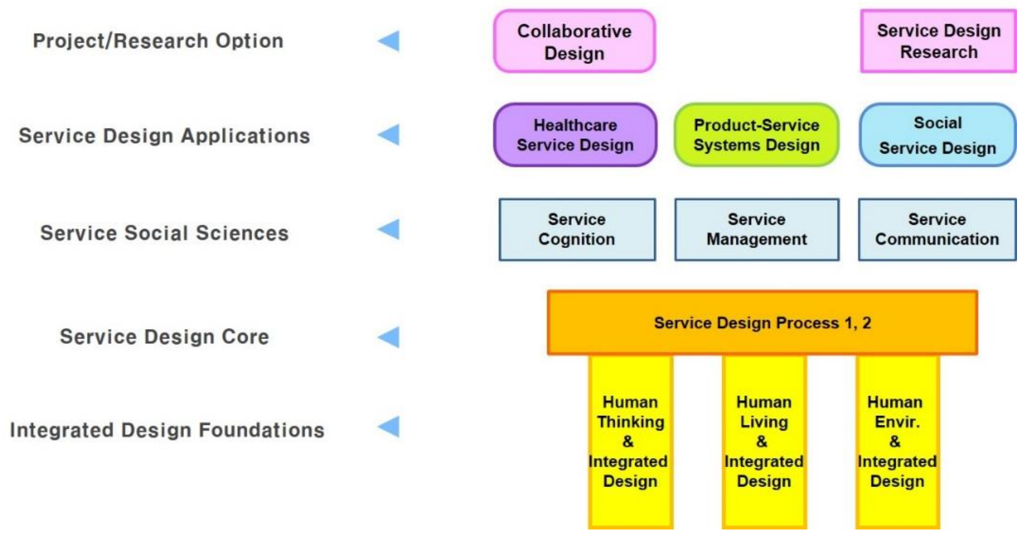


Figure 1. Curriculum of the masters degree programme

3 AN ILLUSTRATIVE PROJECT

A PSS had been designed for a glasses sales company with more than 200 franchise stores to improve customer purchase experiences [5]. A student team supervised by the author with two more faculty members as evaluators conducted PSS design for the duration covering last two semesters of their 2-year masters degree graduate study. A very close collaboration with the company including the CEO and the headquarter store had been made throughout the project.

3.1 Project overview

The design team identified value themes [6], including *functional values* of customization, expertise and choice, *social values* of empathy, pressure and self-esteem, *emotional values* of fun, worry and indecision, *epistemic values* of variety and coordination, through empathy research of consumers and service providers as well as mystery shoppers. The PSS for glasses purchase was composed of 6 service concepts: *Shop Visual*, *Vision Systems Renewal*, *Style Supporters*, *Style Coordinator*, *Concierge Service*, and *Waiting Café*. With new service concepts, several new stakeholders like style supporters, style coordinators and concierge had been created with specific new service roles as shown in Figure 2.

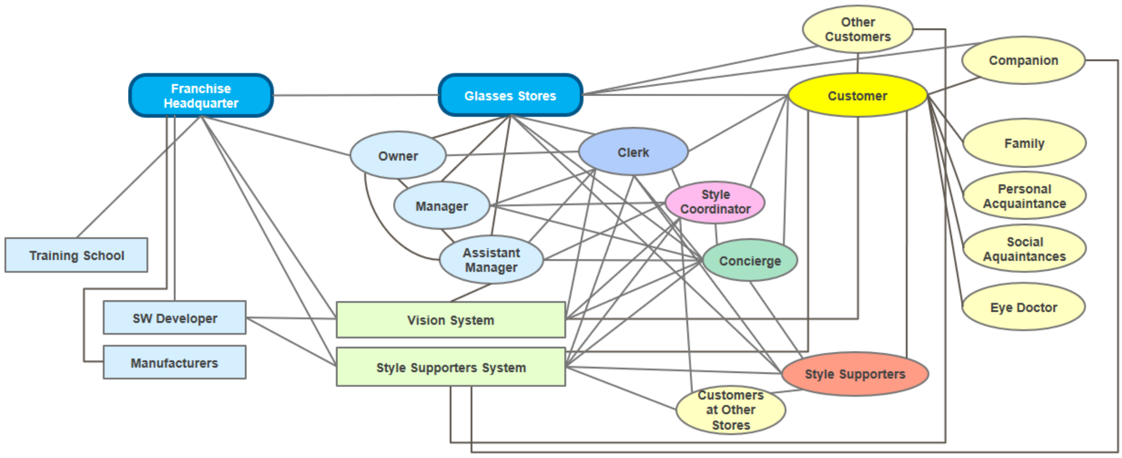


Figure 2. Stakeholder map of the resulting glasses purchase product-service system

The *Style Supporter* service was to provide some support in purchase decision making in real-time using the intranet and other customers who would be waiting for their glasses to be prepared in the store and in other stores of the franchise. The headquarters of the franchise demanded the clerks in the stores would not make any premature suggestions in choosing glasses frames as not all the clerks would be qualified to give such suggestions. But customers needed some suggestions in making their selection of frames. Particularly customers wanted light suggestions which they could take or reject. On the other hand, there were a lot of customers waiting in the café after going through their own decision makings in selecting frames. The Style Supporter service was to get votes from the waiting customers through intranet if a customer would like to seek some opinion on her choices of several frames using photos as shown in Figure 3, where a man in café participated in the vote as a style supporter and the buying customer received vote results obtained from eight style supports for her trials with 6 frames.

Some experienced clerks could provide proactive style guide services as shown in Figure 4. But the number of such qualified clerks were very small and not all stores could have such clerks. The *Style Coordinator* service was to provide such proactive style guides to customers by qualified clerks in other stores through intranet.

While the project team of two master students and the advisor collectively designed these 6 service concepts and conducted extensive prototyping, two master students conducted specific individual tasks respectively so that these design tasks were used in evaluating their individual contribution and level of mastery for the degree.

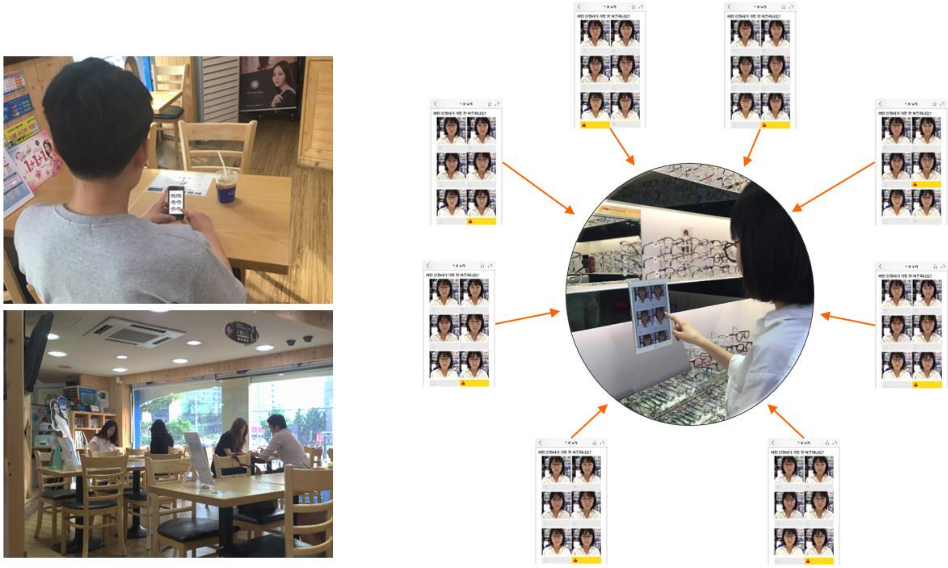


Figure 3. In-store prototyping for the style supporter service

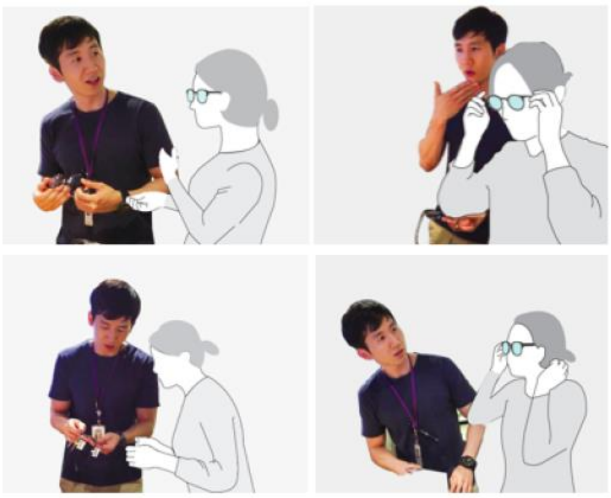


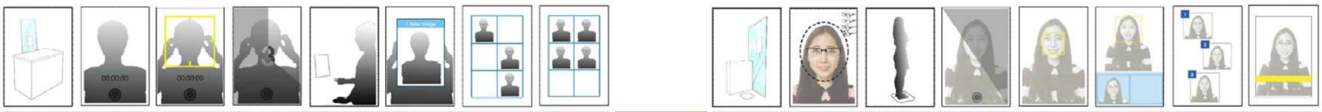
Figure 4. Style coordinator service

3.2 Individual Component of Student A

For the Style Supporters service, new product-element needed to be designed so that the activity of taking photos to be used for voting can be supported. Various user activities and functions of such a product-element were investigated to design affordance features to smoothly induce user activities in photo taking while trying several glasses frames. Specific design for affordance method [7] had been used in the design of the new product-element. This task was conducted by Student A individually. The evaluation of two designs of product-element for taking photos (Glasses Trial Station) was made with specific value themes as evaluating criteria using a morphological chart approach as shown in Figure 5.

3.3 Individual Component of Student B

Student B individually developed intensive instructions to train style coordinators including developing video guides in interacting with customers as shown in Figure 6.



0	1	1	0	1	1	0	0	Customization	1	0	-1	0	0	0	1	0
0	1	1	1	1	1	0	1	Easy	1	0	0	1	0	0	0	0
0	0	0	1	0	1	0	1	Kind	1	1	1	0	0	0	0	0
1	0	0	1	1	0	0	0	Boasting	0	1	0	0	1	0	0	0
0	1	1	1	1	1	0	1	Helpful	1	1	0	1	0	0	1	0
0	0	0	0	0	0	0	0	Empathetic	1	0	0	0	0	0	0	0
0	1	1	-1	1	0	-1	-1	Pressure	1	-1	-1	0	0	0	-1	0
1	1	1	1	1	0	1	1	Reliable	0	0	0	1	0	1	1	1
1	1	0	0	1	0	0	0	Fun	0	1	0	0	1	0	0	1
0	0	0	-1	1	0	1	0	Embarassed	1	0	0	0	0	0	0	0
0	0	0	-1	1	1	1	0	Troublesome	1	-1	-1	0	0	1	1	1
1	1	1	1	1	0	1	1	Stylish	0	1	0	0	0	1	1	1
1	0	1	1	1	1	1	1	Sincere	1	1	1	1	1	1	0	1
1	1	1	1	1	1	1	1	Smart	1	1	-1	0	1	0	0	0
1	1	1	0	1	1	1	1	Information	1	1	0	1	0	1	1	1
							Sum : 64		Sum : 40							

Figure 5. P-Element design comparison for glasses trial station of the style supporter service

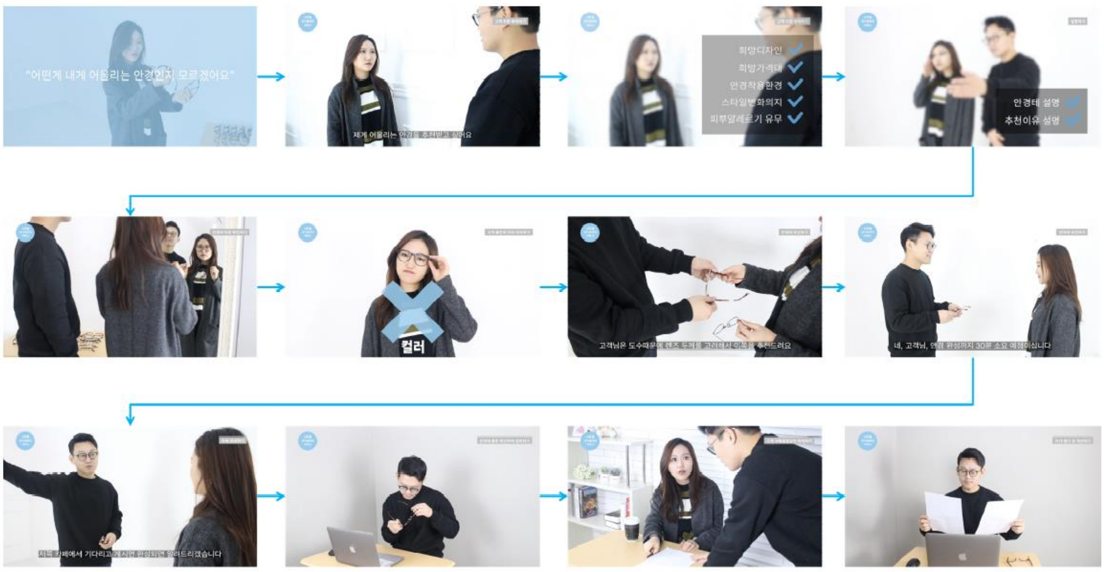


Figure 6. Guide video for style coordinator training

4 DISCUSSIONS AND CONCLUSION

In this paper, how team-based design projects for thesis projects of masters degree can be conducted has been discussed so that the required breadth and depth of industry-sponsored project culminating the master-level project-based design education are fulfilled and the thesis requirement at the university level are also satisfied. The comprehensive report of the project is also important to report the overall and detailed description of the project with proper recognition of all the people involved in the final project of the team-based project-based education. Some overlap of contents in the comprehensive report and student theses must be tolerated, rather than criticized, as these represent the fact and the reality in this kind of design education.

Please note that some master-degree programmes do not require a thesis. A typical example is MS degree programme of Stanford University where a most successful design education at master-level with industry-sponsored, team-based design projects have been conducted [1]. The student teams would prepare comprehensive design project report to be provided to sponsoring industry partners. For some master-degree programmes requiring a thesis, students can select individual design projects or team-based design projects. In the case of team-based design projects, the student team can prepare a collective report to satisfy thesis requirement. In programmes where individual thesis is required, as shown in the illustrative project of this paper, theses with some common contents describing overall project design and with some individual design tasks would be desirable as long as these include specific statement that the design project was conducted by a team. What is more important is that design education ensures industry-relevance with enough breadth and depth for masters degree.

ACKNOWLEDGEMENT

The author is grateful to the two master students, Oh, H.R. and Jung, S.Y., who conducted the project to design the PSS for Glasses Purchase. The author also thanks glasses sales company Davichi for sponsoring the project. The project and related master theses were conducted at Sungkyunkwan University before the author moved to the University of Turku in 2022.

