Continuity and Adaptability in Design and Engineering Education

Editors: Hilary Grierson, Lyndon Buck, Erik Bohemia,
Anne Louise Bang, Mette Terkildsen, Paul McElheron.

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DESIGNING SERVICES IN PANDEMIC CONTEXT

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ABSTRACT
This paper addresses the challenge posed by COVID 19 to 60 bachelor students from the 3rd year of the Design Programme at the Faculty of Architecture, University of Lisbon, that had to develop design services (in groups of 3/4 students) without the possibility of doing fieldwork or any other type of presential interaction. The imposed lockdown due to Coronavirus dictated not only changes on the themes and problems to be tackled but also introduced the need to adopt new processes and tools to collect, discuss and interpret information.
By the end of the course, 13 projects were developed (but not implemented) and 13 promotional videos were created to disseminate the work done. The projects were mostly focused on developing services to support old people, high education students, risk communities considering the adverse consequences of the virus in daily life and the wellbeing of people. Besides mentioning the main target groups, it is also important to refer to the areas of intervention that were chosen: mobility, education, security, health.
The critical analysis of the design processes as well as of the results of the work done in this design services' course allowed us to suggest numerous guidelines on how to collaborate in an effective way in design processes in a pandemic context that will hopefully help the academic community as well as students to better frame and act in this type of impacting situations.

Keywords: Design high education, designing services, pandemic context

1 INTRODUCTION

Designing services, as defined by the author and in terms of the construct to be used by students, means to design the relationship and connections among people, and amid people and objects having as the main goal the development of sustainable and ethically compromised solutions that will enhance people's wellbeing.
Designing services is also to operate mostly in the immaterial world depending heavily on people's behaviour. Thus, it must encompass a strong dialogue and empathy from the very beginning with those who will interact and be served by those services. That empathic and dialoguing process was severely constrained due to the pandemics and the interactions to be made had to occur almost without the physical presence/contact. The challenge we were facing is according to Bozkurt and Sharma [1] *emergency remote teaching* (ERT) and aims to maintain continuity of teaching-learning processes allowing students to complete the semester, even if the course was not what was originally planned. In fact, and a broader and inclusive term we are talking about Distance Education, which implies: a separation either geographical or in time between students and teachers, the existence of a two-way communication system among them, and the integration of education institutions [2]. The first and most critical aspect related to a teaching-learning process that was identified was: Interaction. Student-teacher and student–student interactions are the basis of the teaching-learning process and assume different typologies – individual discussions; design reviews; answer and questions moments; progress assessment; final assessment – that includes auto-evaluation and peer-evaluations besides the one of the teachers. In Design services that depend heavily on fieldwork interactions (in class; outside class) were assumed as the core aspect to be solved.

2 A FIELD WORK RESTRAINED BY COVID

Going to the field to understand the context and be able to characterize it is a task to be developed with high intensity in the first phase of the development of a service. That was blocked due to the lockdown and implied new ways of gathering information, different modes of interaction, and engagement with people and their environment. This "revolution" had place at the beginning of the course and the students (ages ranging from 20 to 24) were severely impacted (both in psychological terms and in performance ones) since they never experienced such a restrained environment. Thus, the solution was to identify in which ways it was possible to pursue information and interaction without the presence and face-to-face contact. The immediate solution was to make intensive use of digital processes with a close follow-up from the teacher and opening and close class sessions' talks to stimulate positive attitudes and to discuss their difficulties and offer support and solutions. Regarding the practical aspects of the class processes especially the ones related to fieldwork, the challenge is well-posed by Favilla and Pita [3] when they ask "Are digital methods a possibility for opening the field, or are these methodologies limited in some cases? Can the proximity and collaboration generated by dialogue and interpersonal interaction be maintained in virtual contexts?"

Regarding these questions, it is important to notice that among the advantages several researchers identify in online modalities is the access to a large amount of information and the diminishment of barriers to participation, while in contrast there are the disadvantages of the lack of social interaction and the observed tendency that these modalities are more suitable to students with consistent and independent motivation and learning skills [4]. In special the disadvantages are intimately related to the essence of fieldwork.

3 PROJECT BRIEFING AND THE PROPOSED PROCESS

As previously said developing the process of designing services while being in a virtual environment was one of the consequences of the lockdown imposed by the first wave of COVID 19 (March/May 2020). That occurred without any previous preparation hence requiring on the part of teachers and students to find ways of collaborating and achieving results without jeopardizing its quality.

The Service design briefing (prepared in/to a Covid free moment) encouraged students to develop services having as a support element to their choices a table with different areas of intervention, target groups, and a set of possible stakeholders (from which they had to guarantee the participation of three). The choices to be made should have a clear impact in terms of social empowerment and sustainable commitment. In Table 1 we present the names of the projects as well as the areas of intervention and the target groups.

Table 1. Groups and its services thematic/target groups

Nº	Title service	Area of intervention	Target population
1	Security at night – old town neighbourhoods	Security	Night users
2	Giving the hand – living the city	Wellbeing	Informal caregivers
3	Ajuda's Hand	Food waste	Vulnerable people
4	Your Wave	School Dropout	Teenagers
5	New Living	Elderly's Isolation	Elderly
6	ReAjuda	Recycling	Poor neighbourhoods
7	Sol a Lés – Solidary Transportation	Mobility	Elderly
8	Happy Place	Temporary lodging	Students lodging
9	Javô	Elderly's isolation	Elderly
10	PorLisboa	Inclusive tourism	Disabled people
11	Rehabita	Rehabilitation	urban citizens
12	Overcoming Covid	Wellbeing	urban citizens
13	Between Us	Education	University students

The definition of the problems to be tackled is the first and decisive step of the process in its e*xploratory phase* and it includes a reflection about the causes and effects (consequences) of that problem. In Design services, the focus is the person and its interactions with other persons in a way that problems are solved in an ethical, inclusive, and sustainable way improving the wellbeing of all.

As it can be seen in Figure 1 one of the techniques used to define the problem is the “Problem Tree” that must be articulated with the tool “5 why?” (a cascade of 5 questions aiming at understanding the pertinence of the chosen problem) to establish a consistent and relevant problem to work with. This type of exploratory work was developed online thru the “zoom platform”, using the breakout rooms so each group could discuss its ideas and jointly achieve the problem they would work with. The schemes, diagrams, and all the information gathering, analysis, and synthesis regarding problem identification were shared by the students that were using simultaneously “miro" – a collaboration tool that allows participants to ideate, diagram, map, and plan in real-time.

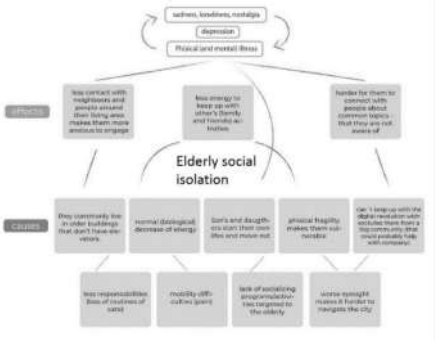
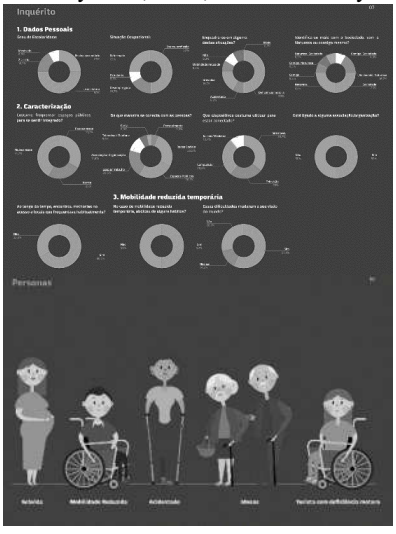


Figure 1. Example of “Problem Tree” definition – group 5

The *making sense* phase, which can be seen as an iteration of the exploratory one is a bridging phase towards a *generative* one in which students propose design services solutions to the identified problem. It is natural to do work on both phases, *making sense* and *generation* as a natural sequence or even simultaneously as co-evolving phases. These specific phases are supported by a set of activities that integrate the fieldwork. The process of *making sense* of the information gathered in the previous phase includes the use of tools such as 1) *story world* (allowing the students to define a survey to capture information about the user); 2) *personas* – designed with the information gathered in the 3) *surveys*; 4) *storyboard* – that implies the design of the whole process of interaction between user and service – either in a daily basis, week, month or even year basis (a kind of service journey) (see Figure 2).



Group 10 - Survey graphs – on the up-left side; Personas image on the down left side; Storyboard excerpt – right side

Figure 2. Example of “survey treatment”; “personas” and a “storyboard excerpt “from group 10

Moreover, the *generation* of solutions depends on 5) the identification of all stakeholders that must be done by mapping them and defining a *partner constellation* in which the level of participation, the connection, and trade-offs among parts must be accurately defined; 6) the creation of a *service proposition, (including* its Logo symbol based in the 7) design of a *service ecology* and in the establishment of an 8) *blueprint* and of the *9) touchpoint display* (see Figure 3). Besides the support of the teacher, students had the book of Kimbell and Julier [5] as a Guide to methods' usage and application.

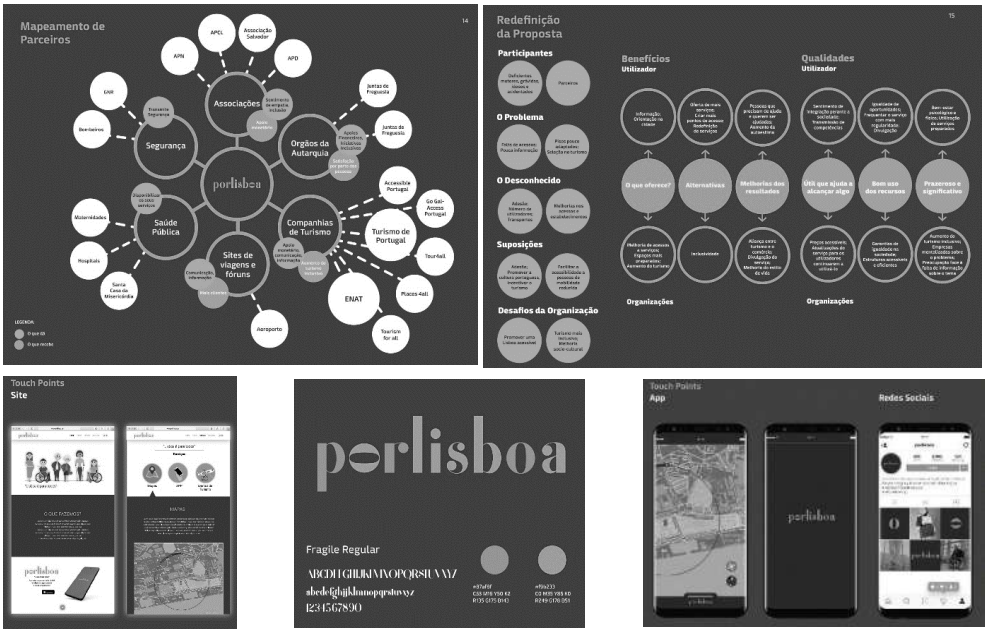


Figure 3. Group 10 -up-left side – partners constellation map; up-right side – the service proposition; down-left side- the site; down-middle figure – the logo symbol of the service, down-right side – touchpoint- app

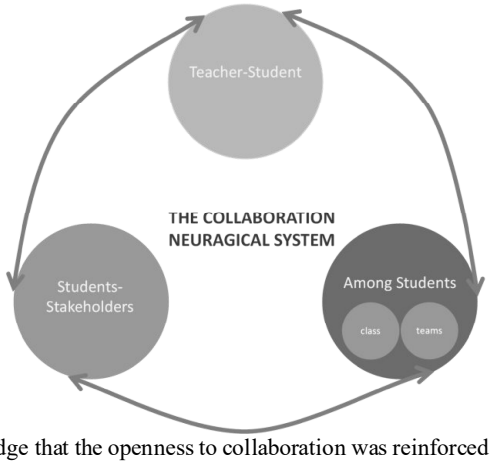
The use of all these methods (which results can be briefly appreciated in figures 2 and 3) depends heavily on the interaction with potential service users and other stakeholders. Being so, we had to guarantee a solid collaboration among students and inside teams as well as a fluid interaction with all the stakeholders that were vital to the services' creation. Furthermore, a final phase of the process – an *iteration* regarding the services' proposal was necessary to understand what needed to be changed and how to better monitor and ensure the post-service phase. This final stage also depended on interaction and collaboration with external elements.

4 COLLABORATION AS THE NEURALGIC CENTER OF "DISTANT" DESIGNING

Again, we highlight interaction and collaboration as being in the neuralgic centre of designing services in this specific context in which was mandatory to work online (at least during the 6 weeks of lockdown). As Bernardo and Duarte [6] observed "the screen mediated relationship severs the meaningfulness of a teacher-student relation." This aspect concerns what we call the 1st dimension of collaboration – the one between teacher and students – that requests in this specific situation special care with the recognition of student' needs and concerns as well as a keen comprehension of student's environment (home) and responsibilities (e.g., caring), the access he/she has to communication resources and his/her level of proficiency using digital tools. The 2nd dimension of collaboration is the one among students that are twofold:1) as a class group; 2) as a team. At this level, it was fundamental to make explicit the need for a strong connection not only among team members but especially among all the teams suggesting the use of a shared platform of information as well as the use of a class "WhatsApp" group to streamline the

engagement in the designing process and to boost the joint comprehension and motivation to develop the tasks. Finally, the 3rd dimension of collaboration gives respect to the interactions among students and stakeholders that must conquer the collaborative density. All these dimensions are translated in Figure 4 in which are visible all the dimensions connected in a system that presupposes fluxes among all of them and in both directions.

Figure 4. Collaboration as a neuralgic system of designing services.



It is important to acknowledge that the openness to collaboration was reinforced during pandemics. That might be due to the fact (verbalized by several students) that all experienced the same constraint, being linked by that adversity.

5 GUIDELINES TO COLLABORATE AT DISTANCE

As a corollary of this teaching-learning experience in such atypical circumstances, it is now time to highlight some issues that are relevant to designing services in a distant mode and under mobility and physical interaction constraints.

Regarding the Teacher's role

1. Assume that collaborative mode as a neuralgic system that structures the process and that implies a clear commitment to the three dimensions of collaboration – 1. Teacher-Student; 2. A) Students in class; b) students as team members; 3. Students-stakeholders.
2. Create enabler-moments at the beginning and end of the classes (10 minutes) dedicate to explicitly approach the existing and desired collaboration dynamics, energizing the class, "collect smiles" and explore the positive aspects of each constraint.
3. As a teacher make clear that you act as a “mobile member” of each group collaborating with your experience in each of the projects and activating a “cross-pollination” among groups.
4. Besides Synchronic classes teachers must create channels of communication with students that allow them to proceed its work outside classes – that includes the answer to doubts; unblock fixed moments in the process; assess preparatory work to be undertaken with stakeholder’s etcetera.

Regarding Students’ intervention

5. The collective feeling that “all are in the same boat”, being united by this adversity must be assumed as a driver of the collaborative mode, boosting solidarity and meaningful interactions among students and amid teams.
6. The creation of groups based on the selection of team members according to their personalities and competencies enables richer contributions and stability among groups - since they present similar characteristics among their members.
7. The definition of roles inside the teams contributes to fewer misconceptions in the process opening space to clarification of decisions and prompting students to invest more in collaborative modes of sharing information, ideas, aiming to create a common language and a consistent and responsible proposal.

Stakeholders' engagement

8. The collaboration to be created with stakeholders is favoured by this sentiment of "belonging to this larger group linked thru adversity" (that was the case of all stakeholders involved in the 13 projects). Being so students must recognize that openness and value it explicitly with stakeholders.
9. Since part of the target groups is segments of the population with less ability to react and develop resilience in a pandemic context cognitive ergonomics must be central in the development of solutions as well as in the engagement and interactions to be taken with these specific target groups.
10. "Making normal the unusual" must be the *motto* of the interactions i.e., students and teacher must facilitate the interaction moments with stakeholders finding ways of establishing comfortable inclusive and easy communication.

6 CONCLUSIONS

The lack of access to the fieldwork enabled resilient solutions such as phone interviews with elder people or zoom interviews with participants as well as presential encounters (after the lockdown period) that were bounded by pandemic rules. Furthermore, it had also an impact on the choices of the target groups to work with – students tend to choose convenient subjects of study. From the first moment, it was perceived that interactions were critical in this context, and collaboration popped up as a key driver of the projects' processes. It was remarkable how students quickly engaged in collaboration thru online tools complemented by enthusiastic share of information and thoughts in WhatsApp groups they immediately created. Equally rare was the willingness to collaborate on the part of stakeholders being clear that adversity favours human closeness, solidarity, and collaboration.

ACKNOWLEDGEMENTS

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BIO-INSPIRED PRODUCT DESIGN BRIEF MODULE

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ABSTRACT
The principal objective of this paper is to demonstrate the capability of biomimetic inspiration as a useful thinking module while relating to product design brief concerns in design education. This bottom-up approach module is based on the mechanical principle of Salsola Tragus, an annual weed that begins life as a typical multiple branched bush but takes on a spherical form when blown by the wind, spreading thousands of seeds. The research aim was to bridge between the abstraction stage and transfer of knowledge, utilizing a two-step module that links the stages. By applying the module, the organisms and the design are summarized via checklist guide questions, resulting in a clear flowchart which constructs the brief concept. While empathic thinking has detected the wow effect in children's games, analogue thinking exposed the essence of the application of a ball. This combination of thinking methods contributes greatly to the ideation process. Although the WHAT was initially known as a ball attribute, the wide biological investigation via the module operation led to a creative mindset of the HOW: hence, the module principle can be used to formulate a bio-inspired designer brief.

Keywords: Biomimetic design education, formulating, scoping, ideation, brief

1 INTRODUCTION

Nature has always served as an inspiration for problem-solving approaches; its systems operate within restricted conditions, minimizing waste and irreversible damage to the ecosystem [1]. The biomimetic approach is part of nature's design strategy, emulating its solutions, processes, and strategy from a holistic, sustainable perspective [2]. Its aims are to abstract biological principles and apply them to design solutions as, philosophically, endless time-tested solutions can be found in nature [1]. Biomimetics acts mainly in the preliminary stage by expanding the range of possibilities through observing nature. Its application during the ideation stage leads to a search for similar sustainable patterns of biological systems [3], focused on using nature's benchmark to improve man's artificial creations [1]. The approach involves knowledge transfer from biological system to design solution. The first starting point is a bottom-up, solution-based direction, while the second is top-down and problem-based. To support designer access to nature's vast database, varied methods offer a systematic framework for finding relevant biological systems, abstracting their design solutions [4]. These methods differ in operation needs, investigation levels and emulation quality, however, during the transfer stage, most cannot address all design objectives [5,6]. Biomimetic search methods identify appropriate biological systems via biological databases, using keywords such as the AskNature search engine [2]. Abstraction methods focus on understanding biological principles to extract them by design principles such as form follows function approach (FFF) [10] and structure-function patterns (SFP) based on the core components of a functional system [7]. Transfer methods focus on supportive guidelines during transfer development, by comparing biological and functional models, for example [8]. Life principles are nature's survival strategies by adjusting structure to function, functioning in symbiosis with the environment as a sustainable benchmark [1]. Tumbleweed, with its unique structure and function, is a distribution vehicle for plant seeds. NASA redeveloped this structural concept, using spherical rolling objects based on tumbleweed type strategy. Besides innovation, the core of design is establishing rational connections between discourse types emerging throughout the development process, resulting in new insights. Designers often use analogies when examining function or behaviour. Analogies also link fundamental structures with design challenges, serving as a domain for possible solutions. Thus, design thinking aims to control and ensure accuracy by using a checklist which sharpens the objectives, segments the problem into sub-problems, and clarifies goals hierarchically. The gap between the problem space and the solution space is the ideation stage, which emerges from the WHAT and HOW

stages, acting as a creative bridge to form new ideas [09], prior to their selection and evaluation. The ideation role assembles knowledge, continuously reiterated by examination, synthesis, and experiment processes, to develop innovative solutions [10]. During the product design (PD) process, creative solutions are formed to meet user requirements. Design solution is based on the designer's individual brief, aiming to address expectations, utilize attributes from the WHAT stage, and implement methods in the HOW stage. Using multidisciplinary means, tumbleweed's natural mechanism was explored through biological investigations. The research applied biomimetic steps to map gaps, focusing on PD briefs, and produced a solution to facilitate access to biomimetic design education (BDE) through hands-on experience.

2 METHODOLOGY

Methodology derived from mixed biomimetic methods adapted to BDE, with a framework modified to suit that terminology (Table 1-3). The method comprised three stages: Search, Abstraction and Transfer. The stages were a series of research events, divided into steps (Table 1-3, step 1-6), then subdivided into goals, tasks, and research questions. These step divisions formed the research framework. A trial run employing a bottom-up approach was analysed through qualitative research. The research process was synectically-based to optimize collaborative brainstorming by specialists from biology, engineering, and PD, to innovate from direct and indirect analogies. The WHAT lies in the information mapping process and in the abstraction end stage, involved with attribute definition. The HOW is created in the formulating process in developing a bio-inspired design concept. During the design process a two-step module facilitated the research objective (Table 2).