REFERENCES

[1] Carleton T. and Leifer L. Stanford’s ME310 course as an evolution of engineering design. In *Proceedings of the 19th CIRP design conference–Competitive design*. Cranfield University Press, 2009.

[2] Hirsch P. L. and McKenna A. F. Using reflection to promote teamwork understanding in engineering design education. *International Journal of Engineering Education*. 2008, 24(2).

[3] Goedkoop M. J., van Halen C. J, G., te Riele H. R. M. and Rommens P. J. M. Product Service Systems, Ecological and Economic Basics, the Dutch ministries of Environment (VROM) and Economic Affairs (EZ). Hague, The Netherlands. 1999.

[4] Kim Y. S., Lee S. W., Lee S. I., Kim K. O., Kim M. and Won J. H. Product-Service Systems Design Education and a New Interdisciplinary Service Design Graduate Programme, *International Conference on Engineering Design, ICED'13,* Seoul, August 2013.

[5] Kim Y. S., Cho W. H., Lee J. S., Kim S. E., Oh H. R. and Jung S. Y. Glassess Purchase Experience Service Design, (MSSF Report 2016-10), Sungkyunkwan University, Nov. 2016, ISBN 979-11-960525-3-9 (In Korean).

[6] Cho C. K., Kim Y. S. and Lee W. J. Economical, Ecological and Experience Values for Product-Service Systems, *Design & Emotion Conference*, Chicago, October 2010.

[7] Kim Y. S. A Methodology of Design for Affordances using Affordance Feature Repositories, *AI in Engineering. Design, Analysis, and Manufacturing*, 2015, Vol. 29, pp.307-323.

INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

ONBOARDING, A LEARNING APPROACH TO OVERCOME ADOPTION THRESHOLDS WITH EXTENDED REALITY

Anders BERGLUND
Mälardalen University, Sweden

ABSTRACT
Never before has restrictions at a global scale due to the Covid-19 pandemic put industry at such unprecedented transformation need. Sustainability by using resources with greater consideration in order to continue to stay resilient, and to thrive post-pandemic has put attention on how benefit the most out of emerging technologies. The advent of extended reality (XR) is today reshaping the way people experience the physical and the virtual environments, from observation to immersion. Due to the turmoil caused by the pandemic technologies that minimize equipment threshold has increased in popularity. Today XR enable experts to be more productive to detect and debug problems and resolve production issues remotely. Currently, both clear advantages and potential disadvantages may exist based on degree of the maturity level of integration. XR provides opportunities for immersive learning, upskilling and renewal. Still, it involves several uncertainties in benefits. XR implementation therefore remain very dispersed among companies. Implementation of these technologies has been considered more to the level of having an inhouse highly sophisticated playground, with potential for later consideration. However, what is missing in many instances is a clear understanding of the impact and transformative mechanisms that AR, VR and MR could provide if only equipped with learnings of how to introduce and adopt knowledge embedded in various use-cases. With a growing experience in testing these technologies the possibilities and requirements needed for successful decision-making are also starting to emerge. Consequently, by understand learning adoption and value drivers in industrial settings, skills practiced in academia can be sharpened not only from a contextual understanding but also to new academic domains and to incentivize implementation initiatives. This paper is looking at distinct value indicators for onboarding as a way for industry professionals to learn new XR skills.

Keywords: Extended reality, immersive learning, industry relevance, value proposition

1 INTRODUCTION
New technologies appear as fast as old ones disappear, and the digital environment seems to be in a state of continual flux [1]. From communication to operations and strategic implications emerging technologies has become a way for enterprises to push forward and innovate for their survival. Swedish industry has been particularly successful showing a strong upswing due to well-founded digital infrastructure to support different new ways of working. In the fourth industrial revolution, communication to operations and strategic implications, emerging technologies has become a way for enterprises to push forward and innovate for their survival [2]. For emerging technologies, the challenge of dealing with uncertainty is many times overwhelming because the technologies have little testing in operating environments leaving several design aspects in the unknown [3]. Using resources with greater consideration has turned attention to continue to stay resilient, and with the potential to eventually thrive post-pandemic digital technologies such as extended reality (XR) has risen in attention [4], [5]. The advent of XR is today reshaping the way people experience the physical and the virtual environments, from observation to immersion. XR is used as the umbrella term, encompassing both augmented reality (AR), mixed reality (MR) and virtual reality (VR). MR consists of high-fidelity holographic 3D models integrated to the real world. AR superimposes virtual and real objects in a real-time display, and VR allows users to control and navigate their movements in a stimulated real or imagined world [4]. Industrial application for XR is vast with a growing body of examples connecting to machines and vehicles that need maintenance, and for technicians that need remote guidance. Still, many companies

have not incorporated parts of XR into their organizational system [6]. With uncertainties in overarching adoption and digitalization processes across different business areas [7], the dilemma for assessing emerging tools with accuracy has arisen with great concern also from the education side [5], [8]. Due to the turmoil caused by the pandemic what is considered as enabling technologies has increased in popularity attention has turned to integration and consequences thereof e.g., adoption thresholds. Currently, XR is becoming more and more significant in promoting industrial products and educating audiences about product offerings and in-built potential. For engineers and designers, the XR technology offers a brilliant way to demonstrate new technologies, products and services at a very early stage. Engineers and manufacturers can by using XR experience their creations before they are built, which has impact on both strategy and the heightened sense of reality.

Since learning attempts and knowledge building is deeply rooted in the performance of complex operations, experiences from more controlled educational settings have potential for commercial practices and vice versa, which may motivate further work in the field [9], [10]. With rising interest in providing guiding examples, experiences from learning practices and adoption steps towards an embedded practice of XR research may support continued practical implementation efforts [11]. Practicing XR in controlled educational contexts have shown that a platform approach to engagement and build-up of lessons learned have been very useful for investigating modular design ideas and assembly work [10]. Attempts that are too short-sighted and concentrate merely on instant return on investment rapidly increase risks for hold-ups constraining expectations of exploration and exploitation. Although research indicates the existence of uncertainty involved in implementation together with an inability to realistically quantify the return on investment [12], the convinced majority with willing to test these emerging possibilities is rapidly growing stronger [3], [8]. The tendency among companies that have been keen adopters of this technology are also strong actors in different part of the supply chain as system providers. A major dilemma for XR implementation is usability, which causes tools to have ripple effects in other part of the company, affecting subsequent change procedures and praxis.

The range of application areas already trying to adopt and make use of XR create an array of opportunities to provide for smoother knowledge acquisition and establishment of new skill sets. Although a myriad of critical challenges exists, difficulties in overcoming technology thresholds provide by default a readiness gap that may early put down good intentions too early [13]. Essential knowledge is currently limited concerning digitally enabled adoption and implementation to support innovation and strategic management [4], [6]. The weakness in adoption rate shown by industry has led to a strong technology push where reluctant attempts to incorporate short-sighted solutions creates an overwhelming dissonance towards leveraging the potential of XR. This research paper put attention on minimizing the uncertainties that many of today's industries face when adopting XR. Assessing value from perceived actions using XR cause a mapping of pros and cons that has implications on aspects ranging from tools, implementation, operations, learning, performance, output/performance, and strategy. Potential benefits in relation to maturity level makes it vulnerable also in relation to security concerns. This way adoption and integration become a critical strategic concern although direct benefit resonance differently between operations and management. XR allow the possibility to discern different effects of diverse sensory or perceptual stimuli on multiple levels of immersion and presence. This support designers to select suitable technological features to stimulate the desired immersion and presence [14]. Understanding how to adopt and properly learn from XR become critical, consequently, aspects relating to assessment becomes fundamental to better establish a harmonized adoption of XR to enable a suitable toolbox for leveraging learning, embedded value, and performance drivers.

2 STATE-OF-THE-ART

Understanding the how to adopt and properly learn from new technologies become critical, especially during societal digitalization transformation. The number of publications on XR technologies has escalated in recent years in areas such as manufacturing assembly [16], educational and skills learning purposes [10][11] and challenges for industrial implementation [15]. Although XR technologies are increasing at shopfloors, there is still need for further validation to make good strategic decisions regarding implementation [6]. In support for this upswing is a genuine growth in digitalization skills, and an increased use of XR to provide organizations with transformative power. Based on the scarce existence of research targeting application adoption of XR, the connection between learning progression and professional training, e.g., manufacturing training has until now recently been kept underexposed [16]. Features that bring most attention when testing XR for learning purposes is a general belief that it provides a 'learning advantage' (43.75%), and that XR also increases 'motivation' (31.25%) [8]. People's anticipated role expansion due to immersion when they are involved in XR need to be part of a strategy and operational tactics so that human aspects does not set aside and cause promising attempts to early failure. Such attempts impede learning and production of use-cases that can provide valuable business opportunity to pursue further [9]. Insufficient resources allocated in-house with knowledge around XR and with a network to build progression around it as competence area in-house only minimizes potential offsets. Past attempts place XR in loopholes or vicious circles that leaves strong business cases of implementation value unexplored [15]. This involves, integration of data and information which can potentially be facilitated at different levels of maturity [18], and people, processes and technologies that are important to balance as part of a digitalization process [19].

3 PURPOSE

Building on challenges and attempts of existing XR frameworks [15], [17], capabilities and antecedents that incentivizes XR as part of a mechanism for change [8], the purpose is to bridge potential thresholds. Consequently, refinement is a natural ingredient in an iterative approach to overcome obstacles and creating a better fit, thus the research question is kept relatively broad. Using the theoretical lens that outline a technology acceptance model, decisions to adopt emerging technologies have shown to deviate based on technology readiness and usability thresholds [20]. To expand insights and make adoption processes more concrete capability growth concerns has been vital in exploring potential value [21]. Consequently, the study is approaching XR implementation from a meta perspective on engineering design education where insights to the adoption process and research question is formulated as follows; 'How can adoption of XR translate corporate value benefits to readiness for immersive learning?'

4 RESEARCH DESIGN

This paper is merging industrial needs for extended reality through the adoption of new technologies allowing shorter and intensified ways for creating efficiency in both learning and performance. By adopting a snowball approach to increase our understanding a process where probing questions were used. The guiding questions were given on several occasions has taken place with four industry professionals, one solution provider, and together with four different teachers. Also, a case company specializing in AR solutions was investigated using a triangulated method. This involved the XMReality's (XMR) Onboarding programme and involved internal archival records, interviews with responsible onboarding managers and technical specialist, and the customer success manager. Based on implementation steps, distinctions have been made to determine stepwise actions to speed up the learning curve among users and features that can support to distinguish value-driven learning processes. To extend authentic use-case practices as usefulness and applicability has been central pillars. Besides the case description four additional interviews and one remote assist workshop with industry experts' experiences has been gathered for the purpose of an explorative study with aim to address XR adoption thresholds. By purposely using pedagogical guidance and testing, the initial overview of XR was initiated during 2021 and explored XR value propositions and demo workshops where distinct features were presented. Interviews followed with both adopters and tech providers concerning critical use cases and perspectives on how to manoeuvre strategically a transition towards an integrated use of XR.

5 THE XMREALITY ONBOARDING PROGRAMME

The XR learning process at XMR has five steps with to reassure user adoption, and as customer it is aimed at shortening integration time, minimizing thresholds and building an in-house expertise in the form of domain specific knowledge repositories. Assessment from a corporate perspective has been highly concentrated to individual value gains that can be portrayed in various use-cases. This learning process has been developed and fine-tuned recently resulting in a formulized routine, the "Onboarding programme," which runs for approximately three months. The steps are as follows:

1. **Handover from sales**
   The first, internal, step when the sale has been made is short handover from Sales manager to Customer Experience (CX) team, with relevant information about the customer and deal for the CX team to know prior to the onboarding begins.
2. **Get Started**
   CX activates domain and contact the customer to schedule a kick-off meeting.

3. **Kick-off Meeting**
   In the kick-off meeting XMR aim to understand the customer the best way possible to tailor the onboarding to their needs. Discussions with the customers concerning intended use cases, roll-out plan, objectives and how to measure success, training and follow ups. At this stage discussions are more concentrated to what the customer has defined themselves and XMR's role is here about giving reasonable suggestions and inspiration.
4. **Training**
   Conduct the trainings as decided upon at the kick-off meeting. Based on a variety of offers depending on user needs, functions like "admin", "user" and "smart glasses" are provided through distinct training programmes. Learning efforts are focused and aimed at the customer's proper target group, meaning that tools are provided on a teaching the teachers manner. Execution differs between on-site exercises or in formats that solely concentrate on different forms of remote practice.
5. **Roll out**
   Involving users in the process with communication, training, testing and start using the software within the company. In practice, step 3 is embedded as part of step 4 yet with the importance of clarifying uncertainties in user-derived needs.
6. **Follow ups**
   XMR do three follow ups with the customer during the onboarding, about two weeks after training, after one month, and three months. These follow ups are provided with three different aims. The first aim is to make sure that initiation is properly set align with the short-term goals. Next aim is a follow up on software and potential need for revising goals for the upcoming time period. Lastly, evaluation of the onboarding and updating of the goals takes place, also long-term goals are decided upon based on parameters for continued partnership and dialog for post sessions once onboarding is finished.

As part of the defining process XMR place much attention upfront to understand the distinct learning challenge ahead. Potential to bring users to a more enhanced level make commitment and engagement a priority on company level as well in the attention to the individual user. Unless this is done properly, it will become difficult to maintain a smooth adoption process, causing a lower value from existing users. By strengthening the adoption process, XMR follows up on the status of their active users to determine how they are performing in contrast to their targets and defined use cases. The company seeks to define milestones for the customers related to purchases, user adoption and activities to push the customer forward. Prior to the release of the systematic onboarding programme, the users were given crash-courses that they paid separately for and were given 1-2 hours training, and once done users were seen as "seen as ready to go". The onboarding programme has allowed XMR to follow the customer journey, and to manage problem and queries at an early stage. The tool is also communicated as "simple to use" but despite that XMR could see a low user adoption and realized that it is not only related to understanding the tool but also change management in terms of changing old ways of working. To facilitate customers concurrent meetings, they build upon users' preferences to establish deepened commitment to benefits and gains established to leverage involvement.

6 FINDINGS & ANALYSIS

Important success factors related to the onboarding programme:

- Allocate resources on management level close to end users and identify "site champions" to support users and push user adoption. Commitment is necessary on all levels.
- Allocate time for users after training to test and become comfortable using the tool prior to using it for real with customers.
- Important for the people giving assistance to understand both sides of using the tool to understand what the person receiving assistance sees.
- Important to distinguish between the value for top management and the value for end users as there are often different driving forces between the two groups.
- It is therefore important to involve end users in the process and following up with them for a successful roll out in the organisation.
- Once end users see the value the tool brings them, user adoption increases, and change happens from the bottom up. This step has provided XMR with some of their most successful use-cases characterized by high satisfaction, motivation to further exploit interaction possibilities.

- To increase success rate, it has been important to start small with clearly defined use cases.
- Define and change processes to incorporate the use of a new tool into a new way of working.

In responses from the tech experts, both short-term and long-term ambitions mention upgrade and the potential to leverage intelligence across the organization. XR provides a prominent way to accelerate decisions, reduce costs, increase productivity and improve worker safety. From the tech user perspective, implementation of XR involves, but is not limited, to technical layout and information flows. With rapid increase and demand for systems that are self-sustained, visual and remote access to existing knowledge become more vital than ever. Preparation of a smooth transition interface, i.e., using clear routines and highlighting transparency via communication, can potentially increase impact of use-cases. The Onboarding sequence that aims to reassure user value along the implementation phase is deemed successful by the case company XMR as they recently formalized a path forward to support new users. Customization has become a way to deliver high end solutions and continuous feedback and with the preferred updates. This has also become to shorten learning curves and to minimize thresholds and potential bottlenecks in application and up-time in using XR tools. Features that could engage operations through visual execution provides further secure processes where XR could expand their both individual and factory engagement in value-driven processes and knowledge expositions rooted in employees. From an individual's perspective XR tools provide both room as boundary spanners where actors can experience more depth than ever before and with the opportunity to go beyond traditional domains and expected roles.

With industry and universities having distinctively different purposes for adopting XR, authenticity become vital in order anchor relevance from an individual level whereas flexibility in form of task benefit and time become more powerful from an organizational level. Three distinctions are made to successfully scale up activities in relation to learnings and value propositions based on this study; ***i) generated XR value***, i.e., what is accounted for, and based on what considerations? ***ii) time-on-task***, individual learning should benefit mastery to overcome domain specific knowledge, hours of systematic testing and exploration provide useful slack when extending operations act, ***iii) learning approach***, avoid short-sighted efficiency since not everything will run smooth from start, be progressive and accelerate so that leadership may mobilize. As past research [16], [20], [21] has pointed out adoption of i-iii) involves alignment of a technology acceptance model, allowing decisions to deviate with less regarding technology readiness and usability [15]. Experiences address how contributions can advance conceptual and practical understanding of XR implementation as the findings are expected to provide more solid empirical evidence that put the cases of provider and user perspectives as ubiquitous sources of scientific and experienced knowledge.

7 CONCLUDING REMARKS

This paper explores ways to overcome adoption thresholds of XR by building on authentic educational challenges rooted in an industry relevance. To enable an educational scale-up, the paper reveals the existence of a synergy between functional learning environments and individual learners. The introduction of onboarding programmes such as the one XMR have introduced show distinct features on how to facilitate users' attention rate and at the same time roll-out a smooth adoption process. From an educational point-of-view lessons learned, i.e., experiences gathered in use-cases, are vital to utilize and also to build wisdom from as these can disrupt traditional practices, remove thresholds and increase transformation power. A structured process to facilitate existing users and new adopters involves high degree of 'guidance,' where a self-directed learning approach is used to establish interaction value. Continued research has an important role in building more knowledge on how use-cases and engagement level can provide a strategy towards tolerance for failure, tolerance for design, and tolerance for efficiency.

REFERENCES

[1] Alizadehsalehi S., Hadavi A. and Huang J. C. From BIM to extended reality in AEC industry. *Automation in Construction*, 2020, 116, 103254.

[2] Bravi L. and Murmura F. Industry 4.0 enabling technologies as a tool for the development of a competitive strategy in Italian manufacturing companies. *Journal of Engineering and Technology Management*, 2021, 60, 101629.

[3] Bergerson J. A., Brandt A., Cresko J., Carbajales-Dale M., MacLean H. L., Matthews H. S. and Sleep S. Life cycle assessment of emerging technologies: Evaluation techniques at different stages of market and technical maturity. *Journal of Industrial Ecology*, 2020, 24(1), 11-25.
[4] Alsop T. Number of human machine interface dedicated augmented reality (AR) & virtual reality (VR) devices worldwide from 2020 to 2030, by context. Available: https://www.statista.com/statistics/1259882/human-machine-interface-augmented-virtual-reality-devices-worldwide/ [Assessed: 2021, 19 December] (2021, 19 December)
[5] Diao P. H. and Shih N. J. Trends and research issues of augmented reality studies in architectural and civil engineering education—A review of academic journal publications. *Applied Sciences*, 2019, 9(9), 1840.
[6] Fast-Berglund Å., Gong L. and Li D. Testing and validating Extended Reality (XR) technologies in manufacturing. *Procedia Manufacturing*, 2018, 25, 31-38.
[7] Rogers D. *The digital transformation playbook*, 2016 (Columbia University Press).
[8] Akcayir M. and Akcayir G. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 2017, 20, 1-11.
[9] Osypova N., Kokhanovska O., Yuzbasheva G. and Kravtsov H. Implementation of Immersive Technologies in Professional Training of Teachers. In *International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications*, 2020, October, pp. 68-90 (Springer, Cham).
[10] Gonzalez Almaguer C. A., Acuña López A., Pérez Murueta P., Aguirre Acosta Á. C., Román Jiménez O. R. and Zubieta Ramírez C. Virtual and Augmented Reality to Exploit Stem-Skills-Based Learning for Engineering Students using the TEC21 Educational Model. In *DS 110: Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021)*, VIA Design, VIA University in Herning, Denmark, 2021, 9-10 September.
[11] Berglund A., Zhou Y. and Martinsen M. An Assessment Review of Learning Performance when adopting Augmented Reality in Engineering Education. In proceedings: *8th Development conference for Swedish Engineering Education,* Sweden, Karlstad Univ., 2021, 24-25 November.
[12] Butt J. A strategic roadmap for the manufacturing industry to implement industry 4.0. *Designs*, 2020, 4(2), 11.
[13] Oke A. E. and Arowoiya V. A. Critical barriers to augmented reality technology adoption in developing countries: a case study of Nigeria. *Journal of Engineering, Design and Technology*, 2021. Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JEDT-12-2020-0519
[14] Chuah S. Wearable XR-Technology: Literature Review, Conceptual Framework and Future Research Directions. *International Journal of Technology Marketing*, 2020, 13, 205-259.
[15] Wannerberg P., Löfvendahl B., Larsson F. and Stridell E. (2019). The Challenges with Implementing XR In the Industry: A study on why industrial companies haven't fully implemented XR yet.
[16] Doolani S., Wessels C., Kanal V., Sevastopoulos C., Jaiswal A., Nambiappan H. and Makedon F. A Review of Extended Reality (XR) Technologies for Manufacturing Training. *Technologies*. 2020, 8(4), 77.
[17] Gong L., Fast-Berglund Å. and Johansson B. A framework for extended reality system development in manufacturing. *IEEE Access*, 2021, 9, 24796-24813.
[18] Berg L. P. and Vance J. M. An industry case study: investigating early design decision making in virtual reality. *Journal of Computing and Information Science in Engineering*, 2017, 17(1): 011001.
[19] Annarelli A., Battistella C., Nonino F., Parida V. and Pessot E. Literature review on digitalisation capabilities: Co-citation analysis of antecedents, conceptualization and consequences. *Technological Forecasting and Social Change*, 2021, 166, 120635.
[20] Chaudhuri A., Rogers H., Soberg P. and Pawar K. S. The role of service providers in 3D printing adoption. *Industrial Management & Data Systems*, 2019, 119(6), 1189-1205.
[21] Suh A. and Prophet J. 'The state of immersive technology research: a literature analysis,' *Computers in Human Behaviour*, 2018, Vol.86, pp.77-90.

DESIGN AND ENGINEERING PEDAGOGIES AS AGENTS FOR DISRUPTION, INNOVATION AND TRANSFORMATION AND THE TRANSFER AND APPLICATION OF REVERSE PSYCHOLOGY ACROSS DISCIPLINES

Deborah ANDREWS[1], Elizabeth J, NEWTON[2] and Ben LISHMAN[1]
[1]School of Engineering, London South Bank University
[2]School of Applied Sciences, London South Bank University

ABSTRACT
Design and engineering have individually and collectively disrupted and transformed societies, economies and the environment through innovative and regenerative practice and activities. Design and engineering education have also been transformative especially the former to which experiential, active, problem and project-based learning has always been central. This paper considers an innovative and particular teaching method – reverse psychology – that employs disruptive thinking and is being used to teach design and engineering students about sustainability. The project, results and impact are discussed in detail and were presented at EPDE21 [1]. The method proved highly successful and feedback suggested that it could be applicable to participants other than university students. This paper describes the subsequent research and its relevance to design and engineering education. The theory was tested in a workshop at an academic staff conference. Feedback was again very positive and a further workshop for academics from different disciplines was organised to develop subject–specific material and assess whether the method was transferable across disciplines. The experience proved highly beneficial to all parties who learnt from each other; the bespoke materials developed during the session were subsequently tested with students who again responded very positively, which soundly endorsed transferability. These various results show that design education remains innovative and is leading and supporting development of pioneering educational practices. Furthermore the design and engineering academics involved in the research learned from colleagues in other disciplines which supports and illustrates the benefit of transdisciplinary collaboration.

Keywords: Reverse psychology, disruptive thinking, deep learning

1 SIMILARITIES AND DIFFERENCES IN DESIGN AND ENGINEERING EDUCATION

1.1 The origins of design and engineering education

Engineering has been practiced for thousands of years although ‘modern’ engineering and the engineering profession began with the first and second Industrial Revolutions in the 18th century; the profession has continued to evolve and to push and pull development of the third and fourth Industrial Revolutions and technologies. Design has also been practiced for thousands of years as an activity in its own right and as part of the engineering process and more formal practice also emerged and evolved from the first and second Industrial revolutions. Although it was initially practiced by architects, craftspeople and engineers, the introduction of new technologies, materials and manufacturing processes encouraged development of more independent design practice and profession, which have also progressed continually and responded to and initiated technological development and change.

The various technical and economic changes associated with engineering, design and society as a whole necessitated the establishment of specialist training and education provision. For example the Royal Society for the Encouragement of Arts, Manufactures and Commerce (RSA) was founded in 1754 to ensure good links between the arts, manufacturing and society, as a result of which an associated school was set up in 1762. Subsequently in 1836 the first design (Normal) schools were founded near to manufacturing centres and in addition to preparing individuals from employment, their mission was to development of ‘good’ design. In 1824 the first engineering college was also founded in Manchester to prepare local working men for employment in industry by training them in the principles of science. The sector subsequently evolved and diversified and in 1920, the Borough Polytechnic Institute (now London South Bank University) became the first institution to admit female students to engineering courses.

1.2 Design education and methods as exemplars of good practice

Although design and engineering education share similar histories, there were and are some significant differences in the approach to teaching and learning. For example, traditional engineering education employed and employs passive (lecture-lab) learning methods and subjects were and are compartmentalised. Conversely, design education has always focussed on experiential and active learning, which goes hand-in-hand with problem-based and project-based learning (PBL). Although the former tends towards discovery of knowledge and the latter to focus on the application of knowledge, [2, 3], both are well-established learning methods that have been shown to increase engagement, the outcome of which is higher marks [4, 5]. By demonstrating the value of experiential learning, design education has served as an exemplar and adoption of this approach to teaching and learning across disciplines including engineering is increasing.

Design Thinking is another example of innovative practice that has been embraced by other disciplines. Although it has always been integral to the design process and profession, it was not formalised and widely publicised until 2005 by the UK Design Council, who subsequently expanded it and promoted it as a framework for innovation in 2015. Design Thinking was also publicised by Tim Brown and IDEO who actively promoted the approach as an aid to creative problem solving to business in general. This methodology has proved very successful across disciplines and professions and consequently a number of high profile educational institutions are running Design Thinking courses that are open to participants from any discipline. There are numerous publications that describe the impact and success of Design Thinking in a wide range of sectors including FMCG, commerce, non-profit/NGOs, healthcare, transport, education, finance and self-improvement, which confirms the transferability of another design-based methodology to other disciplines.

1.3 Encouraging innovation in engineering education

Although engineering education is evolving there is still scope to learn from design education. For example a 2017 report Royal Academy of Engineering report [6] proposed that engineers should be encouraged to be open, personable, and able to (sometimes) dispense with tradition in order to address the challenges of the future Similarly a 2018 report jointly produced by UCL Centre for Engineering Education and Lloyd’s Register [7] proposed that engineering needs to adopt practices that are already inherent to design: “the new roles engineers are forging need reimagined imagery that highlights them creating, innovating, designing and using technologies, working together in teams, being in a variety of settings and working across disciplinary and cultural borders”. Overall, then future education in engineering should break down barriers, and encourage a culture of openness and diverse thinking, which are inherent to design education.

In response to the need to encourage a break with tradition and promote diverse thinking among engineering students as well as the need to address changing environmental and social factors among engineering and design students, academics at London South Bank University developed a project that disrupts conventional approaches to teaching and learning as follows.

2 DISRUPTION AS AN AID TO DEEP LEARNING AND EDUCATION FOR SUSTAINABILITY FOR DESIGN AND ENGINEERING STUDENTS

Students, young people, and society in general are currently facing many unforeseen challenges, and there has been a significant increase in reported mental health incidents. This is partly due to increasing service provision, and acknowledgment of mental health problems (the most common of which are depression and anxiety) and also to social and environmental changes. Triggers are complex and vary and may be associated with personal relationships or more general phenomena such as climate change, which is directly linked to conditions such as eco-anxiety, eco-apathy and climate depression. As educators it is our responsibility to support students’ health and wellbeing and the ‘Being Bad to do

Good' design assignment was developed to simultaneously teach first year Product Design (PD) and Engineering Product Design EPD) students about sustainability and the UN Sustainable Development Goals while helping them to address negative feelings about the climate and environment and to foster empowerment. The assignment was also a catalyst to encourage students from technical and engineering (as opposed to pure) design backgrounds to engage in untraditional, exploratory, interdisciplinary project-based learning. The assignment was introduced in 2018 and has run annually since then. The assignment employed reverse psychology and disrupted common pedagogic practice in that students were asked to develop the most unsustainable solutions to a series of themes including resource use, water, food, energy. The approach proved very effective and all students who took part not only enjoyed the experience but qualitative research also revealed that they believed that they learnt more than they would have learned from a more conventional assignment. Further analysis of design output revealed that that generation of more innovative design proposals and quantitative research also resulted in an upward trend and marks for this and for subsequent higher-level sustainability-related design assignments. This is because 'Being Bad' encourages students to consider challenges in unexpected ways, to engage in deeper learning and retention of information [8]. It is also 'fun' and enjoyment also increases learning and retention of information. This research is on-going and the project, methodology and results at various stages have been presented and acclaimed at the 2020 Life Cycle Innovation conference, the Forum for Sustainability through Life Cycle Innovation and most recently the 23rd International Conference on Engineering and Product Design Education [1].