2.1 Module functions and structure

The module enables definition and key data transfer from a biological source of inspiration to establish product brief using a design thinking approach. The module serves as a new filter, conducting information between abstraction and knowledge transfer stages during biomimetic process. The abstraction stage objective is to abstract, identify and consider the biological solution aspects to define the context via mechanism performance. The transfer stage provides guidelines for concept implementation, through multidisciplinary knowledge translation from biology to design. The module consists of two linear matrices of qualitative and quantitative data assessment with independent knowledge spaces. It engages mainly attributes and environment contexts required for success. The first step maps information, the second formulates concepts, while the design checklist organizes important information on task execution.

2.2 Formulating step structure

The first step is a mid-stage validation of the entire process, logically mapping search, and abstraction stages. This step is applied after the abstraction stage and aims to summarize the knowledge concisely. The structures derived from the FFF are extended to the attribute: form follows function approach (AFFF), referring to the linear, logical correlation between form and function. The structure consists of five nature checklist principles. Its linear hierarchy clarifies biological system uniqueness. Aims are to apply strategy, define context, explore functionalist attributes and environment. The checklist steps are attribute (strength or weakness, dependency on functionality, process, and strategy); form (structure with external appearance of function); function (reasons why procedure or action occur naturally); environment (factors affecting organism survival) and similarity (identify similarly functioning systems in different contexts). The main step-guiding question is: What are nature design principles' guidelines? A flowchart summarizes the step based on SFP [7].

2.3 Scoping step structure

The second step concerns implementing solutions. It examines biological system data with a particular objective for idea creation and emphasizes how nature design principles influence solutions through analogue thinking. This ideation process, applied at the start of the translating and implementing stage, enhances solutions through empathic thinking. Aims are to define context and explore required attributes through user needs. The checklist includes keyword function (defining the action), context descriptors (affinity that gives significance), clarifying process and physical attributes (contextual), constraints (limitations affecting concept implementation) and performance (describing the desired operation qualitatively and quantitively). The main question is: Where can the guiding idea be applied as a

successful, sustainable conceptual solution? A summary was performed through a flowchart based on the WHAT brief checklist [11].

3 CASE STUDY AND RESULTS

Table 1. Pre-design mapping process (search and abstract stages)

Process		Guiding Questions
Step 1	**Discovering**	1.Which natural models to select in databases and habitats? 2.Which strategies support survival?
1.Objectives	Discover	
Tasks	Find and research an organism	
2.Objectives	Abstract	1.Which essential attribute mechanisms promote successful strategies? 2.Which actions and principles enable system operation?
Tasks	Summaries: biological strategies mechanisms and process	
Step 2	**Biologize**	1.What is the biological function definition? 2.What are the keyword definitions (search method)?
1.Objectives	Identify	
Tasks	Identify biological function and match structure to function	
2.Objectives	Define	1.How does the solution work? 2.What are the mechanism parts? 3.Define functional morphology and anatomy.
Tasks	Define biological solution	

First, multidisciplinary professionals planned the work process, examining and modifying natural structures. After several flora and fauna were explored, biomimetics directed them to the Salsola tragus species of tumbleweed. Tumbleweeds are dried-out parts of various plants which detach from their root systems and roll with the wind. The plant has the evolutionary advantage of dispersing seeds over dry open terrain. The carefully orchestrated formation and synchronization of programmed cell death after

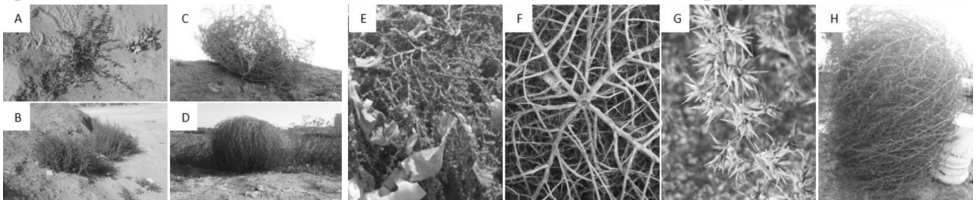

Figure 1. Tumbleweed plant's growing stages (A-D) and findings (E-H)

the seed development is complete, and adequate drying of the plant body allows ideal movement using wind power and effective seed distribution [12]. After locating a biological system, the team performed the abstraction, including system analysis, and defined biological process mechanisms. Comparative investigation diagnosed plant strategies. The biologist and designer reached the step-wise process enabling emulation. Information formation included flow sketches of plant performance, describing the relationship between forces and functions creating the phenomenon. Abstraction involves physical and conceptual disassembly, to reveal structural complexity. Figure 1A-D shows plant growth stages, from seedling to ball structure, prior to their tumbling journey. Early-stage research shows the plant alive and green, with, upright stems a strong footprint, and steady roots. The plant structure with erect stems usually bends inwards when dry, transforming it into a ball form. Removing its lowermost part reveals spiral stem development with fractal dimension. Patterns can be identical or repetitive and detailed.
(Figure 1F). With imagination, one notices a chaotic thorny entanglement with individual order in its lower section, evident in its structure, dimensional placement, and range. The circular, repetitive element in the stem's fleshy root and seed-laden thorns is significant, considering unusual mathematical qualities when calculating fractal structure equations, and translating structure principles into geometrical shapes.

Table 2. Pre-design and design process (module location)

BIO-INSPIRED PRODUCT DESIGN BRIEF MODULE			
Abstract stage		**Transfer stage**	
		Step 3	**Creating**
Objectives	Formulate	Objectives	Scope

Tasks	Summarize	Tasks	Create bio-inspired ideas and find relationships between strategies
Organism checklist guiding questions		Design checklist guiding questions	
What are nature design principles' guidelines?		Where to apply guiding idea as conceptual solution?	
Attribute	Which are the attributes? Keyword search?	Keyword Function	What principle and function would I like to emulate?
Form	What are the structure and system sub-components?	Context Descriptors	Who needs the attribute?
Function	What does the mechanism do?	Process attributes	Where is the attribute needed?
Environment	How does the mechanism work?	Physical attributes	Why and when is it required?
Similarity	Where in nature are similar mechanisms?	Constraints	How can the attribute be transmitted?
		Performance	Which parameters will be valued?
System flowchart - Organism context		System flowchart - Concept context	

3.1 Discovery of form and function

Salsola tragus, with its winged distribution units has an airy appearance and ball-like volume, with segments repeated in intricate crisscrossing layers (Figure 1D). Its minuscule sails act as a resisting force to the wind that enables their movement. These flexible elastic segments disperse seeds gradually over distances. The observed structure repositions the ball as it moves in space (Figure 1G). Identification of the density, size, and diameter of branches, hollow or not, can guide gravity centre placement. Its thorns too have varying parameters of size, flexibility, adherence, and function – recurring protrusions benefitting movement mechanism, encouraging ground grip while rolling (Figure 1E). Although the research process halted due to funding and time issues, data sufficed for new revelations. Other Salsola tragus structures such as cylinders, streamlined and twisted structures went unexplored. After initial abstraction, a biological investigation summary and related information were mapped in a flowchart based on checklist questions (Figure 2A). The transfer stage led to solution-focused ideation on relationship between strategy, form, and structure, using mechanical definitions of spheres in Salsola tragus to analyse the game concept systematically. Through checklist where and how questions the guiding idea can be implemented as a conceptual solution; the thought process focused on the game

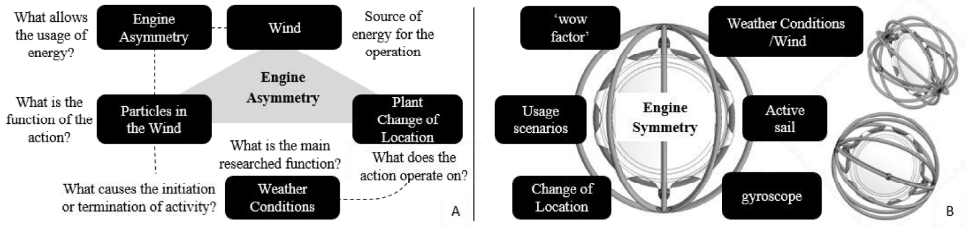

Figure 2. Organism and concept system flowchart

experience, influencing formulation and scoping factors. Defining and transferring attributes from biology to design space led the creation process. During transfer stage, biological investigation integrated nature design principles into the solution approach and analysed them through sustainable benchmarks from the life principles tool. After module step implementation, a flowchart-based design checklist organized implementation principles. Additionally, fast sketches aided alternative design concepts. At advanced information-transfer stages, research findings were integrated into the process. An asymmetrical sphere-shaped structure was chosen, incorporating endless mobility (Figure 2B).

3.2 Implementation: derived from design concept

The research outcome was a dynamic ball game inspired by the tumbleweed and its spatial movements. The ball concept has an independent active sail as inner structure, which enables maximum resistance, utilizing wind energy and gyroscopically-based inertia principles. Additionally, the ball structure acts

as an airy shield and outer support for the inner sail. This ball concept is designed for outdoors, with natural wind flow, whose intensity and direction are significant, as in kite flying. The flexible sail propels ball forward by trapping circulating air, which creates natural motion.

Table 3. Design formulating process (transfer stage)

Step 4	**Biologize**	1.How to improve nature design principle and implement mechanism? 2.How to improve concept via sustainable benchmarks (life's principles)?
Objectives	Integrate	
Tasks	Principles' integration	
Step 5	**Creating**	1.How to optimize application by system strategies? 2.How to measure designs via sustainable benchmarks (life's principles)?
Objectives	Emulate	
Tasks	Copy and apply principle in a conceptual mechanical application	
Step 6	**Measure**	1.Did solution meet goal? (life's principles, quality assessment, criteria, and testing)
Objectives	Evaluate	
Tasks	Verify	

Wind currents, using lift and drag forces, move the sail forward spatially. Optimally, lift exceeds drag, establishing an ultimate driving force. The sails' structural design has a tremendous impact on their aerodynamic efficiency. Important sail functions are height-to-width ratio and concavity degree. Their design also utilizes wind airflow motion: when the ball structure follows the wind, its power pushes them forward; but when the structure faces the wind, air flows from its sides and redirects it, causing acceleration. Sail propulsion is achieved by wind force and kinetic energy. When air flows by the sail's curved object, it is faced with an 'angle of attack': wind moving along its upper and lower parts takes the longer path, causing acceleration. Sails accurately situated to the wind produce pressure and forward motion. The ball is inspired by a gyroscopic wheel-type device, with disc and rings that rapidly turn inside a structure, enabling it to form various angles, or rotate freely while preserving its position. The flat disc is situated on a centred, fixed, vertical pole, while the other axes rotate freely. When the wheel is spun, rotating axes retain their original direction, despite disc direction. Their movement coordinates with the wheel and fixed pole, resisting changes in spin angle. The structure allows the device to balance and is responsible for gyroscope inertia attempts to forcefully change rotation angle cause resistance.

4 DISCUSSION

The validation was directed towards the design objective; quality information was mapped based on overall plant structure, spatial behaviour, and presumed functionality. The information provided the foundation for developing a creative designer brief resulting in a primary concept for a solution proposal. However, a full design process is required for a working prototype that analyses performance using play ball criteria. Topic and sub-topic division provided analysis that led to clues from subsequent steps. Updated checklist questions were useful. By insights of sub-events, flowcharts and module information, knowledge was transferred between biology and design domains, with mapping collaboration at the abstraction stage. The transfer stage used creative brainstorming. Designers focused on benefits derived from the analogous system, with problem-solving followed by engineering integration. Failures between stages were mainly due to objective and terminological gaps. Nevertheless, expert involvement reduced these: biologists clarified bio-mechanisms, while designers bridged biological and engineering spaces. The main gap lay between abstraction and information-transfer stages. The module assisted the design domain to formulate an accessible scope by locating operational attributes. Analogical thinking concentrated on plant phenomena, and empathic thinking on imparting the wow factor to a child's toy. When the module was applied to both formulation and scoping steps, a creative mindset enhanced communication; design synthesis and conceptual maps were expressed by flowcharts and quick sketches. The steps' design outcome linked stages, enabling linear user focus on the WHAT, and afterwards on the HOW. Diverse quantitative data from the abstract stage were not examined. While data analysis could explain tumbleweed seed dispersal dynamics, resources were insufficient. Bottom-up biomimetics examined how nature's mechanisms successfully utilize design elements. A careful morphological study from biological and engineering viewpoints could explain which components most contribute to tumbleweed dispersal and examine their functional properties. Inspiration derived from observed phenomena and designs, including asymmetrical spherical structures, are biomimetically significant. Moreover, expert multidisciplinary knowledge is critical for BDE. Knowledge accumulated

during the abstraction stage was extracted from online databases after nature observation. Biologizing led to analogous thinking that affected design synthesis and concept. The concept mimics the movement of a kite in flight: unexpected motion and dynamics provide a surprise element that maintains the wow factor. The concept requires navigation, intuition, and coordination – enabling physical and cognitive development. The predictable behaviour of a traditional ball due to perfect symmetry is a component eliminated from the design. This altered form offers an unexpected new function. Though potential for natural solutions is limitless, it is currently restricted by lack of pre-knowledge resources and ability to identify, abstract and utilize nature's progress within a defined period.

5 CONCLUSIONS

Biomimetic abstraction is a complex expensive process. The module is bio-inspired, serves as the starting point for defining a designer brief, and leads to a creative mindset that resolves design challenges. During module operation, the main obstacles in mapping information from Salsola tragus enabled the formation of a reliable understanding assimilated in the ball brief. Using the flowchart methods chronologically (first based on SFP, and second on the WHAT brief checklist) distilled information into knowledge through productive design synthesis. The principles outlined in the flowcharts clarify plant insights, focusing on a dynamic sail whose function may offer surprise movements. These parameters made it possible to formulate the idea based on ball brief and validate the module functionality. The module reduced the gaps between the abstraction and the knowledge formation stage, guided by an analogue and empathic design thinking approach. The module improves information accessibility between pre-design mapping and transfer design process via AFFF. Multidisciplinary integration is essential for workflow and high-quality design outputs. Module integration in the main biomimetic method can be applied in BDE without physical contact with inspiration sources. However, such prolonged contact plus module application aid design concept development. Additional structures and functionalities in tumbleweed require analysis. A multidisciplinary approach and connecting function and structure will enable more creative solutions. PD students and professionals may benefit from this module.

6 SUGGESTIONS FOR CONTINUED RESEARCH

Further exploration of the module is needed to address design objectives. This research should also evaluate and expand the module taking inspiration from fauna and flora in online sessions.

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SELFCONFIDENCE & SELFEXPRESSION THROUGH SKETCHING - THE SIGNIFICANCE OF DRAWING IN 'PRIMARY EDUCATION' & THE NEXT GENERATION OF ENGINEERING

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ABSTRACT
The value of cultural practice in design engineering education begins at the age of kindergarten – a playful cultural education. Sketching means self-expression and self-consciousness, in regards of significance of real experiences on hands on design in the earliest stage. In times of crisis, insecurity mirrors from the individuum and the society, and during the twin transition, in case of digitalizing the (design engineering) learning landscapes, the old capacity of sketching by hand seems to be forgotten. This research paper is showing that hands on experiences and constructive skills for the work in Augmented Reality (AR) is depending on sketching and reflecting the 3D-world. This research showcases a revalue of cultural practice for a design didactic approach with regard to cultural education, for design engineering skills within the post digital era. Sketching the world for sustainable designed solutions contributes by design methods in drawing by pencil, by digital tools and by different tangible materials – e.g., textiles. The design didactic approach is triggered by traditional cultural didactic methods, that supports the value of humans made design. If different stakeholder are part of the process, the entrepreneurial engagement in education are shaping beneficial self-confidence of our next design engineers' experts – beginning at pre-school education.

Keywords: Self-confidence by sketching, Sketching at primary education and in the Augmented Reality (AR), 'materialising immateriality', entrepreneurial engagement in 'DEEducation'. (*DEE=Design Engineering Education)*

1 INTRODUCTION

If we look at the first drawings, at real sketching experiences of children in drawing in the sand, we have to consider: 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 as an adult. This research paper is showing that hands on experiences and constructive skills for the work in Augmented Reality (AR) is depending on sketching and reflecting the 3D-world. This research showcases a revalue of cultural practice for a design didactic approach with regard to cultural education and that the entrepreneurial engagement in pre-school education are shaping beneficial self-confidence of our next design engineers' experts. The comparable studies of case studies and expert literature, in addition to workshop experiences in mixed study groups in Germany and Great Britain, lead to educational evaluation and new European interlinked learning structures, that are necessary for didactical approach in cultural education.

2 SKETCHING BY HAND AND BY DIGITAL TOOLS

The phenomena of 'thinking through drawing'[1] becomes more meaningful again today. From the beginning of primitive wall painting during the Stone age, via sketching with hand and instruments during the renaissance time, (constructing the world of objects (machines) like Leonardo da Vinci), to computer added design and virtual sketching [2], we see the necessity to act during the covid-19 pandemic, we have seen a rising of digitalization, that needs a different understanding of the system [3]. Constructing by designing means self-expressing in being conscious about real world objects. This begins by postforming form, surface, outline, proportion, and leads to reproduction and visualization of world in generating and ideating.

The entrepreneur of industry 4.0, the institutions like schools and universities and the society, would be best prepared for finding sustainable answers for the future, if they would invest, in this form of cultural education in earlier phases, than we see at the moment: We have to recover sketching and drawing by hand for getting the advanced designing skill for the digital (virtual) world.
During the "primary education" - at Kindergarten and the first school experiences - we have to look at the cognition-based understanding of world [4]: it is the real three-dimensional experience by hand and mouth (tongue), by tools like pencils and branches drawing in the sand, reproducing, reflecting and rethinking objects and signs. That gives us the ability and adaptability to draw (generate) new cultural significant objects and concepts in augmented reality later as student, adult and design engineering expert.

3 DESIGN ENGINEERING EDCUATION STRATEGIES

3.1 Education strategies in industrial design engineering – case studies in sports design

To underline the thesis above, the next comparison of the industrial design process and fashion/textile design shows different strategies, and each student's pathway to preparing for and finding the right university, which depends on their pre-design educational experience.
One German case study at the Hochschule Niederrhein is promoting an educational system in 'design engineering textile'[5], which is in line with industrial design engineering: They begin by analysing the process and textiles that revolve around material performance. This is achieved, for example, by using body mapping and textile layering, with the help of a warp knitting process for sports-tech trousers or running shoes. Other European study programs are taking a more physics-based approach by looking at the process and developing other solutions with alternative design methods – e. g., the Technical University in Dresden and Strathclyde University in Glasgow. Some European textile engineering programs are using more artistic approaches, according to the university's profile as a university of fine arts. Fine arts had their primary focus on artistic-based education for design objects, from the 1960s until 1980s. [6]
Nowadays, the changing habits in the way products – objects – are designed, are serving as catalysts for applying a more holistic approach to theoretical methods. This begins with sports engineering courses at the higher educational level (master and PhD design students) and is supported by systems-oriented design methods and theory-based design thinking.
Generally speaking, the 'playgrounds' founded more on biology, physics and natural sciences, are used for master programmes in sports engineering (see Strathclyde University and Dresden University). These implement a classical and conventional design process: a process, which is based more on material analysis and can be directly measured in economic profits.
Although, different educational approaches related to industry and consumer habits have been demonstrated in Europe, imagine if the user, the designer or the entrepreneur, whoever is using the product, had a greater insight into the design system at an earlier point, rather than having to wait until university – as early as pre-school, for example. Several renowned architects claim that playing with wooden cubes in pre-school during their childhood, paved the way for their future careers. He or she could be viewed as expert from those very first hours onwards, in a (design engineering) playground. Experiencing such simple processes, optimised by the support of a didactic environment, builds a foundation for future learning and exploration. We can see this being embraced in the UK, where teenage pupils can join design engineering courses at school, allowing them to participate in the courses, practice the methods and learn expert terminology in a more playful manner and an earlier age. Can this indicate 'design' with greater acceptance within the curriculum and with higher didactical worth?
This vision is considering cause and effect for the overall future of our educational systems in Europe: We need earlier design education (strategies) at primary schools, which may coincide with a change in the terms 'design' and 'industry'.
This shows us that, although design engineering solutions often set out with the same goal, the pathway towards innovative designs and concepts varies across Europe. We can benefit greatly from comparing, discussing and reflecting together: diversity is the key to our success.

3.2 Education parameters and models – the value of artistic competences in engineering design

3.2.1 Sketching with material

'*In the last two years it was shown, the demand for high value designed products created across the future European landscape require new educational talents working seamlessly across integrated analogue and digital platforms while responding to evolving cultural needs emerging through new behaviours […] connected European learning landscape to increase creative diversity*.' [7]

On the one side, higher scholarly educational systems tend towards being design-theory based: that means that PhD programs place a higher value on 'thinking design' (Rittel) concepts, used to design solutions for highly relevant societal problems today. Complex problem solving is trained by means of concept-based design theory work. On the other side, this concept has to be mediated and the lack of *visualising* immateriality – caused by theoretical design methods – needs to be addressed. The following figure shows the profitable result of a 'Fashioning Furniture Future' workshop and demonstrates that the 'materialisation' of design concepts in 'design doing': using material rather than being virtual-based, is very helpful within an artistic or practice-based playground. A tangible user interfaced is long time discussed [8]. Here, ideas are transferring into material visualized methods. The aim is to express, mediate, communicate, and visualize, as well as get people involved in discussions, while being able to evaluate your thoughts by using three-dimensional, material-based sketching. The following figure shows a case study in which the PhD student is working on visualising and mediating the ongoing process of the illness, dementia. This is expressed through textile and form, as well as colour and surfaces, and represents the method of 'materialising immateriality' [9] (see figure 1 at workshop at RCA, London) with different qualities. This design method involves different senses, the tangible, tactile one is very beneficial.