The widespread interest in and enthusiastic response to the project from experts working in diverse disciplines and the fact that the design profession and education have an established track record of innovation and sharing good practice provoked the question: like experiential / project based learning and Design Thinking can this particular design and engineering pedagogy - reverse psychology – also be successfully transferred to other disciplines to help educators to improve content delivery and improve student learning and experience?

3 TRANSFER OF A DESIGN AND ENGINEERING PEDAGOGY

3.1 Testing the concept and improving teaching in general

Although the response to the concept from individuals working in different disciplines was very positive, no-one other than PD and EPD students had personal experience of the methodology. In order to evaluate the direct impact on individuals working in other disciplines, and the transferability of the overall concept to another subject it was tested at Staff Teaching and Learning Conference. In this case rather than encouraging staff to share ideas about *good* teaching, they were asked to design a *bad* lecture. The audience participation was recorded over twenty minutes, and a summary of bad teaching, grouped around five themes, was produced. The themes were (a) Teaching Content (which included example responses from staff such as putting the difficult material first and the conceptual underpinnings later); (b) Environment (not enough seating, hot or cold rooms); Classroom Dynamics (uncontrolled talkative students; abuse of web tools); IT (inability of staff to connect to systems; networks don't work); (d) Teaching delivery (no checks on learning or feedback; telling the students that a third of them won't be there next year).

The exercise enabled staff to categorise some of the ways this reverse psychology can be liberating in the classroom. Some responses hint at the catharsis of being able to voice frustrations ("freezing cold lecture halls," "networks don't work.") Some responses are creative and funny ("been lecturing to the wrong students altogether"). Some act as a gentle reminder of serious problems that academic staff need to address and manage ("students bullying and harassing each other"), and some identify small mistakes that staff can all make repeatedly ("being on mute".) There are many different ways to do things badly, and each of them can help academics identify ways to do things well.

The session was one of the most popular at the conference and was highlighted in the conference closing address as an example of innovative educational practice. It was attended by over 30 delegates, seven of whom filled in an optional feedback form. Levels of audience participation (via MS Teams) were high within the session, and discussion covered a range of experiences from teaching staff, administrative staff and senior management. Written feedback was widely positive: six of seven respondents said it had made them think differently about their teaching; five said they would now incorporate the technique into their teaching; and all seven respondents asked to take part in discipline-specific workshops for their specific fields, and as a result, a further workshop was organised.

3.2 The impact of the concept on students in different disciplines

Using reverse psychology to inform teaching practice had proved very successful with PD and EPD Design students and so it was desirable to determine if this methodology could be effective for other subjects. To introduce the practice, teaching staff from various disciplines were invited to attend a workshop where an overview was presented, after which they had the opportunity to work on subject-specific topics to present to their students. This session was attended by delegates from Construction Law, Psychology, The Bakery School (including food science and nutrition) and Information Technology.

The delegates were fascinated by the innovative reverse psychology approach and it is worth reporting some of the comments that they made as they developed their own teaching sessions. It was agreed that this sort of activity lends itself to co-creation, a practice whereby students are active participants, interacting and working collaboratively with academics to co-create their learning space. Co-creation practice has been found to nurture student engagement and motivation [9]. It is important not to be too rigid but the method allows students to learn/achieve in a fun way. Another issue for educators is to ensure that the whole class has input, not just those brave enough to speak out. One person described the method as being a good way to help young people deal with performance anxiety by reducing the fear of being wrong. For students who are worried about being wrong, if the aim of the task is to 'fail' then they may think, "*OK I can do this*." Fear of failure is something that holds back students from fully engaging with their studies, although failure has been shown to be a positive strategy if there is thoughtful feedback. Unlike other teaching methods this method actively encourages failure. One delegate pointed out that they "*liked the fact that it may help weakest students who are afraid of putting their hand up*." They also pointed out that it was a way of teaching students to think.

A delegate from Psychology pointed out that there is a need for the tutor to exercise caution; not all topics would be suitable for this approach, especially sensitive subjects surrounding issues like mental health. Nevertheless we argue that this is a great methodology as it is fresh and new for the student; if it were used for all classes however, students would quickly become inured to it and it would lose its appeal. At the end of the workshop, delegates were asked to give feedback on the session. In answer to the question' why did you join the workshop?,' responses focused on a desire to raise student engagement, making sessions more fun and personal development. There was a desire to learn new techniques for teaching, creative lecture development and to "*do things better*." Everyone reported that they had gained what they had hoped, and more, citing how refreshing it was to have a session like this to be able to meet and talk openly with colleagues from other disciplines. Everyone reported that they found the session really helpful and intended to include this methodology in their teaching in the future. Although all of the delegates stated that they were keen to try this approach some are still developing ideas for modules which are not running yet. To date the method has been used by academics in Psychology and Law. In a Psychology MSc course on research methods, students were given a completed ethics form to critique. The ethics form had been created by the tutor with many flaws, ranging from design errors, ethical debates, things sometimes not considered, and some points that should be immediately obvious. The students were mainly from a professional background with little research experience and therefore this is a challenging, but important, topic. The tutor reported that both the students and the seminar leader enjoyed the session giving unprompted feedback that it had been both enjoyable and informative. This is important because as motivated tutor will get more student engagement.

Psychology also used this for some sessions with second year undergraduate students, specifically to introduce a key hypothesis in cognition to the students. In this case they were asked to design a study to investigate a specific area of cognition but it had to break as many of the British Psychological Society's codes of ethics as possible. They worked in groups and then presented their ideas to each other. A follow up session asked them to adapt their ideas to make the study ethical but to consider the difficulties that also presented to what they were able to do. This was followed by a survey to get feedback (one for the students and one for the tutors) with the results reported in Table 1:

Table 1. Survey responses from students and staff

Questions to students	Definite Yes	Probable Yes	Neutral	Probable No	Definite No
Did you enjoy the activity more than if you had been asked to just design a study?	31%	45%	7%	17%	-
Did you think that this way of thinking deepened your understanding of ethics and their importance?	29%	45%	7%	17%	2%
Did you think that this way of thinking deepened your understanding of a difficult topic?	17%	43%	26%	14%	-
Questions to staff					
Did you enjoy the activity more than if you had been asked to just guide designing a study?	71%	29%	-	-	-
Do you think the students enjoyed this as a seminar activity?	29%	43%	14%	14%	-
Did you think that this way of thinking deepened the student's understanding of a difficult topic?	57%	43%	-	-	-

4 CONCLUSIONS

In conclusion, in design education there are already excellent well-established examples of innovation and leadership of good practice (including experiential and project-based / active learning) that have been adopted and practiced in other disciplines including engineering; similarly the design profession has generated excellent examples of approaches to and methods for innovation and problem solving (specifically design thinking) that are being employed across different disciplines and professions. These exemplars inspired the authors of this paper to ascertain whether a novel pedagogy they developed and that had proved successful on design and engineering courses could be transferred to other disciplines in order to support educators and benefit students. This paper briefly describes an assignment - 'Being Bad to do Good' – that disrupts conventional pedagogies by asking students to design *unsustainable* rather than *sustainable* solutions to problems. The assignment uses reverse psychology, which was found to enhance engagement, retention and deep learning by demanding unconventional thought and making learning 'fun.'

The method appeared to be suitable for transfer to other disciplines and consequently the concept was first tested with academic staff in a conference workshop. In this case reverse psychology was used to improve teaching by encouraging participants to consider and raise awareness of bad practice. Interestingly the initial response of the academic staff was the same as that of the PD and EPD students in that they didn't believe that they were being asked to do something 'bad' rather than 'good'. However once reassured, participation and engagement was high, the workshop was lively and enjoyable, and the positive results indicated that the concept was relevant and applicable across disciplines. A further reverse psychology workshop that focussed on developing bespoke materials for different subjects and subsequent sessions with students also confirmed that the method can be successfully transferred across disciplines, all of which highlights the potential for application in other business and professional fields. Although the 'bespoke subjects' workshop began with an overview of reverse psychology and its application in design and engineering, the session became a valuable mutually beneficial dialogue to which all parties were contributing and learning from each other. This qualitative evidence indicates that the approach also helped to break down interdisciplinary barriers. We conclude that use of reverse psychology has been shown to benefit students and academic staff and to demonstrate the successful transfer of a disruptive design and engineering pedagogy to other disciplines; it has also shown that transdisciplinary interaction is beneficial to all parties and should be encouraged and facilitated in academic institutions.

Finally, this series of academic staff workshops and student activities demonstrate that design and engineering education continue to lead innovation and good practice across disciplines and that 'disruption' can create positive transformation if carefully planned and appropriate. Research into the use of reverse psychology is on-going via collaboration with academics from different design, engineering and other subject areas (including Law and the National Bakery School) and the various results will be analysed and compared to learn whether the method is more successful in some disciplines, subjects and assignments than others. The success of the concept has inspired the originators to continue to explore further innovative teaching practice in design and engineering education and beyond.

REFERENCES

[1] Andrews D., Newton E. J. and Lishman B. Rethinking and adapting approaches to Education for Sustainability to address cultural and behavioural change and challenges. In *Proceedings of the 23rd International Conference on Engineering and Product Design Education (E&PDE 2021),* VIA Design, VIA University in Herning, Denmark. 9th -10th September 2021. Available: https://www.designsociety.org/publication/43488/RETHINKING+AND+ADAPTING+APPROACHES+TO+EDUCATION+FOR+SUSTAINABILITY+TO+ADDRESS+CULTURAL+AND+BEHAVIOURAL+CHANGE+AND+CHALLENGES [Accessed on 2022, 3 February].

[2] Dewey J. *Experience and Education*. 1938, (Macmillan. New York).

[3] Kolb D. A. 1984. *Experiential learning: Experience as the source of learning and development*. 1984, (Prentice-Hall, New Jersey).

[4] Blumenfeld P. C. et al. Motivating project-based learning: sustaining the doing, supporting the learning. *Educational Psychologist*, 26, 1991, pp 369-398.

[5] Tali T., Krajcik J. and Blumenfeld P. C. Marx et al., 2004, Rivet & Krajcki, 2004 and William & Linn, 2003 in Urban Schools' Teachers Enacting Project-Based Science*; Journal of Research in Science Teaching* 2006 43(7), 722–745.

[6] Royal Academy of Engineering. *Creating cultures where all engineers thrive*. Available: https://www.raeng.org.uk/publications/reports/creating-cultures-where-all-engineers-thrive [Accessed on 2022, 31 March].

[7] UCL Centre for Engineering Education and Lloyds Register Foundation. *Innovations in engineering education: inspiring and preparing our engineers for the 21st century*. Available: https://www.ucl.ac.uk/centre-for-engineering-education/sites/centre-for-engineering-education/files/ucl_cee_lrf_report_0.pdf [Accessed on 2022, 31 March].

[8] Craik F. I. M. and Lockhart R. S. Levels of processing: A framework for memory research, *Journal of Verbal Learning and Verbal Behaviour*, 1972, 11(6), 671-684.

[9] Bovill C. and Felten P. Cultivating student–staff partnerships through research and practice, *International Journal for Academic Development*, 2016, 21(1), 1-3 DOI:10.1080/1360144X.2016.1124965.

SWIM OR DROWN: TOSSING 1ST YEAR STUDENTS INTO THE COMPLEXITY POOL

Isabel ORDOÑEZ[1], Guim ESPELT[1], Ainoa ABELLA[1], Oscar TOMICO[1,2] and Jessica FERNÁNDEZ[1]
[1]Elisava, Barcelona School of Design and Engineering, UVIC-UCC, Spain
[2]Eindhoven University of Technology, The Netherlands

ABSTRACT
The sustainability challenges we face today as a society are complex, wicked problems. As designers, we are accustomed to fuzzy problem definitions and the iterative nature of problem solving. However, in education we are just beginning to apply systems thinking to actively explore the connections between particular products or services to larger systems views and sustainability goals. Teaching designers in that complexity from their first year of education might be daunting, but we propose it's necessary to prepare these students for the future requirements of their profession. This article describes our approach to teach sustainability for first year design engineering students. It was done within the frame of the Design Methodologies course, in the Design Engineering programme at Elisava Barcelona School of Design and Engineering, during fall 2021. Based on previous years' course structure, students were expected to do two projects, an intense one done in 3 four-hour sessions and another one lasting 12 weeks. This year, both projects have had a focus on sustainability, and students were asked to collect and clean used packaging and other secondary materials for some weeks, to use them for prototyping during the course. The experience was reviewed through analysing student project outcomes and complementing the findings with a student survey to collect their impressions. The article presents these results, comparing the projects from this year to previous years and other similar approaches to draw suggestions for future teaching.

Keywords: Design education, sustainability, sustainable development goals, complexity

1 INTRODUCTION
The sustainability challenges our society faces today are complex, interconnected, difficult to define and involve multiple stakeholders. Even with the UN further specifying the elusive sustainable development objective into the 17 Sustainable Development Goals (SDGs) [1], each of the goals can still be framed as the desired result of solving different wicked problems [2]. Wicked problems, a concept originally used for problems in social policy, are described as "problems in the real world", that do not have a definite formulation, nor a right or wrong answer, and require negotiation of different value sets among diverse stakeholders [3]. The SDG framing emphasizes the need for an underlying systemic change to achieve the goals and suggests this should be achieved with a holistic perspective through multi-stakeholder partnerships [4]. Professionals of all sectors will increasingly be involved in addressing sustainability challenges; therefore, we need to teach about sustainability and the SDGs as broadly as possible. SDG 4, Equitable quality education, proposes through some of its targets to mainstream education for sustainable development and include sustainability into curricula. But when in the education is it most appropriate to include wicked sustainability problems?
Design, and design education, deals with the ambiguity of wicked problems regularly [5]–[7], with some authors highlighting that not all design problems are wicked (i.e., small scale product design, or software design) [8]. In contrast, non-design engineering students do not often learn how to address complex, multi-stakeholder, ill-structured problems, making it difficult for them later to engage in wicked sustainability challenges [9], [10]. However, design engineering and design students confront wicked design problems early on in their education. Design problems often require taking into account many factors, such as different stakeholders' values and points of view, ultimately requiring integrating technical, social and economic requirements into the proposed solution [11]. This was described as "thinking in relationships" by Moholy-Nagy and is achieved in the design process through the iterative

testing of solutions, using prototypes to obtain input from stakeholders and actors from different disciplines in order to improve the proposed solutions, often changing the initial problem formulation and expected solution space [11]. Since designers strive to "think in relationships" (evaluating how the proposed elements would relate and affect the use context) they effectively foster systems thinking, focusing on the relations between elements and how they integrate to achieve a desired outcome [12]. Systems thinking has been identified as a valuable tool to address wicked sustainability problems [13]. Therefore, it seems possible to propose wicked sustainability challenges to first year students, since they are similar to the design problem they already address. Introducing sustainability early in design education has become increasingly more common, given that design schools see a growing demand and urgency for radical change. This is done with the intention of increasing the presence of sustainability topics in the curricula, and to familiarize the students with the type of challenges they will probably face in their professional life, rather than expecting them to obtain a deep thorough understanding of the complexities such challenges bring in the lapse of an academic course.