The process is demonstrating the synesthetic approach by sketching with pencil and by textiles.

Figure 1. PhD Student B's case study in visualisation the development of the illness dementia, during the workshop, the exercise called for 'materialising immateriality'. Royal College of Art, London, 2019

3.2.2 Estimating the Value of artistic intelligence alongside Artificial Intelligence

The process of 'Artistic Engineering Design' explores a concept that gives us the opportunity to reflect on the needs of tomorrow's creative processes: It takes the perspective of art, design, engineering and humanities into consideration, while simultaneously providing a framework for evaluating each one of these disciplines. In addition, the societal value of a holistic and humanity-centred education in design engineering, which benefits from fine art's freedom, integrates people around the globe and is helpful for solving problems that emerge, as a result of the global connections between human beings.

Needless to say, holistic and humanity-centred education begins early on. The playgrounds in pre-schools are spaces for exploration and creative expression – a concept that needs to be valued and mediated through all phases of education: 'because everything is language'[10], everything is design! To read, to understand and to solve the complex design problems of the post-digital era, we need this kind of valuable design engineering education system, to make the universities attractive as learning landscapes for everyone and create educational landscapes for every age – lifelong learning landscapes. The aim is to fill in the gap between theory and practice – between thinking and acting – and to create the habitus which society needs to form through its anthropological view.

By thinking and acting together, in design engineering education and expert playgrounds (see workshop case study) possibilities emerge that also illustrate how this style of interlinked designing and learning could be implemented through future platforms of educational playgrounds. These playgrounds will be characterised by philosophical experiences that augment more 'corporeality and impulsiveness' for a holistic approach. The goal is to transfer knowledge as early as possible, in a playful and valuable way – thereby acknowledging the value of time. For a change to happen, the valuable visions in design engineering and the ideas behind them need to be applied to a system.

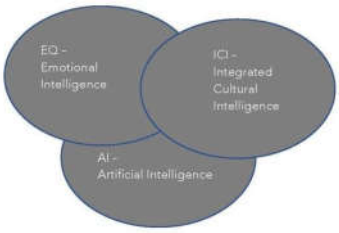

Figure 2. Trigger points of advanced management of knowledge: artificial – emotional – integrated cultural intelligence in design, 2020

Alongside Artificial Intelligence (AI), there is an emerging need for artistic and emotional intelligence forces that reflect the cultural behaviour within a complex design process and in complex interlinked design education landscapes [11]. As we move forward, the behaviourism related to sustainable materials and sustainable design education systems – which is formed before university – will require the basic skills provided by artistic education. These skills will be needed, in order to be able to correctly estimate the ethical values of advanced societies in the future. In addition, they will be essential for managing complex design issues in the post-digital era.

4 BALANCING FINE ARTS + STEM COURSES TO AN HOLISTIC DESIGN-EDUCATION: REVALUE DRAWING COMPETENCES AT PRE SCHOOL TIMES

Optimized design conditions, in design engineering creative fields today at Europe by virtual interlinked designing landscapes, this represents aspects of the benefits of resilience. In addition, the research revealed two essential parameters for creating landscape models:

Firstly, there is an ongoing trend towards theory-based design and design thinking, based on practiced models. This brings with it the risk of losing important handcraft skills and knowledge rooted in various places throughout Europe, which drive creative design and the creative industries. Yet, due to the digitalization, emotional and manufacturing intelligence are more important now than ever before, in every aspect of business as well as the increasing need for competence in using artificial intelligence.

Secondly, the results each team – in design engineering studios in practice and education - produces directly, correlates to the individuals' prior education level, particularly in design or design engineering. All prior knowledge that can be conveyed at schools within the next few years will determine the design engineering competence and success (in this holistic perspective) of any nation or culture on this continent – or perhaps even the planet. If we are interested in empowering Europe's design engineering communities to reach a strong capacity and efficiency, we have to invest in the cultural education at school – in preschool we have to invest in forming and revalue cultural competences: Balancing fine arts + STEM courses forward to a holistic DEEducation Strategies (DEES) means entrepreneurial invest by brands, by universities, by pre-schools.

Aside from the 'designers paradise', with optimised collaboration conditions as described above, a return to the cultural heritage of design education is required. We also have to focus on the prosperity of the futuristic Ps – people, planet, profession, positioning – and define this prosperity's sources:

I. Design education as a role model versus its ongoing relation to society

When art and technology joined forces 100 years ago at the Bauhaus, it was based on technical generated design products for everybody to use, but with a focus on economic benefits. This is changing now, and design education should serve as the foundation – during the digitalization of the present times, that correlates to a different 'design behaviour' to the 'design shift' [12].

II. Preschool playgrounds as a cradle for design engineer skills'

Combing back to human's roots and honouring the potential of 'fine arts', in combining new didactical formats of 'manmade' courses, gives space to shape and to manage future tangible interconnecting design areas – a whish full thinking?

III. Design schools are a source of entrepreneurial spirit and influencers

The influence of an individual who represents a role model – as a designer or a design engineer and design 'educator'– who also proclaims new parameters is highly relevant.

A 'person of the hour' can be very convincing and influential with regard to the education and design system. In addition, they can facilitate exchanges with other relevant communities in European countries. With this in mind, moving forward will entail the entrepreneurial power of design schools and designers: around the globe, across Europe, of all genders. After all, they have already demonstrated an enormous cooperative power to optimize models as drivers of design engineering. This is reflected upon and discussed, which highlights the female designers who operated 'under the public radar' [13] during the Bauhaus era, for example. The best design engineering models for European's future are giving new value to art and design and its influence on children's skills, and also providing new models for mentoring programs in design. These are elements of social entrepreneurship and entrepreneurial universities [14], that are essential for sketching a resilient future in design and educational programs.

Felicidad Romero-Tejedor refers to acting as 'thinking designer' and being something between a scientist and an artist. By this she means to design with an emotion-based, more 'intuitive and synesthetic style of thinking' [15]. So, a designer is someone who creates through thinking and the creative act – in design doing. Within the culture of sciences in the 21st century, designers are able to deal with unknown and undefined things, and they are able to step into new foreign fields while working in interlinked, non-linear thinking processes. According to Romero-Tejedor, the designer possesses interlinked, non-linear thinking, that is necessary for creating accommodative systems. [16]

As such, by interacting with and integrating systems into the design engineering future, it is paving the way for meeting new needs in various industries and in engineering – needs related to the fourth industrial and social revolution, **and** thus also education. Developing concepts for innovative interlinked design theory within complex non-linear economic and common social systems requires design thinking. Digitally based tools are used in analogue linked systems and are influenced by emotionally triggered human behaviour. At the time, this creative (ideating) system is in the process of evaluating and revaluing the sketch as a tool for representing and visualising ideas by materialising concepts.

As illustrated – see figure 1 / workshop – according to the method of material-based design thinking, the sketch (also in architecture) could be considered an epistemic-based scientific object used as an interlinked, collaborative creative tool for visualising ideas [17]. The use and value of sketching and drawing, as a unique and original tool in design, is currently being re-assessed. In addition, the design code, or product language, in design is being transferred and communicated via media. This always relates back to the cultural imprint and sociological determination, on the one hand, and the anthropological significance of the culture of remembrance (Erinnerungskultur), on the other. '*Materials, which determine the terms relating to design objects, also supplement the materiality of culture. […] This specific material code is always a part of social behaviourism and can thus be decoded within that cultural context.*' [18]

Hence, taking socially and politically relevant action in design, combined with the rethinking of technology and of cultural practice, include a revalue of sketching by hand. Needless to say, that self-expressing, and self-confidence is supported by sketching with your own thoughts and 'ductus' and are essential elements for the future quality of creating: sketching by hand, with pencil or textiles or other materials and tools: the sketch is basic for discussing, reflecting, communicating and generating your ideas and design engineering solutions. Sketching competences for the next design engineer experts begins at pre-school and kindergarten.

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FIGURES

[1] PhD Student B's case study in visualisation the development of the illness dementia, during the workshop, the exercise called for 'materialising immateriality'. Royal College of Art, London, pic.: Wachs M.-E. 2019.
[2] Trigger points of advanced management of knowledge: artificial – emotional – integrated cultural intelligence in design, graphic: Wachs M.-E. 2020.

BUILDING SUSTAINABLE MATERIAL NARRATIVES WITH MATERIAL PATHWAYS

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ABSTRACT
This paper introduces Material Pathways, a learning tool developed to strengthen awareness, initiate reflection and support discussion on the multifarious roles, materials can have within the design for sustainability field in a common frame. Its objective has thus been to create a common pedagogical ground for notions and concepts used on materials and sustainability in fields such as art and craft, biology, engineering, geography, economy, culture studies and sociology.
The Material Pathways tool is a physical deck of 22 cards, each describing a 'material position' that can be used to unfold understandings of materials in a design project. The deck has been developed as a follow up and complement to the Sustainable Design Cards, a learning tool developed to articulate and activate approaches to sustainable design [1]–[3]. It builds on the same kinds of information and visual layout, making the two decks compatible with each other in the process. Consequently, the decks can be used independently, but also together, to both cover sustainable design broadly and the role of materials herein more specifically.
First, the paper presents the structure of content of each card and second it describes the development of the cards and as a collection. Finally, the paper discusses, how the cards might be used to create a language on and around materials, to frame and guide a process focusing on materials and to strengthen communication of material-driven ideas and intentions.

Keywords: Learning tool, material pedagogics, sustainability and design, design education, materials in design

1 INTRODUCTION

This paper centres on the Material Pathways deck, a learning tool developed to strengthen awareness, initiate reflection, and support discussion of material roles – or positions as we call them here – in design for sustainability. The motivation for introducing this new tool was to combine, but also to unfold the interdisciplinary fields of "materials" and "sustainability" from a design education and practice perspective.
As developments in the field of design for sustainability grow expansively, materials, as omnipresent as they are, play a vital role and hold the potential to unlock new ways of seeing and being in the world. In contrast to predominantly highlighting technical and environmental aspects, the cards also focus on materials' cultural and emotional values to encourage a critical and mindful approach to working with materials in all stages, from sourcing, to production, using and degradation.

1.1 Background

In 2017, we published the Sustainable Design Cards [1]–[3] containing 28 approaches to sustainability in design. Since then, we have experienced how the cards have spread through our network of educators, students, and practitioners and via the website. From the amount of positive feedback, we have received, we can see that the card tool format suits actors in and around design well.
In the Sustainable Design Cards, the perspective on materials is generic and broad to not overpopulate the cards with material related issues. This can be exemplified with having only one card to cover the deep and multidirectional field of 'Environmentally Friendly Materials'. Nevertheless, we knew that there was a need to unfold this area more in detail and beyond 'conventional' approaches such as sourcing organic cotton or using recycled and recyclable plastic. We wished to point towards considerations for materials that relate to a wider range of aspects relevant for design such as the context and use and thereby aspects related to experience and culture, but also aspects that tie these to notions

such as properties, systems, and time. That is, considering materials in diverse ways when we, as designers, seek to make qualified choices in the shadow of global climate change, social inequality, pollution and decrease of bio-diversity.
The paper outlines the content and structure of each cards and how they have been developed as a collection. As the cards were finalised and published in late 2020, in addition to introducing them in the courses we are engaged with ourselves, we are in the process of distributing them educators, students and practitioners to whom they could be relevant and useful. When doing so, we ask for and hope to receive valuable feedback on, how the cards can be used in different contexts and by different users.

2 FROM SUSTAINABLE DESIGN CARDS TO MATERIAL PATHWAYS

From the positive feedback we had received on using Sustainable Design Cards [2], we chose to work with similar structure of content, layout and visual identity for the new deck except for slightly adjusting the intensity of colours used and changing the font. We also saw this as important for emphasising the strong link between the old and the new deck so that it will be both possible and easy to combine and use the two decks interchangeably in a design process.
The card template we have worked from consists of an information side and a graphics side. The information side consists of information on 'What' the material position is about, 'Why' it is relevant to consider in a material in design for sustainability context, possible 'Challenge' with introducing the material position in a design concept, 'Examples' of companies that work the material position, other cards in the card deck that the 'card links to' and 'Further reading' with three to four references for user to read more about the material position.
The graphics side consists of two illustrative means that considers a material position from respectively a material lifetime and a material lifecycle perspective. The two perspectives: one that proposes to prolong the use of materials and products as long and efficient as possible [4] and one that proposes to enable indefinite material and product circulation [5] are often regarded as being in contrast to each other. Nevertheless, we see that the two can co-exist and co-relate, when breaking down the overall complexity.

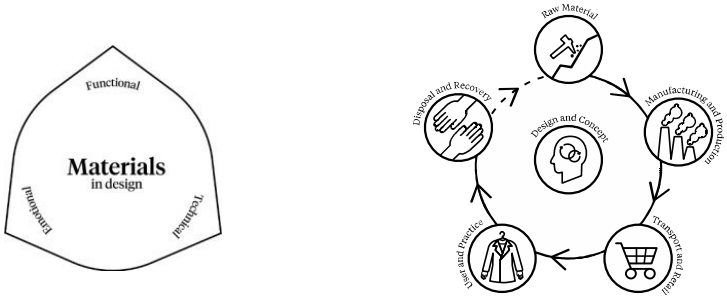

Figure 1. The design compass (left) and product lifecycle (right) applied in the Material Pathways deck

2.1 The design compass

Product lifetime can be defined as "the extent of efficient or sufficient use in a product" [4] and can be described by e.g. physical life, functional life, technical life, economical life, legal life and desirability life [6].
In the Material Pathways deck, we specifically consider lifetime from the material perspective and how materials engage in the value creation of the product and facilitate this with a visual compass where the lifetimes are condensed as a tension between technical, functional, and emotional aspects and where. Here we see that:

- Technical aspects refer to those related to the length of time a material or product stays in use before it breaks or wears out
- Functional aspects refer to those related to the length of time a material or product stays in use before its functionality no longer meets the user's expectations or needs
- Emotional aspects refer to those related to the length of time until user loses interest in the material or product

In the visual model, the compass shown in Figure 4, the material position is indicated as a coloured cloud space rather than a point, as we acknowledge that the understanding of and consideration for a material position will affect its relation to technical, functional, and emotional aspects.

2.2 The product lifecycle

In combination with the design compass, six phases illustrated with icon link a material position to a product lifecycle. This feature provides the user with two entrance points to the deck: you may be interested in a particular material position and gain understanding related life cycle phases. But you may also be interested in a specific lifecycle phase, say use phase, and are then able to identify material positions residing in this phase.

The lifecycle phases used in the card decks are:

- Raw Material relates to aspects concerning resource extraction and refining.
- Manufacturing and Production relate to aspects concerning the conversion of resources into products.
- Transport and Retail relate to logistic and handling aspects such as shipping and service concepts.
- User and Practice relate to aspects in use and can be influenced by the user.
- Recovery and Disposal relate to the recovery, reuse, or recycling of a product in post-use.
- Design and Concept relate to aspects in the design and can be integrated by the designer.

3 WORK-IN-PROGRESS DEVELOPMENT OF CARDS

Having established a predefined template and frame for cards to be described into and knowing in which direction we were heading, allowed for multiple explorative activities to happen simultaneously.

A first activity was a controlled brainstorming exercise, where we mapped notions that could relate to materials in design for sustainability in the design compass. In that way, we could understand and discuss, which areas that were overrepresented and which ones that needed to be further investigated and developed. This ended up with a preliminary selection of 33 positions that with the help of two student assistants from our intradisciplinary design MA program in sustainability and design were researched and described through individual writing, sharing documents and co-creation sessions for six months.

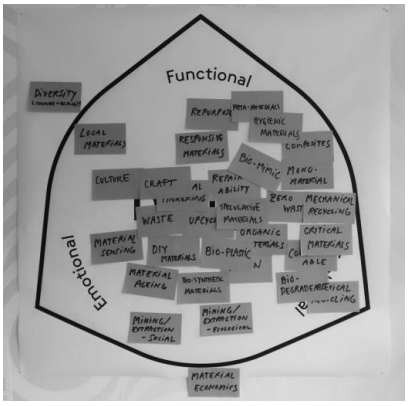

Figure 2. The design compass with preliminary material positions

3.1 First student engagements with the cards

The cards are mainly developed for students. In our own institution, the Sustainable Design Cards are introduced on BA-level to make operational sustainability in design. However, with the increasing attention on sustainability in society, the notions and concepts applied are often already familiar to students or some that they can relate to when being expanded on and discussed.

The Material Pathways were believed to possess a higher level of complexity; not necessarily in the logics of material positions themselves, but because they offer and apply a range of new notions and concepts that students have to become familiar with. In that regards, the Material Pathways can be

regarded as increasing the complexity from the Sustainable Design Cards. Consequently, we saw that students in our MA program on sustainability and design, being used to consider and integrate sustainability in their design projects and knowing and previously having worked with the Sustainable Design Cards, were suitable for 'testing' the first version of the cards.
In November 2019, the Work-in-progress deck of cards was tested in an independent workshop in a course on material narratives with first year MA students. The workshop was conducted as a 2.5-hour session, where students individually and in seven groups of two to four students in each were asked two tasks. To invite students into the process as co-researchers and not only as potential users, but the tasks also aimed to support active discussion rather than solely testing a prototype.

3.1.1 Task 1: Relatability to proposed material positions

After a short introduction and being provided with a physical print of the deck students were given the first task. As a way for students to become familiar with the deck and for us to acquire insights on how students would relate material positions to previous work, they were in this first task asked to describe previous projects based on one or more material positions. This was documented in a written template that students were asked to hand in after the workshop (figure 3, left) and was later used to understand, which material positions students were familiar with and had used and which material positions that according to students' work are often combined.

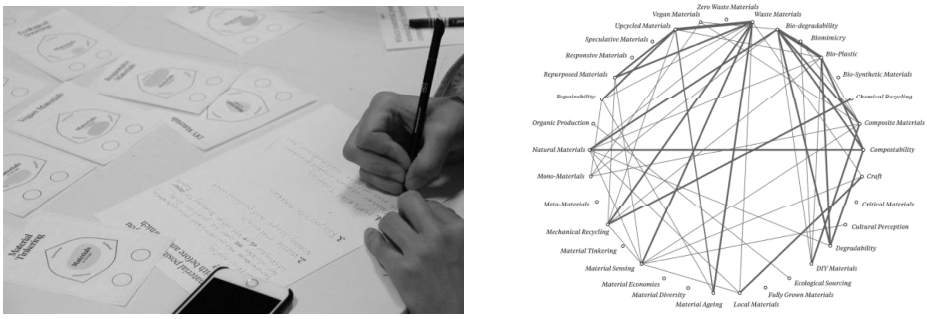

Figure 3. Linking material positions to own previous project work (left) and affinity diagram showing how material positions are linked according to the students (right)

Here the material positions 'Upcycled materials', 'Waste materials, 'Craft' and 'Local Materials', 'Bio-Plastic' and Mono-Materials' were represented most. It shows a concentration around waste, which makes sense, as waste materials are often accessible to students in that they are very tangible and hands-on resources that are inexpensive to source and that can be manipulated within the studio or at home. Furthermore, the strong representation of craft and the local can link to the arts and craft root of many design programs including the one we represent.
In contrast, material positions such as 'Bio-Synthetic Materials', 'Fully Grown Materials', 'Material Diversity', 'Meta-Materials' and 'Speculative Materials' were not represented at all. We believe that this can (partly) be because they require particular knowledge or available technology to work with that go beyond what is expected in design education.
Likewise, in an indicative affinity diagram showing students' links between material positions (figure 3, right), it is evident that the links were not evenly distributed among material positions. This, in addition to insights from the ongoing discussion throughout the workshop, indicated that it would be valuable to reconsider the framing of some of cards, both by means of relevance and relatability.

3.1.2 Task 2: relating material positions to product lifecycle phases

In the workshop's second task, in groups students were asked to discuss and assign product lifecycle phases to the card of each material position, this either using the stickers that were distributed or hand drawing the icons. Photo documentation from the task is provided in Figure 4.
Overall, students seemed to find the task easy to approach and most groups finished in time. Students were asked to leave the prints after the workshop for us to use in the further development of the cards.
From this, we could see that not all cards had been assigned phases, which we assess as an indication of the students not always fully understanding the content of the cards. For most material positions there

was coherence in how groups had assigned phases, here we consider this as at least four out of the seven groups, with the 'Manufacturing and Production' and the 'Design and Concept' phases being the most represented and 'Transport and Retail' being the least and almost not used. For us, these inputs and insights were valuable as guidelines for us to assign the phases in the 'final' version of the deck.

Figure 4. Linking material positions to phases in the product lifecycle

3.2 Revising the cards

The above-described concrete insights from the workshop as well as from oral feedback afterwards -the students were overall positive towards using the deck - motivated us to revise the cards. For example, by means of how the content on the cards was framed and described, if we should consider to merge or split some material positions and generally how we saw the deck being positioned in the world. Furthermore, it also meant clarifying that the cards are not and should not be seen as value-laden guidelines or methods, but as neutral material positions in the world that support that materials' engagement with sustainability can have positive as well as negative impact.
Based on this, the position titles were aligned, with exception of two cards, using 'Material' as the first word. Furthermore, the number of cards in the deck was cut down from 33 to 22, for example by merging cards that related to circularity into one position called 'Material circulation' and related to degradation into one position called 'Material degradation'.