This paper explores how this complexity could be implemented into education, specifically in the first year of the undergraduate degree in Industrial Design Engineering (IDE). Currently the IDE programme introduces SDGs and life cycle thinking to students during the first year. Then, students are taught to reflect on specific sustainable design criteria during the second year, they learn to quantify environmental impact of products and services during the third year and are expected to integrate sustainable design criteria into their own practice by the fourth year. Studies reflect that students at entry level of engineering-related degrees may have not been exposed to sustainable development issues [14], and that the use of SDGs as part of project briefings may help students' motivation [15] as well as the teachers'.

Additionally, and to promote resource recovery from waste, these students were instructed to collect and clean used packaging and other secondary materials at home for some weeks, to use them for prototyping during the course. This was an additional characteristic that intended to put into practical terms some of the sustainability strategies described to them in class.

The article is structured as follows: First the context and the methodologies used are detailed. Then, project results are categorized to give an insight to the complexity and challenges the students faced, followed by the answers of the student survey. To conclude some major points are discussed.

2 CONTEXT AND METHODS USED

The course used to introduce first year students to wicked sustainability problems was Design Methodologies. This course is taken in the first semester by all first-year students of the undergraduate degree in IDE. This year consisted of 91 first-year students, aged 18-20, that were divided in 4 class groups, of 21 to 24 students with one teacher each. Design Methodologies is an introductory course to design processes and methodologies, consisting of theoretical lectures and readings about the subject matter, with two applied exercises where the students experience doing a design project for the first time. The focus of the projects is not really on obtaining specific outcomes, but rather on the students exploring their creative process to test the tools, steps, and methods they have heard and read about in the theoretical sections. The two projects developed during the course are the Dynamic Sessions (DS) and Extended Design Project (EDP), referring to their respective time dedication. Their respective academic briefs are described in the following subsections. Both projects are a practical introduction to the design process in general, and the Elisava design process in particular [16].

2.1 Dynamic Sessions academic brief

DS are three sessions of 4-hour agile group work, where students are asked to tackle a challenge. For these sessions, students from the 4 class groups are combined and mixed, to foster their ability to work with different people. Once the groups are created (approx. 8 students each) they choose to work with one of the following challenges: How would you improve Elisava students' well-being? (SDG 3: Good health & Well-being); How would you foster gender equality in Elisava? (SDG 5: Gender equality); How would you increase green and safe spaces in the city? (SDG 11: Sustainable cities and communities); How would you reduce electronic waste in the city? (SDG 12: Responsible consumption and production); How would you reduce garbage in the city's coast? (SDG 14: Life below water); and How would you nurture biodiversity in in the city? (SDG 15: Life on land). The challenges had similar formulation with the ones presented in previous years, but the topics were slightly different. This year

each challenge was explicitly linked to a SDG and described in a context that was familiar to the students so they could relate to the problematic (e.g., Elisava, local beaches).
The 3 sessions are structured following the Elisava design process (Table 1). During all three sessions students are free to exit the classroom to gather secondary materials, data, or feedback from other students, teachers or from the streets. Figure 1 shows students working on a Wallmap (left) and the general classroom situation during the DS (middle left).

Table 1. Dynamic Sessions structure and the Elisava Design process stages they relate to

Research	Definition	Conceptualization	Validation	Technical Rendering	Communication
Session 1: Research Students are provided with a Wallmap containing six predefined sections.		**Session 2: Prototyping** Each group works on one or several rapid prototypes that respond to the value proposal generated on the first session.		**Session 3: Communicating** Groups work on communicating their project, preparing a 3-minute presentation and exhibition of the material made.	

Figure 1. Images from the Dynamic Sessions. Left: Students using a Wallmap. Middle left: classroom set up. Middle right: materials for prototyping from previous years. Right: Secondary materials collected by students, stored in class for prototyping

2.2 Extended Design Project academic brief

The EDP is the first project that students face in the degree spanning several weeks of dedicated work. They work in groups of 3-4 persons, for 12 weeks, to explore a semi-open brief. This year the brief was to ideate products or services that can improve or innovate on gastronomic experiences from a food design perspective. The topic of the brief is different every year, but the dedicated time and formats for the expected outputs are the same. During the first sessions, a food design researcher gave them an introduction to the topic, and students were then asked to describe some personal gastronomic experiences –either good or bad–, discuss them with the other members of their group, and relate them to one or several SDGs. From that discussion, they defined a more concrete briefing of their choice, framing their research and project development associated to at least one SDG.
The main goal is that students understand that gastronomic experiences –or any kind of experience– become so thanks to the interconnection of different scales: elements, materials, tools and products, the environment where the tools are used, associated services, production chains or people involved in any of the previous. Students shared their projects in a 5-minute final presentation.

2.3 Materials and tools for prototyping

In previous years, teachers provided materials for the students to prototype in the DS, such as pieces of cardboard, rubber, wire, plastic straws, balloons, foam, fabrics, etc. (see middle right image in Figure 1). For the EDP, no specific instructions were given on what kind of material they should be using, so students usually bought what they needed to build their prototypes. This year, after an introduction to sustainability lecture (3 weeks before their first prototyping session) students were asked to gather discarded packaging or other materials and bring them to class for prototyping. The gathered materials were kept in the classroom for most of the semester, at the students' disposal (see Figure 1, right), however no further explicit instructions were given for students to use these materials in the EDP. For tools, students use the workshop facilities and tools available at the school. Many also bring with them simple tools like cutters, scissors, glue and markers. Tool availability was the same as previous years.

2.4 Analytical approach

To analyse the experience presented in this article, information was collected on the two design projects and with a student survey. From both design projects, quantitative and qualitative data was gathered and analysed. First, observations while tutoring were made during the entire project. Each class group had an assigned tutor but some of the dynamics allowed students to get feedback from the rest of the teaching staff. Additionally, at the end of the semester students were asked to share their thoughts about the course through an anonymous 12 question survey. Results from both projects of all the class groups were gathered in a visual map where tutors categorised following an affinity diagram (also known as KJ technique [17]). Two aspects were reviewed and categorized for each of the 36 projects: the materials used in prototyping, and the final design proposal. Finally, for the EDP results, what SDG was associated to the resulting proposal was also reviewed. The categories and their occurrence are described in the following section.

3 ANALYSIS OF PROJECT RESULTS

The DS presented a total of 12 projects, 2 for each SDG related challenge. The EDP resulted in 6 projects per class group, totalling 24 unique project results. All 36 projects were used in the analysis, regardless of what project type they were developed in. Some projects fitted into more than one category, resulting in a higher count than the number of projects.

The final design proposals were categorized in 5 different groups, depending on their scale and typology. Comments on the prototype nature for each type are provided:

- **Urban (n=4):** Proposals at an urban or city level. Scale models, mostly using discarded cardboard, drawn over or covered to provide a cleaner, uniform look. Those models were used to gather feedback on the area they represented and were later modified (Figure 2, bottom middle).
- **Interior Design (n=8):** Proposals within a building context. Scaled models using discarded cardboard for the main structure and varied materials to provide texture finishes for realism, getting a rawer aesthetic when using discarded materials (Figure 2, top left).
- **Product (n=20):** Physical products. These prototypes were in 1:1 scale, to test for usability. Several materials were used depending on the project (Figure 2, top right and bottom left).
- **Information (n=11):** Communication campaigns or applications, from posters to websites. Both physical and digital prototypes were presented (Figure 2, top middle and bottom right).
- **Services (n=16):** Several projects associated a service to one or more of the previously mentioned proposal types. None of the projects was presented solely as a service.

The materials used in prototypes were categorised as follows:

- **Purchased materials (n=12):** to cover specific aesthetic of material needs. E.g.: balsa wood, silicone, methacrylate.
- **Discarded materials (n=6):** gathered from the students' homes or at the school and used as bits and pieces. E.g.: Cardboard; bottle caps as basins, eggcups as toilets, or espresso-to-go cups as bins to build a restroom model (Figure 2, top left).
- **Reused objects (n=13):** gathered from the students' homes or at the school and used as essential parts of the prototypes. E.g.: flowerpot, water bottle.
- **Food waste (n=2):** turned into material. E.g.: mix of clay and fruits to model a cup.
- **Digital models (n=9):** using online apps for graphic prototyping, or 3D representation software. E.g.: website for low waste recipes, interior design model.
- **Printed elements (n=23):** as the prototype itself, or for graphic customisation. E.g.: posters.
- **Rapid digital prototyping (n=4):** E.g.: 3D printing, laser cutting.

In the prototypes made during the DS, very few materials were acquired especially, most were reused from what the students gathered. This could be due to the lack of time for prototyping, or due to direct instructions of prototyping with what was available. Prototypes done for the EDP were more varied and included more purchased and printed materials, and digital models.

Regarding the 24 EDP results, all but 2 final proposals had a clear connection to one or more SDGs. The most frequent SDGs being #12: Responsible consumption and production (n=12), followed by #11: Sustainable cities and communities (n=5), #2: Zero hunger (n=4), #3: Good health and well-being (n=3), then #4: Quality education and #10: Reduced inequalities (with n=2 each) and finally with #11: Life below water and #15: Life on land, both considered in the same project (that proposed a bio-plastic from coffee waste to make disposable cup lids). Fifteen projects related to just one SDG, 6 could be linked to

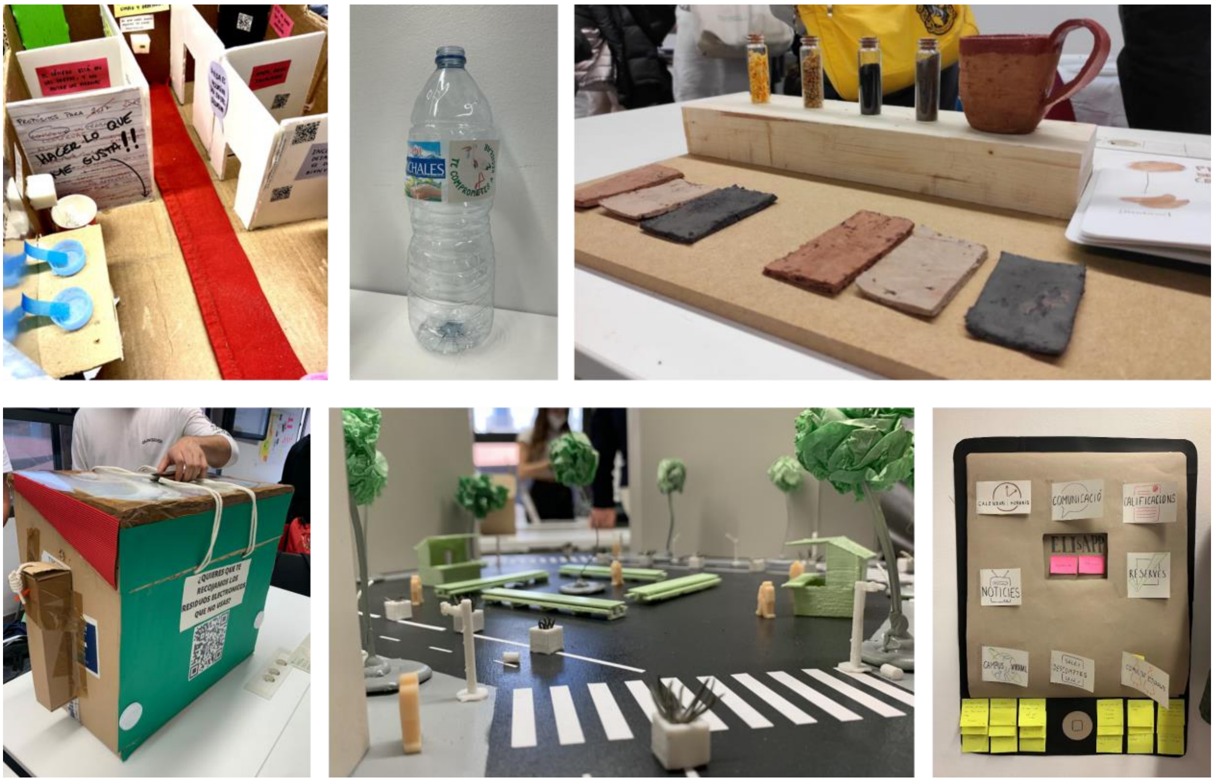


Figure 2. Examples of final project prototypes. Top left: Scale model for a gender inclusive toilet. Top middle: Information campaign against plastic littering. Top right: Ceramic made with organic waste. Bottom left: Backpack for residential electronic waste collection service. Bottom middle: Food sharing experience in urban areas to promote local commerce and avoid food waste. Bottom right: An app to promote student well-being

two SDGs and one connected 3 SDGs with a solar oven (i.e., SDGs 2, 12 and 13).

4 STUDENTS FEEDBACK

After the course a survey was circulated to students to collect their perceptions about the challenges and complexity they had faced. It was an optional activity, in which unfortunately we got low participation, with only 26 of 91 students responding. The survey started with a general evaluation of the course, with students justifying their answers by mentioning the methodologies used in the projects, the topics covered in the sessions, and the feeling of learning by doing from the beginning. Students scored their knowledge about SDGs as almost non-existent before the course (77% of the respondents) and reported that after the course this knowledge had changed (80.8%). Including SDGs in both exercises were perceived as very interesting and appreciated to be included as a statement (88.5%) however in the EDP it was a key element they chose to apply (61.6%) and in the DS, it felt more forced (30.8%). SDGs were considered in all project phases (61.6%) and helped them to think about the sustainability of the final design proposal (61.6%) but at the same time, added a bit of complexity (38.5%). On the other hand, secondary/reclaimed materials in order to prototype were scored as a good idea (92.3%), inspiring (76.9%), adequate (50%), not hard nor easy (42.3%) and almost all respondent groups used only secondary materials (61.5%).

We think one of the reasons for low participation is that it was an action separate from the course learning activities, a few weeks after the final evaluation. It could be more appropriate to integrate the survey in the final reflection of the course. In this way, sustainability becomes equally important as creating their own personal design process.

5 DISCUSSIONS

The typology and complexity of the resulting proposals seem to stem from the complexity of the challenges proposed. Of the products proposed, few were presented as only a product (i.e., only 9/24 EDP and none in the DS) all other products were proposed as being part of a Product Service System (PSS) or broader interior design or urban interventions. If we relate this to the Design for Sustainability

(DfS) evolutionary framework [18], we can draw clear relations between the categories observed in this study to the levels of the framework, with the three first levels of said framework clearly present in this article's categorization (i.e., Product, PSS and Spatio-Social Levels). The last level of the DfS framework, the Socio-Technical Systems levels, requires a deeper understanding of the underlying socio-technical systems that are present in society before one could attempt to change or re-design them. This seems too much to ask from first year students with no previous introduction to systems theory or socio-technical systems. However, they intuitively envision several types of PSS and interventions in the Spatio-Social dynamics observed.