4 THE MATERIAL PATHWAYS DECK

After the overall structure of the cards was settled, the content of each card was continuously re-written and revised until the cards were printed as a physical deck in the fall 2020. As shown in figure 5, the material positions represent all areas of the design compass (left) and all material positions have (strong) links to other positions (right).

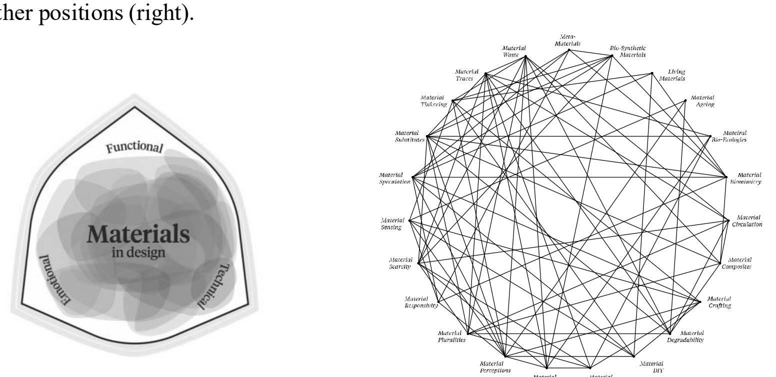

Figure 5. The design compass including the 22 material positions (left), an affinity diagram showing relations between the 22 material positions (right)

In figure 6, the material position 'Material Ageing' is included as a card example. The graphics side shows that the position is linked to the lifecycle phases 'User and Practice' and 'Design and Concept'

and that it, according to the design compass, is positioned in the space between technical and emotional lifetime.

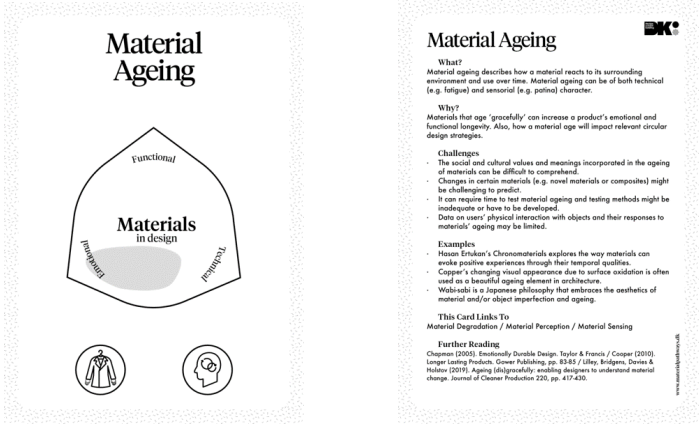

Figure 6. Example of the card, Material Ageing with a graphics side (left) and information side (right)

5 WHAT COMES NEXT?

We are now interested in understanding how the cards might be adopted within traditional design disciplines to further material engagement and reflection. Our own MA program, XX that comprises five disciplines. It thus provides us a rich context to explore this question. However, given the inter and cross disciplinary nature of the program, it also brings an opportunity to understand how the deck might be useful for students when they develop and define material concepts and approaches a cross traditional disciplinary material understandings and traditions.

Second, we believe (as was found with the Sustainable Design Cards), that the Material Pathways deck might hold relevance for disciplinary practices affiliated to design such as architecture, design management, material and product engineering and business studies. We speculate, that by broadening the scope of what materials in design can mean in relation to sustainability by including and explicating notions and concepts from human, social and natural sciences, the tool might potentially be able to bridge knowledge domains and bring nuances to discussions on the role of materials in the world.

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A MODEL FOR LEARNING TEAMWORK SKILLS

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ABSTRACT
In an attempt to resolve some of the gaps associated with the pedagogical integration of teamwork in design curricula, this article seeks to share a model for learning teamwork skills. This model is the result of a multiple case study methodology based on the learning experiences of 22 design students. Data was collected during various team projects through questionnaires and interviews. In relation to the concept of the zone of proximal development, the coded data was organized by thematic categories and training levels to provide a practical tool to support teaching and assessment practices to support the learning of teamwork skills. The proposed model allows for a systemic understanding of the teamwork skills that should be acquired during design training to navigate with efficiency and confidence in the collective projects of design's community of practice. It motivates individual efforts toward collaborative initiatives in the hopes of more coherent teamwork processes.

Keywords: Design, teamwork, collaboration, process, project-based learning

1 INTRODUCTION

From the 1980s to the mid-1990s, the design community started to recognise and value the social dimension of its processes. Bucciarelli [1] positioned design as a social practice, Cross and Cross [2] studied the distinctions of team design processes, and Goldschmidt [3] compared individual and collective practices. Since then, design has been more and more leaning toward shared and collective processes. As Goldschmidt [3] stated, the complexity of design projects led designers to be confronted with 'the need for multiple expertise and division of labour' (p. 189).

In recent years, professional designers have been invited to join projects initiated by many disciplines, ranging from medical products, ergonomic solutions, technological innovations, marketing initiatives, etc. In that sense, the designer has become a generalist that masters a creative process and analytical skills to converge to meaningful and inventive propositions.

Still, the integration of teamwork within design curricula around the world has not been the subject of consistent inquiry ensuring the coherence of its teaching, learning methods, and assessment practices. From our experience, we notice that teachers are proposing team projects as part of their classes or workshops, but most often without reflecting on the necessary skill set to gain performance for team projects or the optimal learning progression to achieve such performance. Among others, Tucker et al. [4] and Kleinsmann et al. [5] did start to draft typologies distributing teamwork experiences across typical design curricula. However, the lack of attention offered to assessment practices and methods to judge the performance of students or teams does not encourage the optimal integration of these frameworks within the pedagogical environment – which is composed of three equally important dimensions: teaching, learning, and assessing.

1.1 Difficulties regarding the learning of complex teamwork skills

Lack of structured approaches to implement teamwork within design curricula results in recurring challenges that are reported by various teachers and researchers. One recurrent challenge touches on the difficulty to bring students to collaborate. Collaboration is defined by specific characteristics that translate into a complex team dynamic, with high interdependence, shared comprehension, and common objective [6]. It has been noted that most students tend to work in teams according to less complex dynamics, such as cooperation or coordination, by distributing tasks and limiting exchanges [7, 8]. However, although collaboration might ask for increased efforts from team members, important advantages should result in higher quality projects [9]. Such benefits have to be communicated to students, so they can perceive their value. Otherwise, they will not understand why it is worth investing

time and effort. In the professional world, Stompff and Smulders [10] have noted that this tendency on the division of labour within teams leads to a lack of global vision resulting in fragmented solutions.
In hopes of proposing paths for meaningful solutions to the identified gaps, this article will use the data collected through a multiple case study methodology. A detailed analysis will allow to make sense of the learning experiences of 22 design students during their team projects by creating links with the theoretical concept of the zone of proximal development, which understands learning as continuously ongoing and collectively influenced. Such an interpretation will allow us to propose a model to facilitate complex teamwork skills integration during design training. To conclude, the paper ends by identifying some of the benefits for design education and elaborates on the preparation of novices to navigate with confidence in the collective projects of design's community of practice.

2 MULTIPLE CASE STUDY METHODOLOGY

Wishing to gain a deeper understanding of the learning experiences of undergraduate students during their team projects, a multiple case study methodology was put together to access a complementary pool of experiences. Twenty-two undergraduate students were recruited to participate in the research from various design programs offered at the Faculty of environmental design of University of Montreal (Canada; industrial design, interior design, urban design). The participants were accepted in the research if they were working as a team on a workshop project during the period of data collection. For ethical reasons, all participation was determined on an individual basis (which results in sometimes having only one team member to comply with the research). Still, the participants of Group E worked in pairs and all teammates accepted to join the research. According to the pedagogical project, data collection varied between five to seven consecutive weeks. Participants were of various training levels and in strategically different learning situations to provide a scope of experiences. Figure 1 shares contextual information on each group.

	Group A	Group B	Group C	Group D	Group E
Discipline	Interior design	Urban design	Industrial design	Interior design	Industrial design
Age range	18-23	20-40	22-24	35-36	22-33
Training year	First year	Third year (final)	Third year (final)	Fourth year (final)	Fourth year (final)
Type of teamwork	Disciplinary	Disciplinary	Interdisciplinary	Interdisciplinary	Disciplinary
Number of participants	4	4	4	2	8
Data collection *(Length in weeks)*	6 weeks	7 weeks	5 weeks	5 weeks	6 weeks

Figure 1. Portrait of participants

All participants were asked to fill weekly questionnaires describing the state of their project, their personal or collective challenges, and their decision-making strategies. These questionnaires were designed to take less than 20 minutes to fill to encourage students to participate in the research. They offered information about the *present* events of the participating students. The content of the questionnaire was explained in more detail as part of a past EPDE conference [12].
The questionnaires were combined with a one-to-one interview at the end of the workshop projects. These interviews provided clarifications on the reported experiences described by the participants. They allowed the researcher to dig deeper into the challenges reported by the student and to gain a more accurate comprehension. Most of all, the interviews contributed to the understanding of the participant's vision of his or her experience. Interview questions were organized to bring the participant to gain perspective on his experience, develop its reflectivity regarding his team situation, and propose alternative ways to overcome or address the main or recurring challenges in the future.
This multiple case study methodology resulted in a mass of data from which sense needed to be made by finding patterns and creating meaning through data analysis, which is described next.

3 DATA ANALYSIS

All data from the questionnaires and the interview verbatim were transcribed in the coding software MAXQDA. A total of 97 codes emerged from that process. Cross-verification and code organization allowed us to combine or delete some of these codes, resulting in 33 codes describing the teamwork experiences of our 22 participants. Moreover, all codes were organized into five categories,

corresponding to thematic groups around a shared topic. The codes and their five categories – interpreted as characteristics of teamwork learning experiences – are shared in the following Figure 2.

Categorie (Zone)	Personal	Project	Organizational	Learning	Social
Code (Caracteristic)	1.1 Adaptation to context 1.2 Personality traits 1.3 Motivation and engagement 1.4 Trust 1.5 Stress management 1.6 Focus on the project 1.7 Affirm role or position	2.1 Project activities 2.2 Expressing ideas 2.3 Taking initiative 2.4 Shared comprehension 2.5 Feedback on the project 2.6 Attention to details 2.7 Project complexity 2.8 Project feasibility	3.1 Time management 3.2 Meeting deadlines 3.3 Task management 3.4 Personal responsibilities 3.5 Prioritization 3.6 Disciplinary expertise 3.7 Team habits	4.1 Learning tools 4.2 Sharing new information 4.3 Skills complementarity 4.4 Inclusion of experts 4.5 Authenticity with the professional environment	5.1 Getting to know each other 5.2 Communication 5.3 Team ambiance 5.4 Team hierarchy 5.5 Agreeing together 5.6 Team meetings

Figure 2. Characteristics of teamwork organized into 5 categories

All characteristics were analysed across the set of data, which allowed the identification of 81 analysis factors, increasing our specific and global comprehension. These factors allowed for pattern identification according to the levels of training, allowing the clear categorization of the new information. Unfortunately, the scope of this article does not allow us to provide more details of the descriptive factors. Still, a good example would be according to characteristic 2.2 – *Expressing ideas* that is associated with three factors: (a) Proposing ideas individually, (b) Combining ideas, (c) Fixation. These factors provide alternative stages in a team's effort to communicate possible insights according to a person's effort, a team's contribution or not being able to do either of these possibilities. Factor A was identified in all groups, Factor B only in some of them (Groups A, C, and E), and Factor C, only in group E. These distinctions across groups of students show that not all students did achieve to combine their ideas as part of their teamwork experience. Moreover, investigating deeper into group E's difficulties translates the high complexity of their projects, resulting in a decline of some students' abilities to generate ideas.

Such an analysis was carried for all of the characteristics, to shed light on the similarities and distinctions of each group of students. The analysis also guided the identification of which characteristics and factors were predominant in the teamwork experiences of each group. Also, it underlined in particular which challenges were considered optimal for learning or too difficult concerning a certain learning context (for ex.: level of training or disciplinary/interdisciplinary). Such distinctions motivated the connection with the theoretical concept of the zone of proximal development.

4 ZONE OF PROXIMAL DEVELOPMENT

The zone of proximal development is a fundamental concept of the sociocultural perspective. This theoretical perspective was introduced by Vygotsky in the 1970s [11]. Through his study of children's development, Vygotsky came to understand cognitive growth as a continuous process according to which present abilities offer clues of one's future capacities.

The zone of proximal development is often illustrated as proposed in Figure 3. This representation shows the various stages that a learner encounters as part of its learning process. Still, the zone of proximal development is not entirely based on the sole learner, but also according to external support being provided to the learner as he develops more autonomy. Therefore, as shown in Figure 3, the central part of the model indicates all abilities that are mastered by an individual and that can be accomplished autonomously. The next section of the model translates what the learner can do with the help of a peer, teacher, or adult (often said to be a *more capable peer*). Finally, the external zone of the model identifies what the learner is not able to do either alone or with external help.

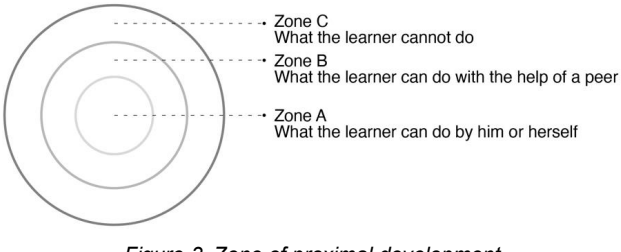

Figure 3. Zone of proximal development

As part of the described learning process, social interactions are crucial for the learner to progress across the zones. Of course, travelling in the model is a cyclic process as the learner gains more autonomy for certain abilities, tasks, or knowledge. This program enables the learner to access more complex fields of knowledge, for which he or she needs external support.

5 ZONE OF PROXIMAL DEVELOPMENT FOR TEAMWORK SKILLS MODEL

The interactions that emerged between the data collected, the analytical interpretation, and our comprehension of the zone of proximal development guided the development of an integrative model. As shown in Figure 4 below, the model entitled 'zone of proximal development for learning teamwork skills' is strongly inspired by the initial zone of proximal development model. Still, some differences are noted. First, it is divided according to the five categories that emerged from our analysis process, creating zones of skills to master. Secondly, it is composed of four different circular levels. The core of the model represents the prerequisites that are requested by academic institutions. The next circle is concerned about first-year students, integrating a new environment based on high standards. As part of the personal zone, the participants corresponding to this stage showed they needed adaptive skills to adjust to the requirements of their undergraduate program. Similarly, the other zones also translate the need to acquire disciplinary-specific tools and skills to ensure a good progression throughout the following stages. Therefore, the project zone is set to understand and master the design process and the organizational zone seeks for the development of organizational skills to facilitate task division among team members. The learning zone is specific to mastering some of the basic tools of the designer such as drawing technics or software. Finally, the social zone asks to work on communicative skills, so students can share time with other individuals, recognize each other's forces and manage conflicts. These characteristics were mostly identified in Group A.

Figure 4. Zone of proximal development for learning teamwork skills model

The next circle is related to second- or third-year design students (depending on the curriculum). A different set of skills are identified in continuation with what was acquired in the previous level. Interpersonal relations tend to grow into friendship as students get to know each other: therefore, the personal zone is described in seeking concentration to stay focus and not disturbed by workshop stimuli. The next zone (project) is associated with students' initiatives to navigate more fluidly in the design process, take action and propose frame structuration. The organizational zone is concerned about

efficiency to gain autonomy to formulate and accomplish tasks. The learning zone is related to skills development as a global improvement of disciplinary-specific and generic abilities. Lastly, the social zone corresponds to the development of the capacity to defend an opinion or position. As communication and relational skills should be practiced during various project experiences, one also as to be able to build its own perspective.

The last level, which leans to the professional world, corresponds to third- or fourth-year design students (last year of a training program). These students should be transitioning towards their future community of practice as they acquire a certain skill set in interactions with professionals. Both the first and last zone seek similar objectives in the construction of the professional identity of the student: affirmation of self and building an argument. The project zone and the learning zone both translate the authenticity of the proposed learning situations, the increased complexity of the project, and the feasibility of the proposed solution. The organizational zone proposes to facilitate prioritization during projects to meet the deadlines, comply with constraints, propose a realistic timeline, etc.

In brief, each level of the model corresponds to a specific range of training years but achieves coherence throughout a curriculum by progressing from an individual perspective through a more collaborative attitude. As stages are crossed by the students, more actors join in to contribute to the project with their specific expertise. In the first level, it is mostly the teacher that contributes as external help to the team project. At the second level, the peers or class colleagues are solicited for advice on ideas or the project. Finally, the third level seeks for more complex design projects and asks for the input of professionals according to specific domains of expertise to complement students' knowledge.

5.1 Pedagogical uses of the model

The proposed model has many benefits for design education:

- a framework for the coherent alignment of a pedagogical curriculum,
- a tool to structure the learning process,
- a perspective to develop reflective practice.

Biggs [13] raised the importance of planning a constructively aligned curriculum to provide a coherent structure to the learning process and increase students' investment in diverse categories of knowledge. Constructive alignment seeks to implement a structure between teaching, learning, and assessment practices of a class or workshop, but also, more globally, throughout the educational strategies and learning experiences of a curriculum. Such coherence supports deeper learning and a better understanding of the aimed objective.

In that sense, our model for learning teamwork skills offers a clear structure and sequence to gain autonomy with teamwork dynamics. The model proposes a progression from individual actions to collaborative initiatives by using the design project as its main motivation, guiding students from the centre of the model to its periphery. In that sense, the learner gains autonomy to accomplish teamwork characteristics in more complex contexts as he or she progresses in the model.

This model can be used to prepare teaching activities according to students' training level and to assess learning according to each characteristic's factors and whether the learner is lower or above the attended level. Moreover, the model can also be presented and explained to the students for them to take part in the judgement of their own performance. By using the model as a reference point among pedagogical actors, teachers, learners, or their teams can pinpoint the zone(s) where they feel less confident and see where they should be aiming. By understanding the global picture, design students would be empowered to reflect more deeply on their abilities and skills.

The proposed framework, based on the zone of proximal development, also supports the development of a reflective practice by perceiving the global picture and allowing discussions. During the interviews of our data collection, the participants were invited to discuss further the challenges they faced. The researcher tried to create a dialogue to deepen the perspective of the participant on its own experience. When successful, the participant was able to propose concrete ways to improve either their attitude, take actions or strengthen their team relationship and interactions. The capacity to find solutions based on their interpretation of the situation demonstrates an active cognitive process and a desire for change. As Argyris and Schön [14] demonstrated, professionals work according to their tacit knowledge, indicating that a large part of knowledge unfolds through imitation, observation, and interaction.

Building on this observation, it is possible to see how the model for learning teamwork skills could support the analysis of one's actions and behaviours, resulting in a more autonomous, constructive, and reflective practice. Offering common reference points to initiate conversation and reflection, the model

should lead to a more thoughtful practice in the hopes of developing reflective habits in the behaviours of future professionals.

6 CONCLUSIONS

This article shared a research initiative that sought to understand teamwork experiences as design students live them. The analysis of qualitative data collected from 22 participants of various design programs and levels supported the development of a model based on the concept of zone of proximal development. This model, which is shared as the main contribution of this article, gathers 33 characteristics of teamwork design projects distributed in 5 zones (individual, project, organizational, learning, and social). These zones are subdivided into three levels corresponding to introductive, mid-, and advanced levels. The model can be used in support of all three fundamental activities of educational practice by facilitating teaching and pedagogical tasks, supporting learning, and offering guidelines for self-assessment of co-assessment. Such coherence within the pedagogical strategies of a training program can only be more positive for the learners by bringing them to see the global picture, understand the need for complex team dynamics, and offer clear stages to reach mastery of design as a social practice. Using the project as its main motivation, the model works around complementary skills for achieving teamwork coherence, as designers often take on the role of group facilitators in the projects they take part in [5].

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MECHANICAL ENGINEERING DESIGN, DOES THE PAST HOLD THE KEY TO THE FUTURE?

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ABSTRACT
Industry design of a complex product has always required a cross-disciplinary team of experts. Is it possible to mimic these teams in academia when training the design engineers of the future, and what disciplinary skills will they possess? The exceptional collaboration potential provided by the internet means industry experts can work as a team, and at the same time, reside anywhere in the world. What are the capabilities of teamwork when the team members may never see each other for real? Though a physical prototype is sometimes required, most prototypes are designed and created in the virtual world using 3D modelling. The model can be tested, checked for accuracy, have materials applied, and be created parametrically which allows the product's geometry to be reset to different sizes by the designer. Collaboration, effective communication, and 3D modelling make it possible to design intricate and complex designs remotely. While we rightly congratulate ourselves on the complexity of modern design and how clever we have become, we must not lose sight of past achievements. Design has become more complex in this modern age, but it would be incorrect to say that complex design did not exist in times past. Before the internet, aircraft were built, global communication systems existed, men went to the moon. What can we learn, if anything, by looking at the methods used to design complex products in the past? How can we apply what we learnt from the past to the future?

Keywords: Design, teams, past, future, industry, 3D modelling

1 INTRODUCTION

For over 50 years, Moor's law has been found true. The number of transistors that can be manufactured on an Integrated Circuit doubles approximately every 18 months [1]. The effect in computing terms is to produce ever more powerful computers, a new generation of faster computer hardware approximately every 18 months. These more powerful computers have allowed the development of more sophisticated software. In the early 1980's, to design a complex system required many thousands of two-dimensional drawings on paper, depicting three-dimensional parts. By the 1990's, as computing power increased it was possible, for the first time, to design a complex system, the Boeing 777 commercial aircraft, not on two-dimensional paper but using three-dimensional software [2]. The traditional design office was replaced with the design world. Geography no longer limited the designer's world. With the internet, complex designs could be produced with design teams who are never required to be in the same physical room. Physical mock-ups were no longer necessary, these could all be accomplished with the aid of computers. While we rightly pat ourselves on the back and say how clever we have become, let us take a few minutes to think of a time, before computers, when complex designs were still possible. Aircraft such as Concorde were designed without the aid of any computers. What can we learn about these 'ancient' methods that will assist us in our computer led design today? What can be learn from the past that will help us in training the design engineers in the future?

2 INNOVATION OR INVENTION?

Go back to the second century BC to meet Philo of Byzantium. Figure 1 is a reproduction of the earliest drawing of his force pump. All the essential principles are present. Water flows into the partial vacuum created by the upward motion of the piston, and on the down stroke, with the valves reversed, the water is forced up the pipe into the tank. This was a significant advance, or step change from anything that had gone before. This is considered a dynamic product as there is room for significant product development. This, it can be argued, was an invention.

With most inventions, Philo's force pump was refined and next appears in the form of Hero's force pump (Figure 2.) from the first century AD, some 300 year later. The refinements which are most notable are the replacement of two pipes for conveying water to the tank into one pipe, the single actuation beam pivoting in the centre and the introduction of a nozzle. The dynamic product is now considered static, with very little scope for significant product development. Hero's force pump is an innovation based on Philo's invention [3].

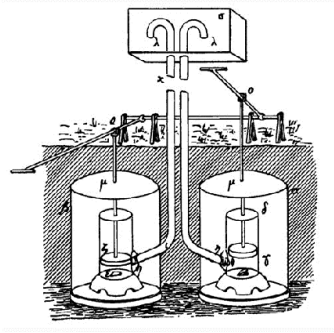

Figure 1. Philo's force pump [3]

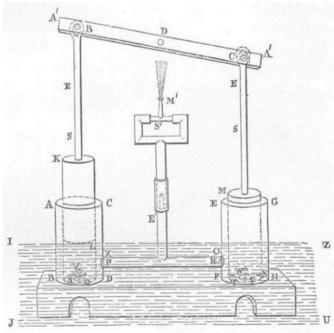

Figure 2. Hero's force pump [3]

Moving forward to the 18th century when Newcomen developed the 'Atmospheric' Steam Engine [4]. Pumps that came before was based on Philo's and Hero's design and were limited to the strength of the operator. They could only pump water from a depth of around 12 m (40 ft) thus limiting the depth of mining operations. With Newcomen's steam engine, water could be pumped from much greater depths even though its efficiency was only around 8-10%. This was a dynamic product with room for significant improvement. This improvement came from James Watt's 1769 patented condenser which improved the efficiency of the steam engine to 12-14% which may not appear to be much but was a major step forward in technology [5].

Early designers probably passed on information by word of mouth. Later they saw the advantages of producing accurate, detailed sketches. Sketches are an important aid in idea generation and a way of piecing together unconnected ideas into design concepts. In our modern era, sketches have become scaled drawings and assist in providing missing data on dimensions and tolerances, and for simulating the operation of the product using 3D solid modelling [6]. Most students are adept at using computers and usually have little difficulty in using 2D and 3D Computer Aided Design (CAD) packages, but they do struggle to produce useful sketches [7]. The stepping-stone of sketching between an initial idea and developing it into a concept is an area that requires investigation.

The importance of a thorough literature review is demonstrated here. Hero carried out a literature review and found Philo's earlier design. The equivalent of a literature review in Hero's day involved travelling

to the few sources of information available to him. The ancient library at Alexandria with its estimated 400,000 scrolls, or of ancient Rome with their earliest lending libraries [8]. How much effort does it take to carry out a thorough literature review? Most design today is not invention but innovation of an earlier design that is found by carrying out a thorough literature review. Do students with their many sources of information carry out a thorough literature review? To be thorough requires researching areas that may appear completely unrelated to the planned design project. To illustrate, a well-known brand of washing powder advertise that it cleans using the power of oxygen. This appears to be a rather spurious claim. While researching, would it be obvious to research fishing boats, no, even though fishermen for years have put their dirty clothes in a net over the rear of the boat. The churning of the propeller releases oxygen which cleans the clothes. Something totally unrelated to washing powder, fishing boats, provided a valuable clue to the researcher. Do students appreciate the importance of such a review? Are they taught how to carry a thorough review?

3 THE R100 AND R101

Moving forward to the 20th Century. On 24 August 1921, the airship R38, with a crew of 49 on board was practicing turning trials over the Humber Estuary. This involved turns at full helm and full speed. It suffered structural failure and broke in two, killing 44. During the subsequent investigation it came out that responsible officials had made no calculations whatsoever of the aerodynamic forces acting on the ship in flight. No one was sacked over it, or even suffered censure. This same team was entrusted later to the building of the R101, see Figure 3.

Figure 3. R101 [9]

In 1924 a team was put together to begin design on another airship, the R100. The team was led by Mr. B.N. Wallis, made famous later during World War 2 for designing the Wellington Bomber, the bouncing mine that destroyed the great dams of Germany, and finally some of the largest bombs of the war, Tallboy (6 tons) and Grand Slam (10 tons). This small team used a pair of 'Calculators', specialists specifically employed to determine the stresses acting on the airship frame. This could take up to 2-3 months and began by estimating the forces in the frame, then re-calculating the forces until a satisfactory resultant of zero was obtained. The final check was made by determining the horizontal and vertical forces throughout the frame, and if the calculations were correct, they too would give a resultant of zero. These hand calculations would fill 50 pages of foolscap [10]. This airship during its trial flights proved to be a successful and safe airship. The R100 clearly demonstrates the importance of stress calculations followed by re-calculations using different but complimentary methods until satisfactory results are obtained.

Let us now return to the R101.The work on it was finished on the 12th October 1929. Two days later it slipped from the mast at Cardington, United Kingdom, on its maiden flight. After several flights it was decided that the lifting capacity of the airship required increasing, and at the same time to initiate as much weight saving as practical. Were these major changes due to a lack of pre-manufacture calculations? The decision was made to insert an extra section in the centre of the airship which would increase the length by 53ft from 724ft to 777ft. The gross lift had been increased to 167.2 tons, with the fixed weight now 117.9 tons, giving 14.4 tons increase in disposable lift to 49.3 tons [11]. After brief trials and a Certificate of Airworthiness that was issued just before departure, the airship left for a journey to India. In poor weather it made it just south of Beauvais, France where is crashed killing 48 out of a compliment of 54.

The two tragedies of the R38 and R101, both designed by the same team which was known to be lacking in producing accurate or any calculations, highlights the importance of applying correct mechanical principles during a design project. Today, software provides many opportunities to determine the stress,

strain, and deflection of a component. 3D modelling with Finite Element Analysis (FEA) can, in a fraction of the time, produce results that the engineers working on the airships could only dream of [12]. But much more is required. Using 3D modelling software is not difficult to learn. Understanding its limitations takes much longer. Students must be aware of the requirement to validate the setting up of the software so that correct results are obtained. SolidWorks, a 3D modelling supplier provides 142 validation examples to help the user understand these limitations [13].
To back up modern day FEA simulations, calculations based on accepted industry calculations are also necessary. When the R100 was in its design stage, 'Calculators' spent months calculating the effect of forces acting on the airship frame. They backed up their calculations by checking them using a different set of equations. Do we teach our students to do likewise? They usually have enough difficulty using one set of equations and getting them to match the results from FEA. When they do not match, which is right, and which wrong? The more methods students understand and can use to calculate stress the more accurate will be their results. As an example, a basic, but extremely important calculation is that of stress in beams. What methods are they taught? Macaulay's, Castigliano's, Superposition, and Elastic Energy. Any or all these methods can be used to determine the stress in a beam, then recheck it and finally to confirm the results using a validated FEA method.

4 CONCORDE

The design and manufacture of Concorde (Figure 4.) was an early example of international cooperation. On the 5th November 1956 the first of 7 meetings took place of the Supersonic Transport Aircraft Committee. Several technical subcommittees each had 12 meetings, Air Registration Board, Aircraft Research Association, National Physical Laboratory, and College of Aeronautics. Finally, Specialist Working Groups met many times. By 29th November 1962, the historic Anglo-French Agreement to build Concorde was signed [14]. This agreement provided details of the responsibilities each country was to assume. Five main areas of equal sharing were stipulated, Structure, Systems, Aerodynamics, Strength and aero-elasticity calculations, and Weight and Centre of Gravity estimates. Later, the aircraft ancillary systems were allocated to each country. A 50/50 split was the aim. As an example, the hydraulic pumps were designed and manufactured separately by both countries to eliminate the possibly of both countries' pumps having the same fault, if any.
Nothing like Concorde had ever been attempted before. The technical problems were immense. All parts were designed using 2D systems to represent 3D parts. Only the most basic computer systems existed, so nearly all calculations were carried out manually. The designers could only dream of Finite Element Analysis (FEA) and virtual mock-ups. Therefore, as Mr. James Hamilton, the Director-General (Concorde) at the Ministry of Aviation said 'This airplane was the most tested airplane of all time. We had rigs for everything…. we were putting all the systems together under real flight conditions for the first time, you can never be quite sure' [14].

Figure 4. Concorde

The effect of coordinating the United Kingdom and France's input, designing, and then redesigning, inflation, devaluation, changes in exchange rates, testing, flight testing was shown clearly in the increasing costs. In 1962 the estimated cost was £150-170m. By 1979 the estimated cost had spiralled to £1129m.
Concorde is an example of teamwork and cooperation between two countries. Regular meetings were held, and clear lines of responsibilities decided upon. The design was world leading which made the development costs extremely high. Software FEA simulation was not an option the Concorde designers had. Even if software FEA simulation was available, it would not have helped with the problems the designers were facing. Software FEA simulation is very good for known problems, problems that the

computer programmers could include, but no good for cutting edge design. When teaching design to students, it is vital that they understand fully the software they are using, but more important, its limitations.

5 BOEING 777 -THE COMPUTER AGE

The designers and manufacturers in early aircraft builds at Boeing were around 50 yards apart from each other. As the scale of the company grew, little enclaves developed. Structures went in one place, air conditioning another. The culture of the company became 'Us and them'. Earlier aircraft builds could have around 100,000 parts produced on 2D drawings. Various mock-ups were produced, growing in complexity, to check that all the different parts would fit together.

When the planning to design and build a new aircraft, the Boeing 777 (Figure 5), it was decided this culture had to change. Design-Build Teams brought specialists together, manufacturing, tooling, planning, engineering, finance, materials etc.

For the first time, computers were powerful enough to design 3D parts virtually. Computer-graphics Aided Three-dimensional Interactive Applications (CATIA) format was used. These virtual parts could then be assembled using a second program, Electronics Preassembly in the CATIA (EPIC). Boeing distributed 2,200 computer terminals among its design team. All this was connected to the world's largest grouping of IBM mainframe computers (8 off). This system allowed manufacturers in Japan, engine makers in the United States of America and the United Kingdom immediate access to the data.

Figure 5. Boeing 777 [15]

During the planning phase, justification for the use of a very expensive computer system to design the aircraft was required. The planners looked back at a previously manufactured aircraft, the Boeing 767. They concentrated on certain aspects of its design such as the doors. On this aircraft there was two doors, passenger, and cargo. The doors, during the design phase required 1,341 modifications. The planner's put a dollar value on these modifications and came to a staggering total of $64 million. To put this amount in context, a new Boeing 767, back in the 1970's cost $100 million. When the doors on the new Boeing 777 were designed by two DBT's using the new CATIA and EPIC systems the errors were reduced by 95% which also equates to similar financial savings. Another example was using CATIA and EPIC to check 20 pieces of the flap system. The computer ran 207,601 checks for interferences between parts. A total of 251 interferences were highlighted. These were printed out and at the next DBT meeting it was decided who would be responsible for which interference, saving any possible duplication.

The importance of modern computer systems is emphasized by the Boeing 777 design and manufacture. Today the CATIA and EPIC systems are combined into one system making for even more savings. The importance of design being a team operation was shown by using Design-Build Teams [2].

6 CONCLUSIONS

Looking through this brief history of designing complex components it becomes clear that our ability to design complex systems with relative simplicity was built on the shoulders of design engineers who were giants in their fields. Philo's and Hero's Force Pump reminds us of the importance and simplicity of communication using sketches. Can computers compete with pencil and sketch pad? Not yet, but this could be an area for development. To get the most benefit from a literature review, be thorough and think 'outside the box'. The crashes of the R101 and R38 demonstrate what could happen when designing an airship, with little to no calculations. Compare them with the successful R100, where the stresses were fully calculated, and the importance of double-checking calculations. Does the reliance of students on 3D modelling and FEA need to be reduced and manual calculations increased? Concorde's technical design, which still marvels today, must be weighed with the astronomical costs involved in

testing and proving. The collaboration between two countries in a design and manufacture project identify the importance of regular meetings, and clear allocation of responsibilities. The beauty of 3D modelling and the advantages in time and money that the Boeing 777 benefited from. Are skills required to successfully work in a team being developed in students?

We do not have to invent something new to improve the way we design. By looking in the past and reminding ourselves about things already proven to work we can improve our designs for the future. Old processes may require a little innovation to bring them into the modern world, but the benefits should be clear.

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HAVE YOU FELT BLUE OR RED? A COLOUR-BASED TOOL FOR CULTURALLY PLURAL TEAMS

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ABSTRACT
The extensive practice of collaborative design-based learning and the increasing cultural plurality of design courses in Design Education is becoming relevant. Students' critical reflection on teamwork experience through structured activities of self-, peer and group evaluation can provide a space for students to ask themselves pertinent questions and to discuss together with the team about each one's reflections. A guided sharing of personal perspectives on teamwork reveals to students the existence of multiple perceptions and increases mutual understanding and sensitivity. To this extent, a colour-based assessment tool for teams, the Teamwork Colour Matrix (TCM), was designed with the idea that colours can take on very different associations for each individual and therefore can leave more freedom of expression, especially when it comes to evaluating teamwork. Students intuitively coded their experience concerning the different moments of teamwork and represented it inside the TCM by using eight given colours. The paper presents the qualitative data collected during the TCM redesign and remote application, showing how it can support students to reflect and evaluate plural remote teamwork, at the same time it helps teachers to monitor team dynamics within collaborative design-based learning courses. The test also provided rich data about the challenges students experienced in the current collaborative distance learning context, contributing to acknowledging students' learning trajectories in this type of course.

Keywords: Culturally plural teams, design-based learning, visual communication, peer evaluation, self-evaluation

1 INTRODUCTION

The collaborative design-based learning approach is widely adopted to teach design in higher education institutions; according to it, students learn design by doing it collaboratively with other peers. These collaborative learning-by-doing practices are continuously evolving according to the socio-cultural changes around and within the educational context where they happen. In this regard, our interest specifically concerns the increasing cultural plurality of classes that have been determined by several contemporary factors such as the growing global mobility, the centrality of internalisation strategies in higher education and the emergence of interdisciplinary curricula, just to mention a few. These generalised phenomena are particularly significant in design education when students learn how to design through group projects. Therefore, collaborative learning becomes the stage where they can also improve their soft skills. Specifically, as described by the EU commission, global competencies are the ability to relate with culturally plural others being sensitive towards individual differences. [1] In recent years, the authors focused on the effective teaching strategies that can support the development of these skills in plural design education contexts. Particular attention was dedicated to self-, peer and group assessment [2] by designing structured moments and activities to promote students' reflective practice on soft skills [3]. The researchers glimpsed the possibility of conveying the students' reflection by using a shared language among all designers: visual communication, which is the basis of the design discipline. The use of the principles of visual communication is proposed, mainly through colour and shape, to activate the dialogue inside the team. The potentialities of visual language to communicate between cultures, generations, or plural groups of people are related to the human ability to deduct information and associate feelings and emotions to images or visual elements [4]. In the context of the Master of Science in Design & Engineering at Politecnico di Milano, we developed a visual communication tool, the Teamwork Colour Matrix (TCM) [5], to support assessment and reflection on teamwork in plural teams where students represent the process of collaboration through an abstract

colour composition. The preliminary test of the TCM in presence was very positive since the visual communication strategy turned out to be an effective and more culture-sensitive way to evaluate a process and people participating in it [5]. However, before we could further test the cardboard TCM version, design education faced another radical shift during the last year toward distance learning due to the pandemic emergency. This situation affected the in-class interactions among students and teachers and the student-to-student interaction within the team. Thus, the distance added a further level of complexity for teams, possibly aggravated by the stress conditions experienced by learners related to the pandemic and working from different time zones. Besides, teachers did not have in-class moments to observe students, adding a further obstacle to monitoring team dynamics. For all these reasons, it became urgent in our context to provide a virtual tool for students to evaluate teamwork and for teachers to monitor teams. Therefore, the TCM tool was redesigned for distant learning by adopting an action research approach and tested within a dedicated path on teamwork within the Master program named above. The paper presents the qualitative data collected during the tool testing. Eventually, the test provided rich data about the recurring difficulties students experienced in this particular education context, contributing to acknowledging the students' challenges in culturally-plural teams and those introduced by distant collaborative learning in traditional design courses.

2 METHOD

2.1 Teamwork Colour Matrix: tool, sample, and remote application

The TCM consists of a blank orthogonal grid designed to be the canvas that each student will fill with one or more colours, taken from a predefined 8-colours palette. Within the TCM, the horizontal axis represents a timeline divided into ten parts, where the left represents the beginning of collaboration activities while the right represents the end. These ten parts can be interpreted as single moments, summed portions, or time percentages during the collective experience of teamwork (fig. 1, teamwork timeline). Students are asked to evaluate teamwork by describing through colours the different moments lived and perceived, by associating one of the eight colours spontaneously and visually representing each part of the process. The diversity of the chromatic palette is intended to motivate the students to visually represent different moods, moments or meanings when communicating the teamwork experience [6]. In other words, the eight selected hues are conducive to be linked to positive-negative, intense-dull, active-passive, and simple-complex associations, among others. At the end of the activity, both group and individual evaluations are expressed inside the TCM as visual communication, in the shape of intuitive colour composition.

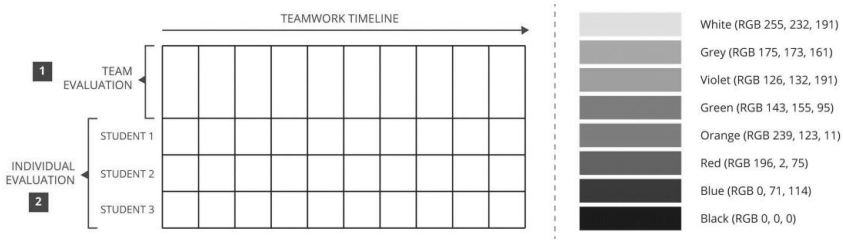


Figure 1. Teamwork Colour Matrix and the colour palette selected

The following instructions are provided to the students to do the exercise and thus create their own TCM about the teamwork they are experiencing:

1. **Evaluate the team.** In the first row (fig.1, Team Evaluation), the student has to evaluate the group and its dynamic by colouring each rectangle with one of the given colours. After colour selection, she is asked to produce a brief written description of the visual representation.
2. **Evaluate self and peers.** Each student evaluates individuals -the self and peers- by colouring the rectangles of the rows below the first (fig. 1, Individual Evaluation). Each row, made of 10 squares, is aimed at representing one team member. Again, the author writes detailed notes about the chromatic composition.
3. **Present the TCM to teammates.** Next, the team gathers, and each student shares her TCM. After individual presentations, the team should discuss possible issues emerging from team members and find solutions to improve teamwork.

The cardboard version of the TCM was tested with 15 international students, during 2019, after the design studio of an interdisciplinary one-year master course. On that occasion, the TCM was physically created in the classroom, with cardboard and coloured paper. The main results showed that all students could evaluate teamwork by using visual communication through colours and that students relied very much on their TCMs to tell others their own experience within the team. An in-depth analysis of the first testing, explaining how the grid was designed, how the colour palette was selected, and the test results can be found in a previous paper published by the authors [5]. Due to the COVID-19 contingency, the TCM was adapted to a digital format. We applied the online version of the tool to 123 students of the MSc in Design & Engineering of Politecnico di Milano. For the aim of this paper, the sample analysed consists of 32 students of the Product Development Design Studio I from very different origins (mainly Europe, Asia, and Latin America) and backgrounds (Design, Engineering, Robotics, Arts, Multimedia, Materials Science, among others).
The course was divided into nine cross-cultural teams of 3-4 people. Teams were decided by the students, and they were required to mix different origins and backgrounds inside the group. They worked together for four months and were supervised by three teachers, which are not part of the research team of this study. Within the course, a specific path was dedicated to teamwork called "Seminar on Teamwork" and led by the researchers as facilitators outside the teaching staff. As in the local education system teachers and learners have a strong hierarchy, teachers decided not to directly interfere with teams' dynamics nor push students with different sensitivity to open up in front of the professors. Therefore, the activities proposed during the Seminar were presented by the researchers outside of class time and were done autonomously by students. The seminar included three main activities for teambuilding and teamwork, namely 1) icebreaker and team formation, 2) team agreement and 3) self-, peer and group assessment after the first delivery. The TCM was done as part of the latter activity. The TCM was adapted to a PowerPoint presentation with 2 slides: the first presents the TCM blank grid and the colour palette available to the students. On this slide, students can perform the group, self, and peer evaluations, as indicated above, and provide the identification data for themselves and each of the teammates. In the second slide students can write their reflection on teamwork and each team member's performance. The activity started with a brief video explanation by the researchers about the matrix, the materials, and the exercise's goal, to proceed to individual work in both slides of the TCM. After the slides were completed, students were asked to gather in teams by using a classroom software to explain and discuss their results as a starting point to motivate conversation supported by visual communication. After the team discussion, students sent back their TCMs to the researchers for data analysis.