Using secondary materials in design education is not new, and here it proved to be unproblematic for first year students as well. To further promote this practice in more courses at Elisava, staff is aiming to facilitate material reuse through an internal material deposit, connected to external resources.

Compared to the most relatable EDP brief from previous years, where students were asked to observe somebody cooking and choose to design something based on those observations, it is clear that this year's results have been of a higher complexity, without missing academic content from the course. Students explore the same design processes but propose with a wider range of possible solution spaces. In previous years most project results were products, with a few PSS ideas, but now that trend is clearly reversed, with higher levels of complexity, in the spatio-social levels also appearing. To summarize, if tossed into the sustainability complexity pool, first year IDE students' swim.

REFERENCES

[1] United Nations General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, 2015.

[2] Oostra S. Wicked problems unravelled: Explaining the Dutch government's incremental approach to the United Nations Sustainable Development Goals, Radboud University, 2017.

[3] Rittel H. and Webber M. Dilemmas in a General Theory of Planning, *Policy Sci.*, vol. 4, pp. 155–169, 1973.

[4] Stibbe D., Reid S. and Gilbert J. *Maximising the impact of partnerships for the SDGs: A practical guide to partnership value creation*, First Edit. Partnering Initiative & UN DESA, 2019.

[5] Coyne R. Wicked problems revisited, *Des. Stud.*, vol. 26, no. 1, pp. 5–17, Jan. 2005.

[6] Dorst K. Design problems and design paradoxes, *Des. Issues*, vol. 22, no. 3, pp. 4–17, 2006.

[7] Cross N. *Developments in Design Methodology*. Avon, 1984.

[8] McCall R. and Burge J. Untangling wicked problems, *Artif. Intell. Eng. Des. Anal. Manuf.*, vol. 30, no. 2, pp. 200–210, May 2016.

[9] Lönngren J. Wicked Problems in Engineering Education, Chalmers U. of Technology, 2017.

[10] Paulsen M. B. and Wells C. T. Domain differences in the epistemological beliefs of college students, *Res. High. Educ.*, vol. 39, no. 4, pp. 365–384, 1998.

[11] Sless D. Scoping Problem Boundaries, 2002.

[12] System Definition & Meaning - Merriam-Webster. [Online]. Available: https://www.merriam-webster.com/dictionary/system. [Accessed: 12-Mar-2022].

[13] Lönngren J. and Svanström M. Systems Thinking for Dealing with Wicked Sustainability Problems: Beyond Functionalist Approaches, in *New Developments in Engineering Education for Sustainable Development*, W. Leal Filho and S. Nesbit, Eds. Cham: Springer International Publishing, 2016, pp. 151–160.

[14] Sheikh S. N. S., Aziz A. A. and Yusof K. M. Perception on Sustainable Development among New First Year Engineering Undergraduates, *Procedia - Social and Behavioural Sciences*, vol. 56, pp. 530-536, 2012.

[15] Silje Alberthe Kamille Friis. Speaking to Design Students' Motivation−When Creating Design Thinking Courses Based on the United Nations Sustainable Development Goals, *Dmi:journal*, vol. 14, no. 1, pp- 60-72, 2019.

[16] del Corral A. M., Fernández Cano J., Gonzalez M. and Ruidor X. A Look at ELISAVA's Industrial Design Engineering. Engineering that interprets, projects, represents and builds, *Temes de disseny*, vol. 0, no. 32, pp. 80–97, 2016.

[17] Affinity Diagram – Kawakita Jiro or KJ Method. [Online]. Available: https://project-management.com/affinity-diagram-kawakita-jiro-or-kj-method/. [Accessed: 13-Mar-2022].

[18] Ceschin F. and Gaziulusoy I. Evolution of design for sustainability: From product design to design for system innovations and transitions, *Des. Stud.*, vol. 47, no. January 2018, pp. 118–163,

2016.

STUDENT EXPERIENCE OF ONLINE INTERNATIONAL DESIGN STUDIO PARTICIPATION

Polina LOGINOVA[1], Vlada KLAKOVA[1], Erik BOHEMIA[2], Tatiana SEMICHEVSKAYA[1] and Anna SOLOVIEVA[1]
[1]Peoples' Friendship University of Russia (RUDN University), Russia
[2]Shandong University of Art and Design, China

ABSTRACT
We argue that students participating in competitive project activities may facilitate development of their skills such as creative thinking, the formation of "vision" and stress resilience. In this paper, we will reflect on students' experiences who participated in the 10 weeklong creative Global Studio project, which was delivered online across five countries. The article describes features of the creative studio project, the tasks and goals that the participating students set for themselves, as well as their motivations. An important place in the structure of our exploration is the identification of the aspects in this creative studio project which students perceived to benefit their learning as well as the difficulties they experienced with the implementation of their projects.
The article reports the results of a student survey and discusses the attitudes of students with different levels of preparation for creative studio projects.
The article highlights the importance of professional projects and project work as an integral part of the educational process of students of creative specialties and notes that competitive projects carried out jointly with students from different countries of the world give a positive experience of combining the educational process.
We conclude that in the modern world, virtually devoid of borders due to the development of technology, competitive project activity is a new educational trajectory that brings out the student's creativity and teaches them to adapt quickly to the changing stressful working conditions.

Keywords: Professional design education, competitive design, online projects, art projects

1 INTRODUCTION
According to Bobryashova and Mosienko [1], Romanovsky [2], Park and Lee [3], today's world, virtually devoid of borders due to proliferation of the communication technologies, provides education with emerging possibilities to form a new way of engaging and thinking in architecture and art education. Chiurea, Philip [4] and An [5], argued that graduates need to develop professional competencies which will allow them to meet the constantly changing expectations at the workplace [6]. The expected skills and requirements are rather high for the graduates in creative industries, including architecture and design. Besides specific technical professional skills, the graduates are expected to have: openness and receptivity to new things, ability to observe, experience in teamwork, and creative thinking [e.g., 7, 8, 9]. What's more, all the constituents of design capabilities are epistemologically and methodologically strongly connected [10].
The development of the above competencies is largely associated with the participation of students in professional creative activities such as problem and project-based learning [11, 12]. Participation of representatives from different countries, different design schools, and directions provides additional learning possibilities [13]. This form of teaching architectural design, which involves solving a specific practical design problem in a team of like-to minded people (students and teachers), contributes to clarify many professional issues and is the optimal form of self-realisation for the students [14].
In this article, we summarise the experience of the third-year students, enrolled in the Design of the Architectural Environment programme at the Peoples' Friendship University of Russia (RUDN University), who voluntarily participated in the 2020 Global Studio project.

2 PROJECT ARRANGEMENTS
The Global Studio has been an annual collaborative programme since 2006. During the 2020 Global Studio, students from these 6 countries: Italy (Suor Orsola Benincasa University, Napoli), China (SUT,

Zebo), Spain (Tecnun, San Sebastian), Brazil (UFRGS, Porto Alegre), Russia (RUDN, Moscow) and Turkey (METU, Ankara), took part in the international cooperative design project.

The distinctiveness of design projects undertaken in the Global Studio lies in the fact that student teams from different international universities are paired to work cooperatively [15]. Altogether 73 students, who were allocated to 22 teams, participated in the 2020 project. Four of the teams were based at the Peoples' Friendship University of Russia (RUDN University). Two of these teams were paired with students from the Universidad de Navarra located north of Spain, the third was paired with the student team from the Universidade Federal do Rio Grande do Sul (UFRGS) which is located in south of Brazil and the fourth team was paired with students from Middle East Technical University (METU) which is located in the capital of Turkey, Ankara.

Table 1. Participating Universities

University	Country	Teams/ Students	Degree(s)	Study Level	Participation mode
Peoples' Friendship University of Russia (RUDN)	Russia	4/14	Design of the Architectural Environment	UG 3rd	Extracurricular activity
Middle East Technical University (METU)	Turkey	9/18	Industrial Design	UG 3rd	Elective course
Suor Orsola Benincasa University (SOBU)	Italy	2/5	Cognitive Ergonomics	Masters	Optional course
Shandong University of Technology (SUT)	China	1/2	Industrial Design	Masters	Extracurricular activity
Tecnun, University of Navarra	Spain	7/21	Industrial Design	UG 4th	Extracurricular activity
Universidade Federal do Rio Grande do Sul (UFRGS)	Brazil	4/12	Visual Design	UG 3rd	Extracurricular activity

Figure 1. Project stages

Each of the student teams simultaneously acted as "clients" (c) who initiated the design task for their paired team, as well as, in the role of "executors-designers" (d) who create design solutions on the instructions of their paired (client) team from another university.

At the initial stage of work (c1, see the Figure 1), the "client" team's first task was to analyse target users to identify their needs. For the team in their roles as the clients, it was necessary for them to find

out what problems exist in the daily life of the selected target audience and what might provide positive solutions. In the 2020 project, the target users were students' grandparents.
The second task for the clients was to collect and process information. At this stage of work, it was important for the client teams to interpret the obtained data and determine the needs of the target audience. The third task was to conduct primary modelling of objects and situations that bring a "joy" to the target audience, by eliminating or mitigating annoying factors. They articulated this in the project briefs which they gave to their paired teams.
The next stage (c2) was the formation of a technical task for the design teams using the clients' project briefs, a description of the functionality and range of application of the designed object. If necessary, indication of the ergonomic or design features of the designed object. The description of the appearance was secondary. The tasks of the clients at this stage include the preparation of materials that would acquaint the "designers" with the peculiarities of the culture and mentality of the customers. In addition, "clients" must approve the proposed design concept (c3), recreate the object in the layout (material and manufacturing technology are not regulated, the choice of execution technique remains with the "client" team) (c5), prepare a script for an advertising campaign for the target audience and conduct it (c6).
Throughout the joint work, the "clients" provided feedback and thus adjusted the work of the "designers." At the final stage, clients' task was to evaluate the work of the "designers" according to certain criteria, such as professionalism, teamwork, the creative potential of the team, the compliance of the designed object with the technical specifications, and the success of the interaction.
The team of "designers," having received the terms of reference in the form of a project brief, must carefully study the material provided by their "clients" (d1-d2). The material explains to the "designers" the cultural and social differences between their country and the country of the "clients" and may include interviews with the target audience, videos, additional information on traditional arts, folk board games, etc. The main task was to find out the needs of the target audience in the context of cultural and social realities; get acquainted with the terms of reference and, if necessary, clarify issues related to the technological part of the project, design, aesthetic appearance or functionality. The work of the designers at this stage (d3) involved the preparation of several fundamentally different primary and general concepts of the object that aimed to meet the terms of reference and solve the assigned tasks; appearance at this stage was deemed secondary. As the experience of participation in the project has shown, often a lack of awareness of the culture of the target audience of consumers complicated the design process. We have observed that generally this resulted in designers taking a wrong direction, and, accordingly, disappointed their clients.
"Client" team selected one or two primary proposed design concepts (c3). Each member of the creative design team offered their idea for solving this object, working out the features of its functioning and aesthetic appearance, complementing the primary concepts (d4). As soon as the customers approved one final concept, joint work on the project was already underway, in which the whole team took part. At this stage (d5), the "designers" had to carefully work out the appearance and ergonomics of the object, the principles of its technical structure, and the process of functioning, to designate its dimensions and prepare drawings, art sketches, and visualisations. The presentation was meant to give a complete picture of the proposed object. The designers supplied the clients, additional instructions for assembling the object using analogy with the instructions for mass-produced items.
In general, the process of joint creativity aimed at achieving the result, considering the peculiarities of a specific culture, gives an understanding of the relevance and practical significance of the Global Studio project. It has been noted that such work develops tolerance to ambiguous decisions and debatable ideas ("tolerance of ambiguity") [16], an important skill for the future design professionals [17].

3 REFLECTIONS

Language practice such as: oral direct communication, blogging, writing briefs, as well as "immersion" in the cultural layer of the customer's team to evoke the necessary emotions through the created object of industrial design in the field of professional activity plays an important role [18].
The participating students highly appreciated the experience gained during the project work. Among the respondents were students of the 3rd year of the "Design of the Architectural Environment" programme at RUDN. Evgenia Solovieva emphasised that *"the project made it possible to look at the process of creating a product from different angles: from the side of customers and the side of designers. This helped to understand all the shortcomings in working with clients and make it more effective. This experience will be very useful in the future."* Kassai Elizaveta, another 3rd-year student highlighted the ability to build relationships between the "clients" and the "designers" as a positive experience: *"The project allowed us to assess our weaknesses and strengths. Thinking through the action plan step by*

step, we could learn from our own mistakes." Separately, students appreciated the lectures that were held as part of the project work and were aimed at developing creative potential. Kassai E. stated in her review that: *"At the lectures, we examined the variety of graphic design using the example of graphic novels of different genres and analysed the main mistakes. We have mastered such ways of presenting concepts as a mood board, mind map, etc. Listening to lectures in a foreign language was very interesting and useful, albeit unusual at first. I think this experience will be very useful in my further studies in the magistracy."*

Another advantage of such cooperative work was the development of the qualities necessary for effective teamwork. Traditional forms of education often do not provide the desired effect in the development of cognitive activity, independence, and initiative. Vlada Klakova stated that: *"The design process allowed us to form into one production team, to understand who is strong in what and to take advantage of each other."*

The Global Studio has revealed that the approaches to design activities differ in different universities. For example, though students from RUDN usually take an active part in project activities, they are not used to writing briefs or making mind maps. Besides, the meanings of some words were understood differently by students from different universities. For example, when the RUDN team used the word "design" they meant a final product in colour, with patterns of ornament, etc. The students from the Universidad de Navarra, Spain limited the meaning of this word to the development of form and functions only.

The cultural differences between the teams were quite a challenge too. Sometimes we faced difficulties not associated with mentality, but because all people have different traits of character. However, in the brief each team tried to clarify the culture-bound issues and the issues of individual perception; attached interviews with the target group; mood boards and videos. If some additional information was needed, e.g., about traditional ornaments, the teams were happy to share it.

It is unfortunate that in some cases the proposed design solutions were based on cultural stereotypes. However, in most cases after the first meeting the confusing situations were clarified and solved, and the design of the product was modified. In general, the Global Studio proved that it was the dialogue between the students from different countries that helped to solve the problems the teams faced due to cultural or personal differences or differences in the curricula.

We would like to emphasise that the creative programme the Global Studio project does not limit the independence and initiative of the participants. Curators (tutors) of student teams from the participating universities do not make edits to the projected object during its development, but can help students with recommendations, submit an idea. Only the ordering (client) team is allowed to evaluate the project and adjust it. It fosters productive collaboration and brings teams closer together. The advantage is also one age category of teams, which allows participants to more freely discuss all emerging issues. The positive aspects of the creative competition allow the participants to enjoy the design process, which contributes to the development of intrinsic motivation during the creative production process [5].