2.2 Analysis strategy for the data obtained

As the researchers did not know the students previously, the qualitative interpretation of data was based on visual communication and then verified with the written descriptions in the TCMs, without any additional information. The analysis focused mainly on three lines of study: a) to further validate visual communication as an effective strategy for plural students to share their feelings about the teamwork experience; b) to map recurring challenges that students experience in culturally-plural remote teams, and c) to provide guidelines for reading the visual elements inside the TCMs. These latter guidelines could support teachers in visually reading TCMs, without asking students to deliver explicit reports of their collaborative dynamics. Indeed, sharing their thoughts with educators could be perceived as particularly invasive according to individual cultures and sensitivity. To this extent, the researchers performed a visual analysis of group representation in the TCMs by focusing on the appearance of alignments/misalignments, colour uniformity/changes and the division of the TCMs into colour phases or moments inside the teamwork process. Then, we analysed the same visual elements regarding the individual performances by tracking colour analogies and differences between the author's colour representation of the self and the teammates and between each person's performance and teamwork representation. A cross-analysis between the group TCMs was then performed to understand the situations that emerged from a complete perspective. The visual analysis led to an interpretation of the process of teamwork, which was finally validated by reading the students descriptions of their TCM.

3 RESULTS

3.1 Team 3: an example of data analysis and results

Before proceeding with an account of the results obtained, an example of the analysis done is presented. In fig. 2, the TCMs created by the four team members (called here as M, R, J and F) are displayed, while in table 1, the qualitative observations noted by the researchers are reported together with the interpretation developed by cross-analysing the TCMs of the entire team.

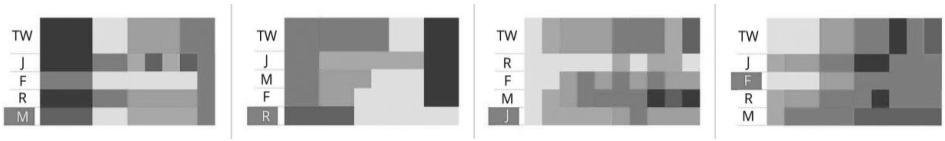
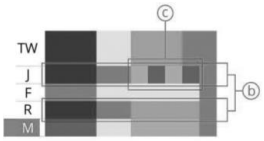
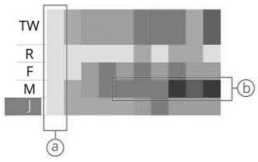
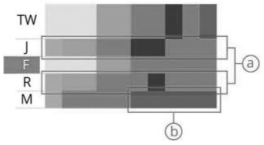


Figure 2. Example: TCMs of team 3, respectively made by students M, R, J and F

The final row of the table is dedicated to a summary of the descriptions written by students, used to corroborate the interpretation. It is possible to notice that the interpretation matches the inner team dynamics without details about the specific facts.

Table 1. Example: TCMs made by team 3, respectively made by students M, R, J and F

Team 3	TCMs Analysis	Notes based on visual communication
TCM student M		a) All teammates are aligned at the end of teamwork (green) b) J and R are represented as very much aligned. F and M are not aligned with them. c) Something is going on at the middle/end phase with J (sudden colour change, increased intensity of colour red) d) M represents herself in a very different way (red) compared to the rest of the TCM.
TCM student R		a) All teammates are never entirely aligned. b) All teammates are aligned in 40% of the TCM, except for R, who does not match this alignment. c) F and M are very much aligned (90%). d) R represents himself differently (red colour) regarding other students and teamwork in the initial and final phases.
TCM student J		a) All teammates are aligned in the initial part (beige colour), but there is a misalignment in the second half (lack of coincidence). b) Something happened with M in the middle/final phase. As a result, she has been represented with very different intense colours.
TCM student F		a) J and R are very much aligned (70%). b) Something happened to M in the middle/final phase. She has been represented with a very intense colour (red). c) M and F are not aligned with each other at all (0%). d) All teammates are never entirely aligned.
Researchers' interpretation of Team 3 based on the visual representations		
It is observed that students identify different moments or phases of teamwork (very clear M's and R's TCMs). The teamwork is not much aligned with team members, despite the colour selection seeming similar in the teamwork and team member parts of the TCMs. J and R are perceived as aligned by M and F, even if J and R do not represent themselves as aligned. The same happens with M and F in the perception of R. Apparently, something happened with student M at some point in the middle, represented by all team members except for R. The final moments of teamwork present a greater alignment among team members.		
Summary of students' descriptions		
All team members describe teamwork very positively, except, for J who acknowledges a conflict at the middle/end phase. In the beginning, team members did not know each other, and everybody describes the initial moment as a misaligned one, especially F, who initially was in her hometown and described distance as an obstacle for teamwork. The final phase was stressful, but all the team was focused on the delivery.		

From J's perspective, a division in the team exists: the two girls are designers (M and F) on one side, and the two boys are engineers (R and J) on the other. Both M and J reported moments of discussion in the middle/final part of teamwork. Student J mentions that the "design couple" excluded the "engineers" because they were not skilled enough in using a specific design software. In his words, there was an explicit call for peer learning addressed to the designers, also for R, who mentions the talent of the two designers and his desire to learn from them. The others' storytelling supports the idea that the two boys were very cohesive with each other, and the girls, despite some differences, were very much connected, aligned, and balanced.

3.2 Results account

The results obtained from the visual analysis that could provide some guidelines for reading the TCMs refer mainly to the appearance of analogies and differences among the chromatic representations. In group and individual performances, most students use the resources of colour similarity and changes to visually mark the duration, the beginning and end of the different moments or phases perceived in the teamwork process. This constancy or inconstancy in the application of colour visually informs the teacher about possible situations or conflicts in the group dynamics, which is reinforced when some coincidences can be seen between students' compositions belonging to the same group. Some of the essential visual elements to notice are:

- Alignments, similarities, and coincidences: within one specific TCM or even in the comparison between the TCMs of the group members, colour alignments are a valuable visual element to observe the students' perception of how the team worked. As the different individual performances can be compared with the group performance inside of a TCM, it is possible to observe which students were (or not) aligned with the teamwork (e.g., the alignments between a part of the students of the group or misalignments of one student with the rest of the group). Also, it is relevant to note the moments in which the entire group was aligned (or not) and at what stage of the teamwork process these coincidences occur. For instance, in most cases, teammates divided the teamwork process into a matching number of colours (3-4 moments or phases within the teamwork).
- Colour differences, sudden changes, and contrast: when noticeable differences or suddenly it appears a great contrast in the application of colour for the representation of teamwork or individual performances, it is usually an indicator of a particular situation or issue, a conflict between teammates, a moment of high stress (e.g., delivery dates) or a very different individual attitude from that of the rest of the group.
- High colour intensity vs achromaticity: although the students do not receive any reference on colour psychology before completing the TCM, the results show a great variety of semantic colour associations. Without going into the specificity of colour language, it is possible to notice the appearance of colour saturation -intense or vivid colours- to indicate intense positive or negative moments during teamwork (e.g., stressful events, discussion between teammates, a very productive phase or high enthusiasm about work). On the other hand, achromatic colours (grey and black) are usually used by students to represent a passive attitude to work, dull moments within the teamwork, confusion, lacking motivation or understanding between the team members.

Another significant result is that all the students involved in the test communicated as much visually as in words, providing a pretty accurate overview of their teamwork experiences. Regarding the tool, it is worth saying that the cross-analysis of the TCMs provided an accurate reading of each team and individual student contribution; this supports the idea that abstract visual communication could effectively enhance self-, peers and group assessment activities. The descriptions provided by each student were essential to understanding specific situations, behaviours or conditions that influenced teamwork dynamics. Another relevant result is that a straightforward plural attitude toward assessment emerged since not all the students demonstrate the same confidence in making explicit reference to the critical points of collaboration, such as conflicts and disagreements (e.g., J was the only one reporting a division in team 3). Still respecting individual and cultural differences in dealing with disputes, the TCM visual representation prompted each student to communicate alignments and misalignments with others and with the overall process of teamwork. This description is highly detailed regarding time and interrelations in the team, but it is generic on the specific facts or behaviours due to its abstraction.

From student's storytelling, some recurring elements emerged. The majority of students described teamwork by dividing the grid space into phases and reporting them in their descriptions. As external observers, the identification of these phases was the first step to analyse the TCMs. The main result is that all teams experienced three phases: an initial phase dedicated to knowing the others in the group; a middle phase where students report moments of misalignment due to various reasons (e.g.,

misunderstandings, lousy communication, different approaches to teamwork, decisions to take, lack of skills, bad revisions with professors) and, a very intense final phase before the delivery. It also emerges that the designers often tend to push aside engineers who do not already have some design-related skills within the course, which is highly design-oriented. In several cases (e.g., team 3), engineers make explicit calls for peer learning towards their design colleagues. Finally, students' descriptions highlight that, in this blended teamwork (i.e., some students at the university and some in their hometowns), those who worked remotely had trouble effectively contributing to collaboration and were sometimes excluded by the other team members.

4 DISCUSSION

The results show that all the students could assess the self, peers and group using visual communication, which guaranteed freedom in the evaluation itself. Students' abstract representation of the teamwork experience was fundamental for an external observer to gain an overall understanding of the process and contributions of each student. The method developed and described to interpret the TCMs was validated and demonstrated to be accurate and possibly replicable by other researchers or teachers. Indeed for 8 teams out of 9, the interpretation based on the visual elements was coherent with the descriptions provided by students, similarly to what happens with team 3. Some relevant themes and challenges arise from students' visual compositions and storytelling and are here briefly addressed. Firstly, the process of teamwork is often visually divided into phases which usually correspond to an initial phase of ice breaking, lack of mutual understanding or knowledge; then a middle phase where the team faces issues or challenges; and a final intense phase before the deadline for the delivery, which appears to be often stressful and related to arguing. In two teams, these arguments took place in an early phase, leading the teams to a deeper discussion and collective agreement on the collaboration rules; in these groups, the final phase appeared to be less stressful and conflictual. Another recurring topic is the division of the tasks within teams, often led by designers intended as the "experts" of the design process and sometimes resulting in the exclusion of engineers from several tasks related to concept development, visual research, and project display. This phenomenon was also detected when students, regardless of their background, demonstrate a lack of hard skills in some domains. Future research should envision ways to develop teaching activities to structure peer learning within teams, possibly reducing low-skilled students' exclusion and enhancing the learning experience for all. The last topic worth mentioning is the difficulties experienced by students working from a distance, who turned out to be often excluded or somehow disadvantaged in participating in team activities. Also, due to the historical moment we are facing, it is crucial to address this reality by structuring teaching and learning activity that can effectively promote the inclusion of distant students in blended learning. For all these reasons, the TCM test was very positive, and also, as a teaching activity, it supported the understanding of the new learning realities encountered by students, which in our view should be expanded and addressed by institutions and teachers. In this regard, the TCM constitutes the first step to raise awareness of the importance of teamwork as a learning experience in design-based courses and could hopefully be used by students to reflect on their learning as much as teachers monitor and support teams they supervise.

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ENHANCING CREATIVITY AND TECHNICAL COMPETENCE FOR DESIGN STUDENTS USING VIRTUAL REALITY TOOLS

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ABSTRACT
Teaching large groups of varying abilities and course ideologies has always been a problem. Many tools have been implemented and suggested over time. The paper highlights these tools and then sets the scene for the use of Virtual Reality and why it is the tool to use. This paper will look at how VR, through case studies, has been used to enhance the teaching and learning of Design and Engineering students. The pitfalls and the lessons learnt which would feed into the next iteration of the process. A discussion of the relationship of these tools and nurturing creativity is also included in the study. It is always, envisioned at the start, what would the ideal platform and outcome should be and then reflect critically on what was achieved because it was achievable.

Keywords: Virtual reality, teaching pedagogies, creativity, user experience

1 INTRODUCTION

There is large gap between what is taught and expected at school and that of universities and the commercialization pressures and income models adopted by universities, has necessitated large support mechanisms in order to achieve retention and progression. Many new post 1992 universities think of this as added value. Many scholars have studied retention and have made recommendations. Many new approaches have been around using the power of internet and online courses. According to Meloni [1] different instructors define “teaching online” and “teaching with technology” differently. Technologies implemented range from using presentations such as PowerPoint to using blogs and flipped classrooms. Platforms such as blackboard, Moodle and Brightspace have been used. However, the need for that face to face still exist and the course has still to be delivered by the lecturer. In fact, without the interaction of the students with the lecturer, failure will be inevitable. This is one of the reasons why, despite the abundance of freely available YouTube videos on various topics, many students still struggle with assessments. Semi-structured interviews with lecturers through questionnaires were used by Gow & Kember [2] to investigate the relationship between parallel teaching and the student learning. Hurson and Kavi [3] have discussed the rise in higher education costs in relation to the demands for computer specialists and the shortage of expertise in offering technology-oriented courses. They observed that most students absorb and retain visual material more readily. There are of course ear-learners and the ones who learn by physical practice. According to them about 20% of what is heard retained compared to 40% of what is seen as well as heard. The ideal is 75% of what is seen, heard, and experienced. This is something which cannot realistically be achieved in the traditional classroom settings with large numbers, cross disciplinary, and only hour long. As can be imagined a typical lecture would possibly contain videos, slide presentation, chalk and talk as well question and answers. Technology has enabled interactive computer courses which offer all three modes of learning. Of course, they recognise that it is important for the student to embrace the interactivity of the lecture.
According to Ausburn et al [4] virtual Reality has been defined in many different ways and now means different things in various contexts. They discuss the benefits of using visual technologies for teaching and learning in industrial education. The capabilities and possibilities for VR technology may open doors to new vistas in industrial and technical instruction and learning. The emergence of desktop VR has made it possible for industrial educators to add this powerful high-impact technology to their classroom instructional mix, and to build a unique research base in the field. Desktop VR may be a technology whose time has come for both research and practice in industrial education. With recent

breakthroughs in technical and cost accessibility, the door to the world of virtual reality is standing wide open. The also discuss the implications and recommendations for the use of VR technology as a potential tool for technical and industrial training. Hoffman and Vu [5] have recognised Virtual reality (VR) for its enormous educational potential. They talk of VR technologies being designed to provide engaging and intuitive environments for learning visually and spatially complex topics such as human anatomy, biochemistry, and molecular biology. These new systems promise to make broad-based training experiences available for students at all levels, without the risks and ethical concerns typically associated with using animal and human subjects. Medical students could acquire proficiency and gain confidence in the ability to perform a wide variety of techniques long before they need to use them clinically. Surgical residents could rehearse and refine operative procedures, using an unlimited pool of virtual patients manifesting a wide range of anatomic variations, traumatic wounds, and disease states. Those simulated encounters, in combination with existing opportunities to work with real patients, could increase the depth and breadth of learners' exposure to medical problems, ensure uniformity of training experiences, and enhance the acquisition of clinical skills. Ortiz et al [6] have proposed the implementation of a virtual tool applied to the field of Automotive Engineering, with the aim of strengthening the processes of teaching-learning, so that the student can achieve meaningful learning. Their system consists of the implementation of a virtual automotive laboratory, in which one can take guided classes, specific practices and evaluations in the automotive field, allowing greater immersion and interaction during the teaching-learning process in order to optimize resources, materials, infrastructure, time, among other benefits. The system would allow the ability to select the working environment and the level of difficulty during the teaching-learning process. Their results show this tool to very versatile and can be extended to other areas. It can motivate the students and facilitate the incorporation and presentation of new elements to develop new practices. According to Horváth [7] from an educational perspective, an important benefit brought about by such technologies as VR is that they lead to a teaching environment that is first and foremost learner centred. This encourages the application of innovative educational methods and introduces new modes of teaching into the learning experience. However, all of this makes it necessary for teachers to spend more time preparing for their classes, as well as growing acquainted with the latest technologies - in short, it is a process that requires improved digital literacy on the teachers' part. Horváth presents an experiment contrasting traditional 2D interfaces and the MaxWhere 3D VR educational platform in order to shed light on how these technologies influence the effectiveness of various operations and workflows constituting teachers' tasks. In the experiment, the same workflow is compared when executed using e-mail attachments, a classical 2D e-learning platform and MaxWhere's 3D platform. The results of the experiment, evaluated in terms of a newly proposed (and clearly motivated) framework, point to the conclusion that when using MaxWhere instead of traditional 2D interfaces, teachers, lecturers, and trainers are able to accomplish the same digital workflows with 37-64% less user operations, and up to 72% less machine operations. Based on these results, the paper concludes that MaxWhere as an educational platform offers users - not only students, but the lecturers, teachers, and trainers too- a number of ways to accomplish tasks that would otherwise require extremely complicated digital workflows in more traditional 2D environments. Kurilovas [8] has analysed the problem of quality evaluation and personalisation of virtual reality/augmented reality/mixed reality (VR/AR/MR). First of all, systematic review of relevant scientific literature on the research topic was conducted. After that, findings of the systematic review concerning evaluation of quality and personalisation of VR/AR/MR learning environments are presented. Kurilovas' VR/AR/MR learning systems/environments quality evaluation and personalisation framework is also presented in the paper. Evaluation of quality of VR/AR/MR platforms/environments should be based on (a) applying both expert-centred (top-down) and user-centred (bottom-up) quality evaluation methods and (b) separating 'internal quality' criteria, and 'quality in use' criteria in the set of quality criteria (model). Personalisation of VR/AR/MR platforms/environments should be based on learners' models/profiles using students' learning styles, intelligent technologies, and Semantic Web applications. As expected according to Male et al [9] safety in design is an important topic in engineering education for which practical experiences are likely to be beneficial but logistically difficult, and high risk. They show that Virtual reality (VR) offers the possibility for students to learn from an interactive experience without the inconveniences and safety hazards in real site visits. One of the challenges of using VR has been providing learning experiences to large classes of students. This investigated the efficacy of VR for teaching safety in design, and an approach to accommodate VR with large numbers of students. Students learned about safety in design

in workshops, using a VR environment. They worked in groups in which only one member wore the VR headset and others observed. They found that students agreed that they identified additional risks after the VR experience regardless of whether they wore the headset. One interesting side observation was that usually quiet students, who were often international students, participated more actively in the group discussions than in their usual weekly group meetings.

Setozaki et al [10] have examined the practical use of screen presentation systems. At first, they developed Multi aspect VR teaching material, and the presentation system was improved. The teaching material produced using this system was then brought to and used in a high school. They taught lessons using the VR. This made a good impression on the students in the class. The students were compelled to get involved in the class. According to Cooper et al [11] Virtual reality (VR) platforms act as a potentially transformative tool in learning and teaching. They examined pre-service teachers' (PST) perceptions about VR, inclusive of their beliefs about its capacity to be used as a teaching and learning tool. They conducted a case study at an urban university in Australia involved 41 participants. Participants' positive perceptions of VR in their teaching relate to its potential to engage learners, the immersive potential of the platform and the scope of VR to offer students experiences they might otherwise not have with other learning tools. Concerns expressed by PSTs include their relatively low self-efficacy to use VR in their teaching, monitoring-related matters, financial cost and implementing the technology in a safe and supportive way. There was a significant difference in PSTs' amount of self-efficacy to teach using VR when compared to their overall confidence to use digital technologies. PSTs typically had greater awareness of the immersive and engagement potential of VR and less awareness about its potential to foster and promote collaborative learning. This paper contributes to an emerging discourse regarding the possible applications of VR in educational environments and particularly in relation teacher-educator contexts. According to Hutchison [12] evolving digital technologies has provided opportunities to engage students in activities that go beyond print-based reading and writing and help them develop skills for reading, writing, and communicating with digital technology. Virtual reality apps are a rapidly emerging form of digital technology that provides immersive experiences in real or imagined environments. Virtual reality creates sensory experiences that involve sight, touch, hearing, and motion to allow users to feel as though they are physically present in that environment. These types of immersive experiences can be used to engage learners in multimodal literacy practices as well as scientific practices such as forming hypotheses and interpreting data to inform courses of action. The author provides a classroom example of using virtual reality in an integrated science and literacy lesson to engage students in discovering, answering, and writing about questions they developed as they explored a virtual environment. Williams and Alrmuny [13] have explored the utility of the virtual reality technology for the purpose of developing visual literacy and understanding about the microscopic world as it relates to the macroscopic properties of matter. Additionally, it shares perspectives of education students in various teacher preparation disciplines about virtual reality as an instructional tool. Through a mixed-method design, pre/post data and interview transcripts provide insight into the VR program and its bearing on learning. Tsuji et al [14] know that it is difficult to understand nursing practically for students who have just started studying nursing, because they cannot imagine the actual medical scene. The authors expected that they could improve nursing learning through experiences in virtual medical environments supported by ICT (information and communication technology). They have developed teaching materials in nursing education, and in a previous study reported that the use of a virtual hospital was useful for students who had not had medical experience. Their aim was to have students consider the meaning of a hospital room ceiling. First, they showed them a few ceiling patterns, and they selected the best one among the patterns. After that, they showed the same one in a virtual hospital room. They had negative opinions about what they had thought was the best one at this time. This demonstrated that the virtual hospital room is effective when students evaluate the ceiling as a part of the hospital room. Martín-Gutiérrez et al [15] state that Virtual reality captures people's attention. This technology has been applied in many sectors such as medicine, industry, education, video games, or tourism. Perhaps its biggest area of interest has been leisure and entertainment. Regardless the sector, the introduction of virtual or augmented reality had several constraints: it was expensive, it had poor ergonomics, or implied too much work to create contents. Recent technological innovations, including the rapid adoption of smartphones by society, have facilitated the access to virtual reality and augmented reality of anyone. In addition, several large companies like Apple, Facebook, Samsung, and Magic Leap, among others, have increased their investment to make these technologies to improve their accessibility within the next few years.

Educational institutions will benefit from better accessibility to virtual technologies; this will make it possible to teach in virtual environments that are impossible to visualize in physical classrooms, like accessing into virtual laboratories, visualizing machines, industrial plants, or even medical scenarios. The huge possibilities of accessible virtual technologies will make it possible to break the boundaries of formal education. Nelson and Ahn [16] recognize that there has been a growing need to teach professional development skills to engineering students at Iowa State University. Students are often lacking these skills even though they are desired skills to have both for academic success and in the workplace. They explored using virtual reality to teach four professional development skills to students. These skills are leadership, teamwork, communication, and ethics. Virtual reality as an innovative tool was used to teach students these skills in an interactive and fun environment. Fernandez [17] presents and discusses the developing role of virtual and augmented reality technologies in education. Addressing the challenges in adapting such technologies to focus on improving students' learning outcomes, the author discusses the inclusion of experiential modes as a vehicle for improving students' knowledge acquisition. Stakeholders in the educational role of technology include students, faculty members, institutions, and manufacturers. While the benefits of such technologies are still under investigation, the technology landscape offers opportunities to enhance face-to-face and online teaching, including contributions in the understanding of abstract concepts and training in real environments and situations. Barriers to technology use involve limited adoption of augmented and virtual reality technologies, and, more directly, necessary training of teachers in using such technologies within meaningful educational contexts. The author proposes a six-step methodology to aid adoption of these technologies as basic elements within the regular education: training teachers; developing conceptual prototypes; teamwork involving the teacher, a technical programmer, and an educational architect; and producing the experience, which then provides results in the subsequent two phases wherein teachers are trained to apply augmented- and virtual-reality solutions within their teaching methodology using an available subject-specific experience and then finally implementing the use of the experience in a regular subject with students. The essay concludes with discussion of the business opportunities facing virtual reality in face-to-face education as well as augmented and virtual reality in online education. Davies et al [18] present their initial experiences integrating virtual reality (VR) 360° viewable images within a university medical imaging teaching session and some general transferable learning points for the successful delivery of VR content. VR has the potential to offer students an immersive educational experience but is not without its limitations. Our initial experience using VR with small groups ($n<7$) and larger groups ($n<35$) highlighted several obstacles which needed to be overcome to be able to successfully use VR in teaching. They found that requiring students to use their own devices to view VR content during teaching sessions (downloading the media content and loading it into a suitable app for viewing) presented a variety of problems, with pilot studies only a limited number of students successfully engaged with the VR content. The problems faced by students were a result of device compatibility (such as software versions, sensor capability such as lack of accelerometers), storage limitations app and browser capabilities (e.g., 360° video on YouTube is currently not supported by the Safari browser). The physical device size, button location and screen brightness caused issues when attempting to use some phones in consumer VR headsets. A diversity in student's digital fluency impacted on the level of student support required in the classroom to ensure engagement, and also made the activity highly labour intensive.

2 CASE STUDY

An existing undergraduate workshop skills project was used as the foundation of the VR experience. Students were required to manufacture and assemble a simple oscillating engine from engineering drawings and operation sheets (Figure 1) that focused upon milling and turning operations. In previous years students had experienced difficulties interpreting the engineering drawings of the project in addition to issues with the order of assembly of the final components.

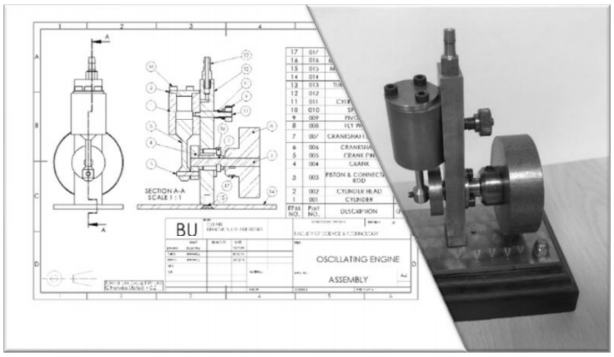

Figure 1. Oscillating Engine

The VR experience aimed to address both issues by providing a scaled up virtual version of the assembly that contained three sections (Figure 2); the first was an assembled version of the oscillating engine, the second was all components laid out for the student to view and the third an animated exploded version of the assembly.

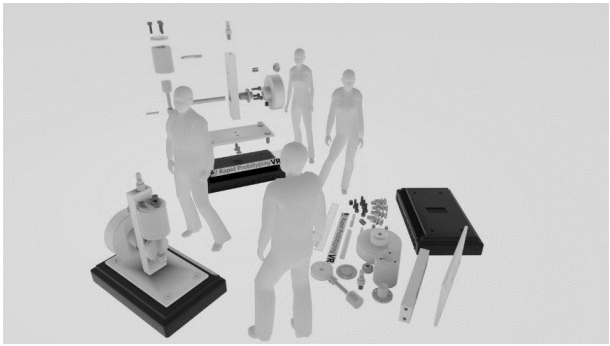

Figure 2. VR Layout and Relative Scale

The students were given access to the VR scene at the same time they started on the physical components, they were given approximately 5 mins to view the scene and watch the animation. Engagement was varied, some students stood still and just looked around the scene whilst other became fully engaged in the virtual environment and were happy to walk around and crouch down to examine specific components in detail.

Overall, the verbal feedback from the students on the experience was very positive the animated view and the scaled-up model were the items most talked about by the students during and after the experience. When returning to the workshop the students found it easier to understand the relationship between the different components and how they fit together in the assembly.

3 DISCUSSION

VR has great potential as a tool to integrate into the design process as it can bridge the gap between a two-dimensional screen and physical prototype. The ability to scale models has been highlighted by participants as a valuable part of the experience. Future work: in order to fully immerse the students in the virtual world scene interactivity needs to be explored, in this case study the student was just an observer rather than an active participant. Future projects would look to allow for the construction of the assembly in VR in order to make a more immersive experience. This would need to be balanced against resources available and the space required if the student's VR time were to be extended.

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TEACHING PRACTICES OF COMPUTER-AIDED TECHNICAL DRAWING IN THE TIME OF COVID-19

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ABSTRACT
This paper aims to describe the teaching practices of computer-assisted technical drawing used during the Covid-19 pandemic. Such practices intend to encourage the engagement of students with the implemented approach. The research was carried out by analysing the data from five technical drawing Engineering and Design courses in a Brazilian public university. Data were collected between August and October 2020 based on the observations by the authors of this paper and on an online questionnaire submitted to the students of the referred courses. The data were analysed at four different moments: selection of teaching technologies in virtual learning environments, planning, implementation, and course assessment.
The study findings revealed higher student engagement when unconventional practices, such as gamification, were used in the classroom, as well as the use of reference animation pieces to serve as the basis for the drawing, and a small number of assignments to be performed with mandatory appraisal from the professors. Another finding indicated that the quality of remote instruction and guidance is conditioned by the evolution of the technological apparatus and its availability at the university with the support and exposition of contents and real-time feedback.

Keywords: Technical drawing, CAD, remote classes, Covid-19

1 INTRODUCTION

Computer-aided technical drawing is a basic academic discipline in Engineering and Design undergraduate courses, which focuses mainly on presenting local and international standards. It also aims at incorporating technological innovations in the area of computer-assisted design. The professor must follow the student's progress and provide real-time feedback during in-class assignments. Due to the pandemic, the pedagogical approach used in these courses had to be revised and updated. This paper describes practices used in technical drawing disciplines with the support of CAD systems at a public university in Brazil during the period of the Covid-19 pandemic. The authors chose to use teaching strategies that favoured the teaching and learning process based on remote approaches, as proposed by [1].
The practices resulted from discussions among the discipline professors regarding more appropriate teaching formats, contents, and student evaluation processes. Also, the theoretical reference in the area was used to support or refute our propositions. Data contained in the observations made by the professors who authored this paper were also used to implement the remote format of the discipline, as well as an analysis of the students' opinion, obtained through an anonymous online questionnaire at the end of the academic semester.

2 CONTEXTS FOR THE STUDY

The technical drawing discipline with CAD system support is mandatory for most of the Engineering and Design undergraduate courses offered by the university in question. Every semester, it offers 12 technical drawing classes with CAD system support. There are two types of classes: specific and generic ones. The specific classes are offered for the Civil Engineering, Mechanical Engineering, Production Engineering, and Agricultural Sciences courses. The generic ones are offered for Design, Food Engineering, Chemical Engineering, Mining Engineering, Cartographic Engineering, Electrical Engineering, Automation and Control Engineering, Environmental Engineering, and Hydraulic Engineering courses. All disciplines present the same theoretical content for technical drawing. However, there are additional modules aimed solely at their respective areas of knowledge for the

specific disciplines. For example, the discipline offered in Civil Engineering courses includes a building design module.

At the university, the classes are assigned to a team of eight professors. Each specific class, in general, has a total class load of 90 hours per semester and 60 hours for the generic classes. On average, 360 students are enrolled every semester. When a class has, in general, more than 25 students enrolled, two professors are assigned to teach in the classroom since it is necessary to provide individualized assistance for each student. Our experience shows that in classes with more than 25 students, it is not possible to provide adequate individual assistance with only one professor in the classroom during the class period. The discipline also has 4 monitors that take turns providing support for all the classes. Historically, there is no possibility of increasing the number of monitors due to budget restrictions of the university. Despite the budgetary difficulties, the university is among the best ranked by the Brazilian Ministry of Education.

Unlike American and European universities, in Brazil, the school year is divided into two semesters, with classes from March to July and August to December. The university in question has 29 thousand undergraduate students and had its classes and activities suspended in the third week of March 2020. The classes resumed in a remote format in August. The four months of the first semester were used to create a statute to legally regulate the remote teaching format, conferring it with the same status of in-person classes at the university. For the remote teaching mode, we adopted the definition of [2], which refers to the context of teaching the classes with asynchronous and synchronous content, without on-site meetings.

Before the pandemic, concerning the technical drawing disciplines supported by CAD systems, seven of the eight professors opposed the possibility of offering classes in hybrid or remote modalities. According to these professors, face-to-face contact is fundamental since it allows them to better monitor the students' evolution and because the tests can be applied with a low risk of cheating. Also, research evidence shows that the students' satisfaction with the course is lower in online classes than in face-to-face classes [3].

The four months following the suspension of classes were marked by uncertainty. However, the discipline professors used that time to study means to adapt it to remote teaching. Most of the information technologies considered were free of charge to facilitate student access. It is important to point out that the discipline already used the Moodle platform to provide information for face-to-face classes.

With the information that the University had acquired a Microsoft Teams educational package to enable synchronous remote classes, the professors began the respective adaptation. The disciplines were initially structed with the intention, above all, to engage students in remote classes since it is known that changes in their routine can cause students to abandon class attendance [4].

To conduct this research, data collected from five technical drawing courses in Engineering and Design were used. Data were collected between August and October 2020 based on the observations by the authors of this paper and on an online questionnaire submitted to the students of the referred courses. The observations concern the students' questions during the classes and the evaluations of the asynchronously applied tests. Only the classes assigned to the authors of this paper were analysed, comprising 72 students in total. The return rate was 55%. The data were analysed at four different moments: selection of teaching technologies in virtual learning environments, planning, implementation, and course assessment.

3 TEACHING PRACTICES ADOPTED

3.1 Selection of teaching technologies in virtual learning environments

The search for technologies made available by the university as virtual learning environments constitutes the first stage of a strategy aimed at implementing remote teaching approaches [5]. Resources should also be implemented to make the class attractive and preferably available free of charge on the Internet [6].

The University studied here uses Moodle and MCONF. However, with the increased use demand due to the pandemic, MCONF proved unstable. That led them to acquire the Microsoft Teams educational package. The technical design professors compared MCONF and Teams based on the available resources in each environment and their stability and opted for Teams. Once the platforms used were chosen, they could move on to the pedagogical planning of the discipline.

3.2 Planning

The professors are responsible for planning the course in the remote format [5]. Among their objectives, they must seek to increase student engagement and decrease the chances of evasion. In this sense, some practices adopted during planning are essential to achieve the objectives established by the professors:

- Relate the discipline to professional practice: during the classes, we tried to exemplify the practical application of the theoretical contents, according to what was established in [7].
- Prepare tests according to the complexity of the exercises performed in class: tests must have the same complexity as in-class or out-class assignments. However, note that the same rule applies to remote classes. They must be planned to increase the complexity of the proposed exercises to train students for more complex problems.
- Avoid having a large number of assignments during the course: a smaller number of assignments provides a sense of completeness and increases the students' satisfaction as they achieve the course goals [8]. This was a point of dissatisfaction for some students in three studied groups with assignments to be completed in all classes.
- Make video lessons of the subject contents available before the day of the class: in this sense, professors can adopt the flipped classroom approach [9] to make use of the synchronous class period for professor-student feedback, making the class more discursive and attractive.
- Develop dynamics to make the classes more attractive and increase engagement: A dynamic exercise was developed through Quizzes in one of the classes. According to [10], there is a positive relationship in the students' motivation through such activities.
- Such activities are extremely important to increase student engagement and integration. They were particularly used to break the ice between the teacher and the students, which was sometimes noticed in remote classes at the beginning of the semester. It is recommended that they be used at the end of the first 1/3 of the course as a way to increase engagement and help students consolidate the contents. In the courses, there was room for a single activity of this type. Dynamics of this nature require a greater number of classes, since the content of the teaching plan to be worked on must be prioritized.
- Develop, along with two-dimensional images, three-dimensional animations of the pieces to be drawn by the students: the use of animations to facilitate the understanding of the format of elements or provide a visualization experience close to reality has a positive effect on the learning process of the students [11], since physical pieces, traditionally used in the discipline, were not available due to the need to maintain social isolation.

3.3 Implementation

The process of implementing the pedagogical plan of the discipline allowed us to identify the need to work with specific operational practices:

- Introducing the operational plan of the discipline in the first class in more detail than in face-to-face classes: this plan needs to detail all the content that will be worked on and when and how the students will be evaluated. Thus, the students get a better view of the path that will be followed since the beginning of the course. Preferably, the links for the recorded video lessons should already be available in the plan, associated with each lesson.
- Organizing and presenting the classes in a logical sequence regarding the content to be delivered. The qualification to use the CAD system should be the course's starting point. Then, contents that improve the student's capacity for spatial visualization should be developed. Finally, we work with drawings intended for the application of standards and project development.
- Making available extra-class hours for students: besides helping students who have had their routines disrupted by the pandemic, these hours allow greater student engagement, increasing their satisfaction [3].
- Quickly answering students' questions: by giving a prompt response to questions, the timing of the student's learning process is not disrupted. We chose to create rooms for solving individual doubts within the virtual learning environment to facilitate the process of exposing the problem, mainly to assist cases of introverted students.
- Providing a greater number of exercises with answers: it was noticed that there are students who ask for exercises and their respective answers to practice outside the class. This contributes to their learning process. In the remote format, there was a greater demand for these types of exercises by

students.

- Recording all synchronous classes: in times of pandemic, it is important to know that there will be students who will not be able to attend synchronous classes due to routine issues. Making the recordings available helps students to review the contents and make their study schedules more flexible.
- Using technological resources that allow remote access to the student's computer: these resources are essential to enable a humanized professor-student service and approach (Figure 1). However, their use should consider the Internet connection service of the professor and the student and their computers.

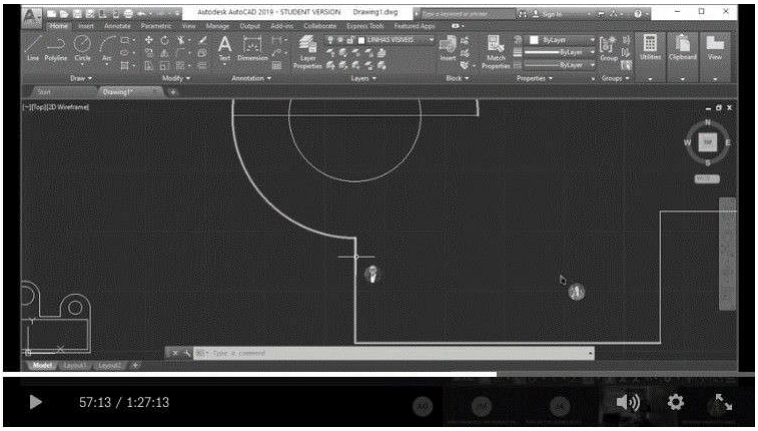

Figure 1. Remote access to a student's computer

3.4 Course Assessment

The first academic semester of 2020 officially ended on December 2, 2020. In the last two weeks of the semester, the authors of this paper invited their students to answer an anonymous questionnaire regarding the teaching practices employed. The students' preference by class type at the end of the semester during which the pandemic occurred was distributed as follows: 60% prefer remote classes, 32% hybrid classes, and 8% in-person classes. Some students have pointed out that the way in which the course is conducted enables it to be carried out completely remotely. One of the students said the following: "I really liked the discipline, it was very didactic, and I don't see the need for this class to be completely face-to-face, the tests must be in person, but the content of the discipline can totally be presented online." Regarding the difficulty of participating in synchronous classes, 60% of the students stated they had trouble attending some classes. From those, 45% informed that they preferred to watch the recorded class videos at other times; 32% had other activities in their routine to perform; 18% emphasized that the videos were enough to provide understanding and that there was no need to attend the synchronous classes; and 5% of the students started internship during the times of the classes.

Although 22% of the students did not have difficulty with the classes, 43% of the respondents listed their study and work routines as the main difficulties (Figure 2). During the synchronous class period, the students' main difficulties were related to their study and work routines. [12] states that one way to deal with routine issues is to provide the most appropriate class format in a flexible manner, according to the student's specific times. Thus, students can transition from a completely online model to a hybrid model at their convenience.

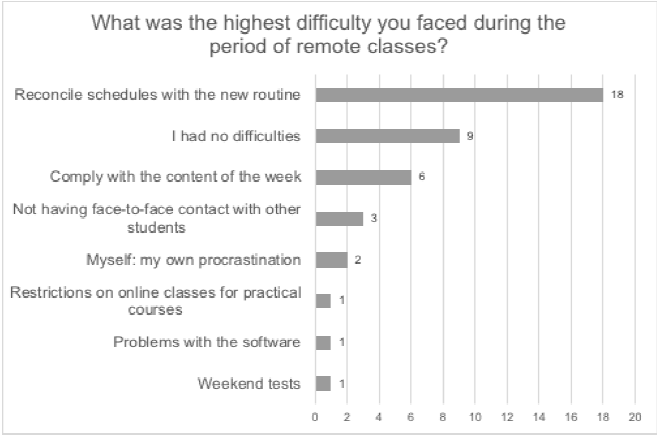

Figure 2. Main difficulties faced by students in remote classes

The students' evaluation showed that most of the practices adopted were successful. On a scale of 1 to 4, with 1 being "I totally agree" and 4, "I totally disagree," Table 1 presents an average of the students' responses. However, the partial disagreement with the high number of weekly assignments (analysis topic number 6) should be noted. The answer may be justified by the students' difficulty in managing their study time and due to changes in their routine – the main difficulties found by the studied group.

Table 1. Evaluation of practices adopted by students

Analysis Topic	Average Mark
1. Classes were organized and presented a logical sequence.	1.10
2. I knew in advance what would be covered in each class.	1.40
3. The course schedule was detailed with the theoretical subject and practical exercises and it was accomplished.	1.13
4. The videos of the classes were made available in advance.	1.18
5. I missed exercises to practice.	3.63
6. There was a large volume of assignments.	3.00
7. The tests were compatible with the subjects covered.	1.28
8. The professor used innovative resources to hold students' attention.	1.20
9. The professor, when asked, solved the students' doubts.	1.08
10. The professor was accessible to students during class hours and outside class hours.	1.15
11. The professor related the discipline of DTII with professional practice.	1.53

4 CLOSING REMARKS

The practices adopted in the discipline were followed in full. The analysis of the applied questionnaire allowed us to identify that its implementation was successful. In addition to the practices adopted, it should be noted that professors tried to deal with the adaptation of remote teaching with effort and enthusiasm, corroborating what was stated in [3]. One cannot face something new without research and preparation for the new context. The four-month period for understanding the problem, learning new technological resources, and studying the new legislation in force were essential for successfully adapting the technical design discipline to the remote format. Other initiatives have proved promising. In one of the studied classes, the "Who Wants to Be a Millionaire in Technical Drawing?" dynamic was used, with questions and answers, suspense music, and an award called "Prestige." Whoever got the answer right won a Prestige award, which gave the student power to increase his/her mark on the subject at the end of the semester. Another important point was the availability of 3D pieces to support the exercises according to the students' feedback. The course assessment showed a strong engagement of

the students and the professor in the activity, corroborating what was explained in [13]. The professors, however, had their workload increased to offer extra-class assistance to the students.
The experience allowed students and professors to demystify the use of new technologies that make the teaching-learning process more attractive, in line with the research by [14]. The process adapting and implementing remote teaching for technical design has changed the idea that it is not possible to deal with a subject of this nature online. The group of professors of the discipline elaborated a plan to offer it both in person and in hybrid format with in-person tests after the pandemic.