3.1 Shortcomings

Along with the advantages described above, extracurricular project work has its difficulties. Each team, despite the officially agreed timeframes for completing the work, demonstrated a certain archetype of thinking, interest, speed, perseverance, and perseverance in solving problems. This has been partly influenced by mentality and culture, style and rhythm of life, which is mostly a human factor. It is also worth noting that Russian and foreign design schools are characterised by different approaches to education [2]. In addition, the language barrier aggravated the situation: sometimes the interaction between teams was difficult, as for example, it was difficult to accurately understand the task, which may suppress the motivation of students.

3.2 Comparison

If we compare our experience of participating in the Global Studio with the assumptions made when initiating the Global Studio project [18], it can be noted that all the assumptions have been proved. Firstly, modern students are digital natives. It was pretty easy for us to work with the WordPress site we were blogging on. Secondly, from the very beginning we had a feeling of "equal status" in all the matters of collaboration with the students from another country, despite the fact that our educational programmes were not very much alike. During our joint work we got to know each other better but we went on to put forward equal demands to each other and strictly evaluate the result.

Thirdly, all students had equal access to all information as well as online project websites [18]. Although the students had different levels of English proficiency, the use of online translators helped to make all the teacher-generated and student-generated information as accessible and easy to understand as possible.

3.3 Survey

As were noted above, all participants of the 2020 Global Studio from the RUDN University were senior students, which meant that they had both theoretical and practical training experience as well as initial professional work experience. Assuming that in many respects interest in creative competitions and motivation is connected precisely with the level of training of students, we surveyed first-year and fourth-year students. They were asked to answer several questions: would you like to participate in extracurricular creative programmes? Do you think that participation in such programmes helps in further self-realisation, or does it distract from the educational process? Do you think that participation in extracurricular creative programmes helps in further studies? Below are charts summarising the respondents' responses collected using Google Forms (see Figure 2).

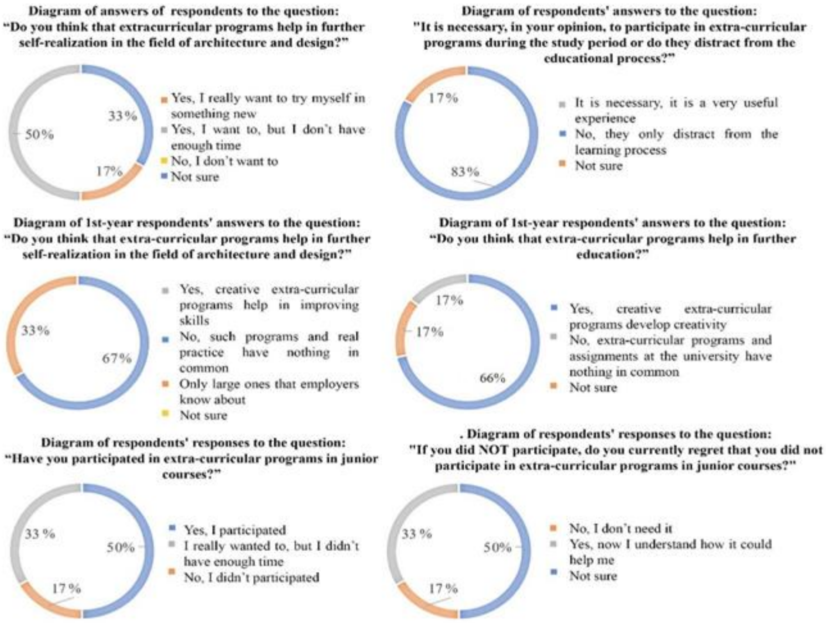


Figure 2. Results of the survey

As can be seen from the diagrams, first-year students, like senior students, understand the uniqueness of the experience that participation in extracurricular project work can give them, but it is often difficult to combine study and creative activity. The respondents noted that extracurricular project activities develop creativity and help in further self-realisation in the field of architecture and design.

We also included in the survey among senior students (year 4 to 5) the questions: did you participate in extracurricular creative programmes in your junior years? If you did not participate, do you regret it? The respondents' answers are summarised in the diagrams in the Figure 2.

According to the data obtained, half of the surveyed senior students did not participate in extracurricular creative projects. Most of them regret the missed opportunity to gain a unique experience that they could get during such an activity.

4 CONCLUSIONS

Summing up, professional design project activities are an important integral part of the educational process for students of creative specialties. Close interaction with people of the same age, but different cultural background, gives a vision of an alternative approach to work, alternative methods of solving problems, and teaches tolerance. A close acquaintance with a different mentality opens new possibilities for creativity. Along with the assessment of his work, the participant of the extracurricular programme could see the work of the others participating in correspondence discussions and expand his creative horizons. It is significant that while preparing for the implementation of the project assignment, the student will certainly study the available developments on the project's topic, which also contributes to the growth of his professional level. At the same time, during project work, psychological stability is formed, which is necessary for everyday work and is not formed in any way in the greenhouse conditions of academic education. Psychological pressure, creative experiences, and precise timing are integral parts of extracurricular programmes. Overcoming difficulties during project activities fosters stress resistance in students, which many authors consider to be the most important skill that needs to be developed among designers-architects [2, 3, 14]. Students who have received such experience will not "float" at the first failures in real work, which allows them to gain a foothold in the team [5, 17].

Students of the Design of the Architectural Environment programme at the RUDN University were especially interested in international training programmes. Joint projects with educational institutions around the world provide a positive experience in combining the educational process and creative work of students and teachers. Participation in the international online Global Studio project was our first and very successful experience in developing cooperation between the Department of Architecture and leading educational institutions around the world. We hope this pioneering educational design initiative, which is unparalleled in Russia today, will continue in future on a yearly basis.

REFERENCES

[1] Бобряшова О.В. [Bobryashova Osana Viktorovna] and Мосиенко Л.В. [Mosienko Lyudmila Vasilevna], *Компаративный Анализ Российского и Зарубежного Опыта Развития Дизайн образования [Comparative analysis of the Russian and foreign experience in the development of design education]*. Вестник Огу [Westrenic Axis], 2014. 2(163): p. 17–23.

[2] Романовский [Romanovsky VG] В.Г. *Современная направленность архитектурно дизайнерского образования [The modern focus of architecturally designer education].* Творчество и Современность [Creativity and modernity], 2017. 2(3): p. 29–39.

[3] Park W. and Lee H.-K. *Creative integration of design thinking and strategic thinking in a design education framework.* Creativity Studies, 2021. 14(1): p. 160–174.

[4] Ciurea C. and Filip F.G. *The globalisation impact on creative industries and cultural heritage: a case study.* Creativity Studies, 2019. 12(2): p. 211–223.

[5] An C., *The content and role of intrinsic motivation in creative work: the importance of seeking "enjoyment".* Creativity Studies, 2019. 12(2): p. 280–290.

[6] World Economic Forum *Global Challenge Insight Report: The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*. 2016. 164.

[7] Beetham H., McGill L. and Littlejohn A. *Thriving in the 21st century: Learning Literacies for the Digital Age (LLiDA project)*. 2009. p. 84.

[8] Amabile T. M. *Educating Leaders Who Make a Difference in the World.* Perspectives on Psychological Science, 2019. 14(1): p. 7–11.

[9] Fisher T. *Designing Our Way to a Better World*. 2016: University of Minnesota Press.

[10] Horváth I. *Design competence development in an academic virtual enterprise.* Proceedings of IDETC/CIE, Philadelphia, Pennsylvania, USA 2006.

[11] Pavel N. *Designing and Learning by Technological Mediation: Adoption, Adaptation, Attainment.* Formakademisk, 2021. 14(3): p. 1–14.

[12] Tregloan K. and Thompson J. *Buckle Up! … BEL+T group learnings from a (very fast) move online.* Charrette, 2021. 7(1): p. 59–75.

[13] Ghassan A. and Bohemia E. *Amplifying Learners' Voices through the Global Studio*, in *Design Pedagogy: developments in Art and Design Education*, M. Tovey, Editor. 2015, Gower: Farnham. p. 215–236.

[14] Ильвицкая [Ilvitskaya SV] С.В., *Опыт конкурсного проектирования в контексте творческого образования архитектора-дизайнера. [Experience of competitive design in the context of the creative education of architect-designer.]*. Вестник РМАТ [Journal RMAT], 2014(4): p. 102–106.

[15] Pott and Behr, *The Leading Edge*. n.d.

[16] Tapanes M. A., Smith G.G. and White J.A. *Cultural diversity in online learning: A study of the perceived effects of dissonance in levels of individualism/collectivism and tolerance of ambiguity.* The Internet and Higher Education, 2009. 12(1): p. 26–34.

[17] Mahmoud N. E., Kamel S.M. and Hamza T.S. *The relationship between tolerance of ambiguity and creativity in the architectural design studio.* Creativity Studies. 13(1): p. 179–198.

[18] Bohemia E. and Ghassan A. *Globally Networked Collaborative Learning in Industrial Design.* American Journal of Distance Education, 2012. 26(2): p. 110–125.

MYRUBRIC, A CO-CREATIVE JOURNEY TO ACTIVATE RESILIENT LEARNING COMMUNITIES

Paula HUESO ESPINOSA, Stefan PERSAUD, Elisa GIACCARDI
Delft University of Technology, The Netherlands

ABSTRACT
Nowadays, designers deal with increasingly complex and meaningful challenges. Because of that, design schools are required to deliver professional designers capable of handling what future decades might bring. Therefore, resilience, generally described as the process of adapting well in the presence of adversity, makes it a valuable quality future generations of designers could develop. As resilience is still an abstract concept within the education domain, this MSc graduation project aimed to explore how it could be built and enhanced in such context. The approach chosen to tackle that question was initially to analyse the literature regarding resilience. Then, to perform an in-depth autoethnographic study in a moment resilience was systematically present in the faculty of Industrial Design Engineering: the COVID19 lockdowns. Finally, the learnings from that period and previous literature research were synthesized into a theoretical framework that aims to assist educators in conceptualizing interventions to foster resilience in learning systems. This framework was implemented to design and evaluate My Rubric, a co-creative guide for adaptive assessment, which aims to offer a constructive and resilient alternative to the current rubric.

Keywords: Resilience, design education, rubric

1 INTRODUCTION
Now more than ever, designers deal with increasingly complex and meaningful challenges [13]. One clear example of those is how the world had to cope with the effects of the COVID19 pandemic on a global scale [4, 15]. In any case, the future decades will also bring all sorts of new threats that designers will need to face for mankind's sustainable development [20]. Such complex problems require complex solutions, as they often involve elaborate systems of stakeholders and issues [4]. However, designing for such complexity is not easy, especially in a world that is changing and evolving at a fast pace. Consequently, innovation in Design curriculums is required [13] to ensure that the next generations of designers are capable of handling what future decades might bring.

It was the beginning of 2020 when the COVID19 pandemic made people's lifestyles change radically [15]. Despite the severe nature of the crisis the world was and still is experiencing, this moment can be seen as a basis for meaningful change and transformation. The pandemic surfaced the need to acknowledge mental health and well-being in our daily lives [7,15]. Furthermore, there is a concept that gained strength these past few years as a response to the pandemic's impact [2]: Resilience, which is generally described as the process of adapting well in the presence of adversity or, in other words, bouncing back despite difficulties and thrive. Those characteristics, along with others that will be further explored through this article, make resilience a valuable trait designers could develop to be ready to face those so-called 'wicked problems' of the 21st century.

Although resilience is widely known in psychology, unfortunately, it is not clear yet how it can be conceptualized within the education domain, as the methodology to implement it in higher education's curricula is still under research [5]. Consequently, some questions arise from that, such as how resilience is conceptualized in that specific domain, how to promote it among educators and students and how it can be embedded in educational structures, practices or tools.

The approach chosen to tackle those questions was to first unveil what resilience entails in educational settings through a literature review. To complement that research, a case study was carried out in the faculty of Industrial Design Engineering (IDE) to gain first-hand insights into how resilience was present in a moment in which was mostly needed, the COVID19 Lockdowns. All those research inquiries are finally synthesized in the Resilient Learning Communities framework, which aims to assist educators in conceiving actions that will serve resilience development in learning systems. Finally, this framework was implemented to design and evaluate a specific intervention, My Rubric.

2 UNDERSTANDING RESILIENCE

2.1 What is resilience?

Resilience has no universal definition [5]; it can be observed through different lenses and those can vary in function of the context within it is described. After exhaustive desk research on resilience definitions, 4 different variables were identified as core characteristics of resilience in learning environments.

- Resilience as the capacity to **overcome challenges**, adapting well in the face of adversity and dealing with unpredictability [1].
- Resilience as the capacity to **embrace setbacks as learnings**, by seeing those moments as opportunities for innovation, meaningful change, and development [6, 18]
- Resilience as the capacity to **manage well-being, stress and anxiety** that directly affect one's physical and emotional state [1, 6].
- Resilience as the capacity to **maintain core elements such as identity and/or structure** when facing difficulties [10, 12].

2.2 How to build resilience?

Resilience is defined as a developmental process [18], which can be indeed modified as new threats or challenges emerge along with life events. In other words, it is performative [6], and dynamic [11]. Some authors even envision it as a practice [12], which educators can foster by creating environments that support it [6]. Therefore, it can be concluded that acquiring resilience is a process that learners can train through time, and the conditions for that to happen can be priorly designed for [6].

Authors generally refer to those threads as risk factors, which represent a detrimental effect on an individual's Basic Psychological Needs (BPN) such as protection, emotional security, attachment, and social interaction [18]. Even though those factors can be subjective, there are several educational and psychological theories that support BPN reinforcement at a universal scale, and therefore when combined, might lead to effective resilience development. For that, Mitchell and Shastri described in their research three fundamental Resilience Building Blocks, which represent a basis for a practical approach to resilience theory [14, 18]. Being those 1, 'Secure base', refers to having a good network of external support figures and a sense of belonging and security. 2, 'Good self-esteem', means to have a clear perception of internal qualities, which are seen as strengths and a sense of worth and competence. And finally, 3. 'Self-efficacy 'addresses the sense of mastery and control, when learners possess a deep understanding of personal strengths and limitations.

2.3 Bringing resilience into education

The RBB serve as a frame to evaluate and choose theories that fit the purpose of building resilience in educational settings by supporting the reinforcement of the BPN and matching with resilience's definition in learning systems. The following elements compose the basis of a construct that aims to translate the theory of resilience to its practical application:

i Self-Determination Theory (SDT): The SDT has its roots in the fulfilment of the basic psychological needs of Relatedness, Competence, and Autonomy, fundamental for social development, growth, and integration, as well as personal well-being [17]. Those BPN, can be respectively related to the RBB.

ii 13 Fundamental Needs: Desmet & Fokkinga identified 13 universal and fundamental needs [8], which are organized in a design-focus typology and are considered essential for growth and happiness.

iii Reflective Practice (RP): Harvey's ecology of reflection theory explains how beneficial reflective practice in experiential learning is [10]. Reflection is a key support for members of a Learning Community in their own learning processes, which may lead to transformative learning, improvement of self-regulation abilities, and development of learner's identity [19].

3 EXPERIENCING RESILIENCE

In order to get first-hand insights into how resilience can be present in learning environments, a case study was carried out. Autoethnography [9, 21] was used as the main method to explore how the Learning Community (LC) of TU Delft's faculty of Industrial Design Engineering (IDE) underwent a

process of building resilience during a specific range of time: The COVID19 Lockdowns, which represented a pivotal moment in education. That resilience emerged from the synergy originated between students, educators, and institution, which led to positive change and transformation from individuals to the whole system; fostering in this way collaborative change and iteration of the community′s strategies to cope with the situation in healthier and effective ways. And thrive.
The recollection of experiences that served as main source of data was supported by interviews with representatives of different parts of the system: 4 Design for Interaction students, 3 Course Coordinators and 4 members of the faculty′s Management Team. The autoethnographic research posed an opportunity to collect the learnings from that time and abstract what made resilience stem in a specific academic context. Those inquiries led to six Resilience Factors:

- **Vision:** Setting a clear and common vision, specific goals, as well as structure in how to get there.
- **Flexibility:** Enabling the right tools to let staff and students choose their own pathways to reach those common goals.
- **Collaboration:** Forming partnerships across the faculty to strengthen each other.
- **Support:** Having open communication that enables safe spaces to voice needs, hopes, and concerns and act upon them.
- **Connection:** Nourishing trust and meaningful relationships based on empathy and kindness and community feeling.
- **Well-being:** Changing priorities from performing efficiently to balancing work and personal life in healthier ways.

4 SPREADING RESILIENCE

All the insights drawn from the literature review and autoethnographic research were synthesized in a framework that would serve as lenses for effective resilience development. The framework, depicted in Figure 1, combines the bits of the theories and factors identified to be essential for it to flourish. Its main purpose is to translate the knowledge on resilience into actionable insights that assist educators to conceptualize interventions that foster resilience in learning communities.

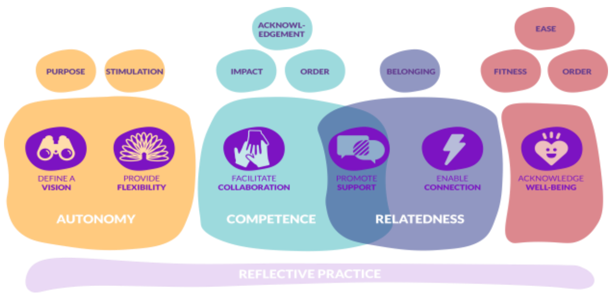


Figure 1.The Resilient Learning Communities

5 FINAL INTERVENTION: MYRUBRIC

The next step was to put the framework into practice by designing an intervention for the faculty of IDE. One of the insights drawn from the case study is how students' BPN are highly influenced by the interactions they have with their coaches and mentors. Therefore, it seemed a context that could benefit a resilient intervention. The focus of the intervention was expectation misalignment in courses, which was identified as one of the main tensions that affects coach-student interactions in multiple levels.

5.1 Intervention design

The articulation of constructive alignment in education [3] is made explicit in rubrics. Currently, the rubric is usually crafted in a unidirectional way coming from course coordination, which might be seen as a hinder to students autonomy and competence. Therefore, the intervention will build up on the main pillars of the Resilient LC framework and aims to reframe this widely used tool towards: **Relatedness:** Feeling welcomed and supported through one′s learning process; **Competence:** Having one′s learning environment under control and a sense of safety to exercise and learn new skills; and **Autonomy:** The facilitation of critical thinking and ownership to steer one′s learning process in the desired direction.

5.2 My Rubric's characteristics

My Rubric is a co-creative guide for adaptive assessment, which aims to offer a constructive, resilient alternative to the current rubric. In a nutshell, it will assist the development of resilience in members of learning communities by facilitating a process in which teachers and students (i) align their expectations by co-constructing a shared understanding of the learning objectives (LO) and outcomes of a given course (ii) prompt active reflection and dialogue to reach that alignment, (iii) develop awareness and ownership of their personal learning experience. My Rubric has three main intervention moments scheduled throughout a course, which are:

- **Kick-off:** This co-creation workshop scheduled at the very beginning of the course represents the core of the intervention. Its main goal is to create a common ground between coach and students and facilitate the translation of abstract course LO's into feasible and desirable actions or outcomes that would contribute to their collective and individual learning progress. Through it, students and coaches deconstruct and discuss the meaning of the original course LO. Furthermore, they are given the possibility to change those LO in agreement with the group.
- **Reflective moments:** Both reflective moments intend to bring awareness back to what was agreed on during the Kick-off session and how that is reflected in students 'learning process and work. Both follow Rolfe's reflective model [16] and are organized around important course milestones. On each moment, students and coaches reflect and discuss the course progress, student's (self)assessment of LO, next steps for the learning journey, and how student and coach contribute to each other's learning experience.

5.3 Intended impact

This research assumed that My Rubric would have a positive impact on resilience. To assess its effects, it was considered how its actions contribute to the 4 resilience variables in learning systems (Table 1).

Table 1. My Rubric's intended impact in the four main resilience variables.

ACTION	OVERCOME CHALLENGES	FOCUS LEARNING	MAINTAIN WELL-BEING	HAVE A SENSE OF IDENTITY
a. Enrich the interactions between coaches and students in dialogue sessions			+++	+
b. Provide the group an environment in which they are welcome to explore	++	+	++	+
c. Collaboratively define a common vision composed by outcomes ought to be achieved, possible actions to get there, and assessment criteria	+++	+++		
d. Facilitate the bridging between personal past and future experiences and examples to enable such reflections	++	++		++
e. Offer the possibility to modify in agreement aspects of the LOs and their success criteria		+++	+	+
f. Reflect on individual ambitions towards the course		++	+	+++
g. Trigger self-reflection and assessment on one's learning process		+++		+++

6 EVALUATIONS

Once the design of the intervention was finished, it was essential to conduct a session to assess such impact. For that, 3 coaches and 4 students from the MSc Design for Interaction evaluated and reflected on My Rubric in a morning session by role-playing its Kick-off session in an already existing course. In it they used its materials and discussed how their journey would have changed if the intervention had been implemented in the course programme. Students and coaches came up with the following reflections:

a. My Rubric helped them understand each other's perspectives and allowed them to introduce to meaningful topics in the conversation.

b. Taking the LO apart could be helpful to get a better grip of what the course is about and what is expected from students and offer the possibility to discuss other ways to reach the same common goal.

c. My Rubric helped them clarify what the definition of 'quality of work' was for the group and offered them opportunity to address things that are never contemplated in a rubric, but definitely affect a project's process and outcomes, such as individual core values.

d. Both agreed on the importance bringing up examples and personal experiences, not limiting the conversation to outstanding results, but rather focus on the process or depict failure as means of learning.

e. From their perspective, when developing the 'new rubric', it would be essential to seek fairness and coherence instead of making the gaps between groups bigger. Despite that, they acknowledged that developing an agreement among their group might help diminish that feeling.

f. Students appreciated the possibility to create a personal goal to reflect on and define their individual motivations on the course.

g. By conveying that the process is open, debatable, and non-linear, students felt they could steer it to the most inspiring directions. Both coaches and students argued the importance of reflection in the learning process.

7 IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS

Resilience as a practice is a widely known concept in psychology, however, the methodology to embed it in educational curricula is still under investigation [5]. Consequently, the purpose of this research was to explore how resilience could be built and enhanced in the education domain to be able to conceptualize interventions, mechanisms, or tools to assist its development in higher education systems. The results of both literature and contextual research inquiries indicate that a theoretical equivalence exists between theory in resilience [14, 18], education [19] and wellbeing [8]. Those insights supported and built on each other, having as a basis the correlation between the main Resilience Building Blocks and the fulfilment of the basic psychological needs of Autonomy, Competence, and Relatedness defended by the Self-Determination Theory [19]. This hypothesis led to a practical construction of resilience′s lenses: the Resilient Learning Communities framework, which aims to fill the gap between resilience theory and practice and assist educators in conceptualizing resilient interventions in learning systems. The research concluded with the design and evaluation of a single intervention, My Rubric.

Because of the lack of methodology in resilience within education, the framework poses an initial attempt to bring resilience from abstract to actionable in learning environments. Furthermore, as it is based on universal needs, it can be applied to multiple contexts and levels of abstraction, from individuals to whole systems. Indeed, the practical application of those lenses in the development of My Rubric, had highly promising results, as the actions thought to make an impact on resilience were positively received by the participants. The most rewarding insight is how the co-creation of a shared understanding among teachers and students of a course learning objectives, could have a huge positive impact on their learning processes, triggering reflection, ownership, and collaboration.

However, there are a few limitations that affect the conclusions of this study. From a methodological approach, the evaluation unfolded through a morning, making it hard to define concrete results on the long-lasting effects of the intervention. Fairness between groups, time, and self-assessment accuracy were the main concerns shared among participants. Following that line, there are some recommendations worth be considered in future research studies. Firstly, to evaluate the effectiveness of the framework by letting other educators or experience designers create new resilient interventions. Secondly, bigger-scaling testing with My Rubric is required to determine its overall impact on learners' resilience.

8 CONCLUSIONS

Now more than ever, designers need to tackle complex problems, which are becoming more and more demanding, as they involve all kinds of disciplines and stakeholders. Therefore, resilience, the capacity to overcome difficulties and thrive, seems a great aspect designers could develop to be able to tackle those future challenges. This study suggests that the best place to start to develop such resilience would be in our current Design Education. Consequently, it explored ways in which it can be built and enhanced in higher education systems. The literature and context studies were collected to fill the gap between resilience theory and practice: The Resilient Learning Communities framework, which aims to assist educators to conceptualize resilient interventions. Such framework is based on three main pillars identified as essential for resilience development, being those: a. Feeling welcomed and supported through one′s learning process, b. Having one′s learning environment under control and a sense of safety to exercise and learn new skills and c. Practicing critical thinking and ownership to steer one′s learning process in the desired direction. All the knowledge gathered is synthesized in a single intervention, My Rubric, a co-constructive and resilient alternative to the current rubric, which evaluation led to promising results in all these three pillars. Consequently, further research needs to be conducted to assess the framework’s effectiveness and My Rubric′s real impact on staff and student resilience.

REFERENCES

[1] American Psychological Association. (2012). Building your resilience. Https://Www.Apa.Org. *https://www.apa.org/topics/resilience*.

[2] Berawi M. A. (2020). Empowering Healthcare, Economic, and Social Resilience during Global Pandemic Covid-19. International Journal of Technology, 11(3), 436. *https://doi.org/10.14716/ijtech.v11i3.4200*.

[3] Biggs J. (1996). Enhancing teaching through constructive alignment. Higher Education, 32(3), 347–364. *https://doi.org/10.1007/BF00138871*.

[4] Bijl-Brouwer M. van der and Price R. A. (2021). An adaptive and strategic human-centred design approach to shaping pandemic design education that promotes wellbeing. Strategic Design Research Journal, 14(1), 102–113. *https://doi.org/10.4013/sdrj.2021.141.09*.

[5] Brewer M. L., van Kessel G., Sanderson B., Naumann F., Lane M., Reubenson A. and Carter A. (2019). Resilience in higher education students: A scoping review. Higher Education Research & Development, 38(6), 1105–1120. *https://doi.org/10.1080/07294360.2019.1626810*.

[6] Chapman Hoult E. (2013). Resilience in Adult Learners: Some pedagogical implications. *Journal of Pedagogic Development.*

[7] Choi K. R., Heilemann M. V., Fauer A. and Mead M. (2020). A Second Pandemic: Mental Health Spillover from the Novel Coronavirus (COVID-19). *Journal of the American Psychiatric Nurses Association*, 26(4), 340–343. *https://doi.org/10.1177/1078390320919803*.

[8] Desmet P. and Fokkinga S. (2020). Beyond Maslow’s Pyramid: Introducing a Typology of Thirteen Fundamental Needs for Human-Centred Design. Multimodal Technologies and Interaction, 4(3), 38. *https://doi.org/10.3390/mti4030038*

[9] Ellis C., Adams T. E. and Bochner A. P. (2011). Autoethnography: An Overview. 36(4), 273–290.

[10] Harvey M., Coulson D. and McMaugh A. (2016). Towards a theory of the Ecology of Reflection: Reflective practice for experiential learning in higher education. 13(2), 22.

[11] Keck M. and Sakdapolrak P. (2013). What is social resilience? Lessons learned and ways forward. 67(1), 5–19.

[12] Knight C. (2007). A resilience framework: Perspectives for educators. Health Education, 107(6), 543–555. *https://doi.org/10.1108/09654280710827939*.

[13] Meyer M. W. and Norman D. (2020). Changing Design Education for the 21st Century. She Ji: The Journal of Design, Economics, and Innovation, 6(1), 13–49. *https://doi.org/10.1016/j.sheji.2019.12.002*.

[14] Mitchell F. (2011). Resilience: Concept, factors and models for practice. 6.

[15] Paredes M. R., Apaolaza V., Fernandez-Robin C., Hartmann P. and Yañez-Martinez D. (2021). The impact of the COVID-19 pandemic on subjective mental well-being: The interplay of perceived threat, future anxiety and resilience. Personality and Individual Differences, 170, 110455. *https://doi.org/10.1016/j.paid.2020.110455*.

[16] Rolfe G., Freshwater D. and Jasper M. (2001). Critical Reflection for Nursing and the Helping Professions a User’s Guide. Palgrave MacMillan.

[17] Ryan R. M. and Deci E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68–78. *https://doi.org/10.1037/0003-066X.55.1.68*

[18] Shastri P. C. (2013). Resilience: Building immunity in psychiatry. 55(3), 224–234.

[19] Tracey M. W. and Hutchinson A. (2013). Developing Designer Identity Through Reflection. *Educational Technology Publications*, 53(3), 28–32.

[20] United Nations Sustainable Development. (2015). Sustainable Development Goals. *https://www.un.org/sustainabledevelopment/sustainable-development-goals/*.

[21] Xue H. and Desmet P. M. A. (2019). Researcher introspection for experience-driven design research. Design Studies, 63, 37–64. *https://doi.org/10.1016/j.destud.2019.03.001*.

Disrupt, Innovate, Regenerate and Transform

In 2022, the conference reflected on the evolution of engineering and design education, and the potential and role of design and engineering as agents for positive change. The growth in inter and transdisciplinary collaboration and activity is encouraging innovation, as is use of technology to support the globalisation of design and engineering work, all of which were included in the conference.

Image: Deborah Andrews

EST 1892 LSBU

the Design Society
a worldwide community

design education special interest group

iED support inspire achieve

ISBN 9781912254163

90000

9 781912 254163