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ADAPTATIONS OF DESIGN PROJECT MANAGEMENT EDUCATION IN THE PANDEMIC

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ABSTRACT
The efficiency of project management processes is strongly related to the way in which the manager and team build, organize, plan, and control the project. Project management processes become even more important when, in one-of-a-kind projects, there are no reports or historical data available on the application of certain work procedures by the company. In this regard, frequent testing and learning of new routines emerge as essential elements to be considered for planning and control of a project.
This paper explores the experience of adapting projects of an undergraduate program in design, whose classes were taught using only a remote learning approach during the pandemic. The data analysed in the study refer to observations on the students' modus operandi recorded in field notes by the authors of this paper, who oversaw the course; the students' answers to an interview on the use of tools and practices in project management during the pandemic; analysis of discipline management documents, i.e., a detailed and controlled project timeline and weekly task assignment plan.
The study showed that student performance did not differ between the remote and the on-site modes. The biggest challenges were found in the prototyping and game testing stages. However, these challenges were partly minimized by utilizing online collaborative work platforms, adopted exclusively for such activities.

Keywords: Project management, design, pandemic, adaptations

1 INTRODUCTION

The existence of reliable historical data that can be used to support design of management processes in new projects contributed to attaining delivery and cost goals. Nevertheless, the experience and routine of team members involved in new projects often impact results [3]. This occurs more significantly in situations in which the people involved in the project possess little knowledge of management processes [4] [5] or, in addition, in contexts of greater uncertainty.
This article describes the experience of its authors regarding adaptation, during the pandemic, of process management areas for students of a design course, with emphasis on product and graphic design. The data analysed in the study refers to observations on the students' modus operandi recorded in field notes by the authors of this paper, the students' answers to an interview on the use of tools and practices in project management during the pandemic, and analysis of discipline management documents, i.e., a detailed and controlled project timeline and weekly task assignment plans.
The study showed that the course chosen for the Emergency Remote Teaching (E.R.T.) mode was able to maintain the same performance standard of classes taught completely on-site. For the Emergency Remote Teaching mode, we utilized the definition of [7], which refers to the context of teaching the classes with asynchronous and synchronous content, without on-site meetings.

2 CONTEXT OF PROJECT MANAGEMENT DESIGN COURSE

In the study course, the classes are geared towards project development, according to the learning by doing approach [8]. To this end, the course was gamified. In this proposal, the professors personify the role of CEOs of a design company and inform the students that they are their employees. Next, they divide the group into teams consisting of students specialized in product design and graphic design. Shortly afterwards, they inform them that a large game development company has contracted a new project and the teams have been tasked with developing a board game that can be played within an hour, including reading the instructions. The teams should deliver a high-fidelity prototype of the game at the

end of the semester. While the board games are developed, the professors teach the students how to manage their projects.
In the in on-site context, the classes take place with the support of the Moodle platform, on which the essential course documents are made available: lesson plans, standards of deliverables of management and board game documents; bibliography; project management file archives from previous semesters; professors' feedback on presentations, documents delivered by students and conceptual spreadsheets. At the end of the semester, the students' high-fidelity prototypes are tested by other students and professors.
Owing to restrictions imposed by the pandemic, the professors had to adjust the course to the Emergency Remote Teaching (E.R.T) mode, as advised by the university's lawyers. This adaptation was based on previously recorded theoretical content, taught in asynchronous form, made available on Moodle links, and on synchronous online classes, utilizing the flipped classroom approach [9]. Furthermore, the strategy was implemented to adapt the students' learning process to their new work routines. Microsoft Teams, made available by the university, was used to teach, and record the synchronous classes. Moodle continued to be used as a central element in the course, but with an extra amount of information in comparison to the completely on-site context. This information consisted of hyperlinks to the asynchronous theoretical classes and the 'dear diary' area, whose purpose is to register the progress of the asynchronous classes. The goal of the 'dear diary' area is to resume quick entries that might be a source of reference for professors and students throughout the class.
In this context, new challenges were posed by the physical prototypes since the students should be able to handle the pieces of the project [10]. Furthermore, the members of the teams need to be in regular contact with each other and observe ways to streamline the mechanic, the dynamic, and the aesthetic components of the game [11].

3 RESEARCH METHOD

This research is qualitative descriptive, based on the collection of several data sources. The data are relative to the 2019-2 semesters (on-site classes) and 2020-1 (remote classes). Table 1 shows the total number of students per semester.

Table 1. Number of students per semester

Semester	Mode	Students
2019-2	On-site	26
2020-1	Remote	29

The documentary data were extracted from previous assignments delivered by students and audited by the professors. Auditing took place to guarantee that the analysis indicators were correctly collected, and calculation procedures were double checked to reduce the error rate. The following data were analysed:

- Student progress: final class grades, project management grades and design team member grades. Notably, the manager and team member are assigned grades by the students in the class at the end of the semester.
- Percent Plan Complete (PPC): this indicator is related to the efficiency of the short-term plan utilized by students in the course and follows the theoretical basis of the Last Planner System [12]. The PPC average was calculated based on the data collected by all the weekly plans used by the students.
- PPC variation coefficient: this indicator was used to check for possible differences in PPC variability between on-site and remotely taught semesters. Variability analysis is important, as it is a consequence of interruptions in the workflow [13]. Thus, differences in the variation coefficient can indicate the existence of further workflow interruptions from one semester to another.
- Average weekly hours per work group: aimed to measure the team effort throughout the project, with the intent of checking for possible differences between on-site and remotely taught semesters. Hours were logged by the students, over the course of the two academic semesters, on the MS Excel spreadsheets made available by the professors.
- Problems that caused the lack of completion of weekly work goals: for this variable, the problems collected in the master's dissertation of [14] were used and were based on course data from on-site

semesters. The data from 2020-1 was identified in the weekly teamwork plans and recorded by the authors of this study.

- Data originating from interviews with remotely taught semester students: the purpose was to detect the major difficulties faced by remotely taught students, as well as enable them to make suggestions for improvements in future semesters.

4 PROBLEMS FACED IN THE ADAPTATION OF THE COURSE

Prototyping and testing of the game were the major difficulties faced by the students in the remotely taught semester, owing to the lack of on-site work meetings. Because on-site meetings could not be held, the physical board game development project became more challenging, although not unfeasible.

Although on-site meetings could not take place for game testing purposes, some teams attempted to resolve the problem by making low-fidelity physical prototypes available to all team members. Despite the limitations, the initial tests took place via remote meetings. Some students, who lived with their parents, asked them to participate in the play tests.

Since it was difficult to carry out on-site playability testing, one student noted that their team used the Miro® platform to simulate the execution of the card game being developed (Figure 1). In this case, one of the team members knew all the players' cards so that he or she could distribute them from a stack of cards that had been placed face-down. This student also undertook the role of an observer, while the other players tested the manual and the other pieces of the game. The observing student did not participate in the play test.

The alternative presented to test the prototype, although only virtually, is one of the possibilities of implementing course adaptations. This is corroborated by [15], p. 39: 'If the lack of prototyping resources prevents completion and delivery of the final prototype, we may need to be flexible and modify the scope of individual projects and course deliverables (such as the final prototype) to accept what teams are able to deliver at the end of the semester with the alternate resources to which they may have access.'

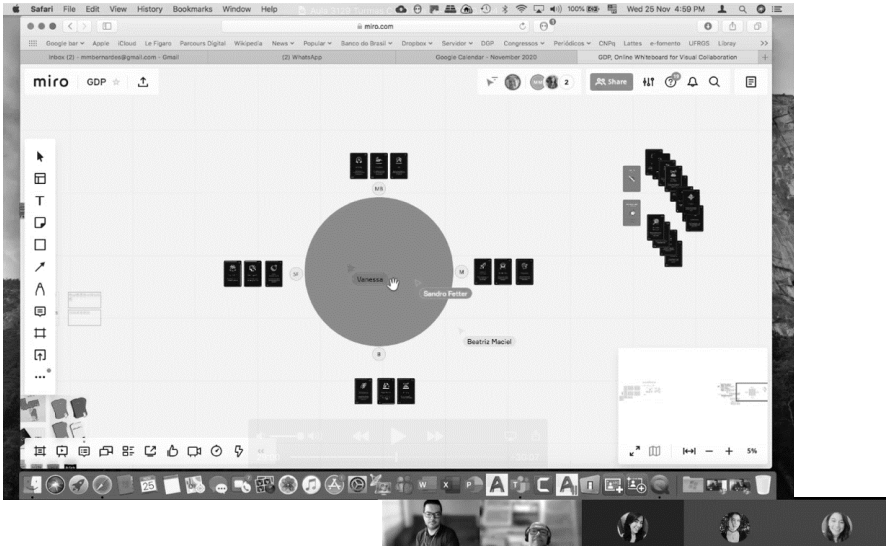

Figure 1. Remote card game testing

Table 2 shows a perceptual comparison amongst the most frequent problems recorded by the students in their weekly work plans. The problems in the Table are listed in decreasing order to facilitate comparisons with the remotely taught semester.

Table 2. Problems detected in on-site and remotely taught environments.

Problem	On-site	Remote
Difficulties in estimating task duration	32.31%	13.79%
Unexpected personal events	23.08%	44.83%
Overload of projects developed in tandem	10.77%	27.59%
Communication noise	10.77%	3.45%
Lack of technical knowledge of software or materials	10.77%	6.90%
Inertia in decision-making	6.15%	3.45%
Lack of commitment amongst team members	3.08%	0.00%
Neglected phases	3.08%	0.00%

In the context of the course, as shown in Table 2, the biggest challenge in the on-site mode was to estimate design task duration. However, in the remotely taught semester, the occurrence of unexpected personal events stood out. An in-depth analysis should be made of these data. At first, one can presume that in the switch from on-site to remote learning, in the case of adopting new routines, the project is more impacted by unexpected personal events than by management issues. In this manner, to deal with unexpected personal events, the data from this research prompts the search and use of technological resources that are adjustable to the teaching and learning modes of the students within this new context. It is also worth noting that, for the present study, regardless of either the on-site or remotely taught modes, there is always a lack of commitment of one or more members of the teams during project completion. This was detected during the interviews. Importantly, the lack of commitment is a type of problem that should be recorded when there is no other reason to justify the late delivery itself. This is also corroborated by the answers to anonymous evaluations of the managers and designers, completed by the students at the end of the course. However, the students are reluctant to formally report this issue to their professors because they wish to avoid conflict amongst their peers. This explains the lack of documentation around this issue at the end of the course. For this reason, it can be concluded that this issue should be clarified and worked through at the beginning of the course, with the intent of improving the ability of students to deal with conflict resolution in the real world, whether using the on-site or the remotely taught approach. If the student experienced unexpected personal events, such as health problems, they should submit a doctor's note to justify their absence. Nevertheless, transparent work should be the goal. If a student does not have the ability to keep up with the workload, it is recommended that they negotiate with the project manager to reduce the workload over a couple of weeks. However, they should inform the project manager when they will increase their workload for compensation. This practice is discussed in the theorical classes of the project management course throughout the semester, but it is hardly put into practice by the students in both on-site and remotely taught modes.

For student performance data analysis, Table 3 shows the comparative results between the averages of both modes (on-site and remotely taught), assuming equivalent variations. Student grades vary on a scale of 0 to 10. No significant differences were found amongst the averages. This is an indicator that student performance was not affected by the change in teaching approach (on-site versus remotely taught).

According to one of the students participating in the remotely taught mode, there were advantages to studying remotely. One of them is the possibility of watching the theoretical class beforehand, which helped the team members to do their assignments.

Considering the lack of significant differences in team member performance between the on-site and remotely taught semesters, certain data from Table 3 need to be deeply discussed by way of comparison of the adopted teaching modes. It can be noted that the standard deviation of the average weekly hours worked in the remotely taught semester was higher than that of the on-site semester. In the remotely taught semester, there was a variation of 17.55 to 39.95 hours of weekly work between teams. In the on-site semester, this variation ranged between 27.2 and 37.57 hours.

Table 3. T-test (95% confidence interval of the difference)

Analysed variable	2019-1	2020-1	t	p (two-tailed)
Designer's average grade	8.70	9.28	2.0048	0.1371
Standard deviation	1.5109	1.4105		
Manager's average grade	8.92	9.36	2.0048	0.1865
Standard deviation	1.0903	1.3571		
Student's final grade	8.94	9.31	2.0180	0.1149
Standard deviation	0.5528	1.0794		
Average weekly hours	32.38	28.55	2.4469	0.5639
Standard deviation	5.1869	11.4018		
Average PPC	89.7%	92.6%	2.4469	0.6153
Standard deviation	9.8%	4.4%		
PPC variation coefficient	14.93%	11.92%	2.4469	0.5048
Standard deviation	7.12%	4.61%		

Upon analysing the data on hours worked together with the problems faced by the students in both semesters (Table 2), it can be assumed that, during the adaptation, the effort made by some teams might have been affected by unexpected personal events. The analysis of the evidence extracted by monitoring the assignments and the interviews with students, showed that the unexpected events did impact students' efforts. The parents of one of the team members contracted Covid- 19. The student had to help his siblings take care of his parents. This situation impacted the delivery of group assignments, even though the team decided to reduce the scope and complexity of their ongoing project. It is worth noting that the course professors offered special assistance to the team to help them reach their goals. However, the students on the team had not asked for this type of assistance.

5 FINAL CONSIDERATIONS

Even without significant differences between student performance across on-site and remotely taught semesters, the findings of this study offer insights for the development of research oriented towards new forms of virtual prototyping and online game board testing. It can be affirmed that these were the most conflict points in carrying out the course via remote learning. Therefore, it can be assumed that, while there is a lack of technological tools that can simulate a testing environment similar to that of on-site modes, the reduction in complexity of the product being developed becomes essential for the application of the learning by doing approach within the context of remote learning. In the project management for the design course, the Covid-19 pandemic posed novel challenges and the professors could observe and analyse how the students can, in fact, apply skills to overcome obstacles regarding the lack of on-site contact amongst team members as the project develops.

Importantly, it is noteworthy that the study shows us the need to help students develop skills to deal with unexpected personal events in a more practical and meaningful manner. They should know what to do to correct deviations resulting from these events because they are usually beyond one's control. During their education, design students should practice the process of analysis and decision regarding these types of events, so that they can be better prepared for real situations in the job market. Notably, during the pandemic, the relative frequency of these problems has doubled. Although these events occur both in the face-to-face and in the remote modes, the increased frequency of the problem in the remote mode indicates that a risk response plan - more particularly focused on these types of problems - needs to be detailed and developed with the students since the beginning of the semester. This way, the implementation of a strategy to prepare students to make decisions in uncertain situations, becomes even more challenging, because some of these events are sometimes related to one's emotional state. Thus, developing and addressing the human factor in the course is essential for adapting education for management of design projects in times of pandemic. In these terms, a teaching approach that privileges only the results of numerical indicators and the final quality of the project, without considering people's difficulties, desires, and needs, can impact the education of design students in the management area. This poses an important challenge, in future academic semesters, for the course discussed in this article.

Other issues occurring in the remotely taught mode took place in the on-site mode as well. This indicates professors need to provide students with appropriate instruction to better prepare them for the real world. It is worth noting that the purpose of universities, especially as regards design courses, is to offer the most productive teaching methods [16]. If we search for design solutions to the problems that affect us, we can explore new educational opportunities that allow us to perform well in adverse situations.

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SOFT SKILLS IN DESIGN EDUCATION, IDENTIFICATION, CLASSIFICATION AND RELATIONS: PROPOSAL OF A CONCEPTUAL MAP

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ABSTRACT
The article brings a conceptual map of soft skills in design education. This study is quantitative and qualitative research which was carried out through a survey with open and closed questions that involved 93 teachers of Superior Design Courses in 26 countries. The survey results were combined with a literature review analysis aimed at defining constructs and identifying their relationships. Finally, we propose a classification for soft skills as Collective/Individual and Cognitive-Metacognitive/Interpersonal-Social. Additionally, we created a concept map about the soft skills in Design Education, showing the classification and the relations between the skills. In our research, we identify some relations that show gateways skills and high order skills as well as the relations between different groups of skills.

Keywords: Soft skills, design education, 21st Century skills, higher education

1 INTRODUCTION

Soft skills are interpersonal, social, and emotional skills. They are transversal to various fields of knowledge and life and are also referred continuously as differentiators in the contemporary context [1], [2]. They are often related to the ability to work in groups, to thinking systematically, to collaborate, to develop self-regulation and socio-emotional skills.
We based this study on the results of a systematic review of literature carried out previously [3]. In this review, we analysed the soft skills linked to design studies that resulted in the identification of 49 skills, from which we point out the 17 most cited skills and added three skills identified by the OECD [4] as necessary to face the challenges of the 21st Century.
The soft skills included in the study are presented in Table 1.

Table 1. Soft Skills included in this study

Communication: to understand and make oneself understood through exchanges of messages; [13]
Critical Thinking: To reason well, to construct and evaluate various arguments, data, reasons, and inferences. [14]
Creativity: To go beyond what exists today and to generate and implement new ideas. [15]
Problem Solving: To overcome obstacles and move from an initial state to a target state. [16]
Curiosity: The desire to learn or know about everything; Ability to be inquisitive. [17]
Research and Exploration: Multifaceted competence which allows to know objective reality through scientific instruments, and to have reliable information about it. [18]
Decision Making: To follow normative principles when making decisions. [19]
Open-Mindedness: To be receptive to emerging possibilities, to share ideas and to consider different perspectives. [20]
Systematic Thinking: The ability to observe, think, model, simulate, analyse, design, and synthesise components, functions, connections, structures, inter-relationships and dynamics between disciplines, functions, organisations, people, trends, and cultures.[9]
Empathy: Ability to take on the role of the other person and imagine the situation from their perspective.[21]
Collaboration The ability to participate in a process of shared creation. [22]

Participation: Ability to participate in or be involved in something [23]
Flexibility/Adaptability: The ability to produce thoughts from different perspectives or to change approaches to problem solving. [24]
Learn to Learn: Ability to pursue and persist learning, to organise one's own learning. [25]
Team-working: The ability to work together, communicate effectively, anticipate, and meet each other's demands, and inspire confidence, resulting in coordinated collective action. [26]
Self-direction/ Self-management: Ability to regulate your emotions, thoughts, and behaviour effectively in different situations. [27]
Ethic/Compromise: The ability and willingness to be moral, to consider the needs, goals, and perspectives of others in their own decisions. [28]
Judgement: The ability to form valuable opinions and make good decisions [29]
Leadership: Ability to exert influence on others through behaviour or action. [30]
Entrepreneurship: The ability to create new businesses, products, services, values and/or a state of mind that thrives on innovations with the potential to improve the lives of many people/customers.[31]

This research aimed to understand the perception of design teachers about the importance of Soft Skills in Design, measuring the importance and weight that each one attributes to each of the proposed skills. We also carried out a survey on the methods that professors use to teach these skills and classified them. With the results we created a conceptual map about Soft skills in the Design Education that brings a classification as well as a visualisation of their relations.

2 METHODS

This is a mixed methods research – quantitative and qualitative. It has been developed through a literature review combined with the application of a questionnaire survey.

The survey was mainly composed of close-ended questions of scale, where the design teachers were asked to assess the level of contribution of each skill to the teaching subjects in the design course. These questions used the Likert scale and asked teachers to assess the level of importance of the skills for the subjects they taught, indicating 1 for not contributing, 2 for contributing little, 3 for contributing sometimes, 4 for contributing and 5 for contributing a lot. The last part of the questionary asked if the teachers used any methodological practices that they felt enable opportunities for teaching soft skills and if so, the teacher was asked to describe the practice. In this last question, the answers were open. The sample was non-probabilistic and was composed of professors who work in higher education courses of Design.

3 RESULTS

93 responses of 26 countries were received. The countries that were most cited were Brazil and Portugal representing 49% of the sample.

The question that sought the evaluation of the average ranking of soft skills asked teachers to estimate the contribution of each of the skills to the subjects they taught. From the statistical analysis done with the SPSS software, the closer the Mean is to 5, the higher the evaluation of the attribute. (showed in Table 2)

Table 2. Ranking of Contributions of Soft Skills in Design Education.

	N	Min.	Max.	Mean	SD	Variance
Communication Skills	93	2	5	4.66	.667	.446
Critical thinking	93	2	5	4.65	.702	.492
Research and exploration	93	2	5	4.58	.727	.529
Creativity	93	2	5	4.54	.760	.577
Problem Solving	93	1	5	4.52	.816	.665
Curiosity	93	1	5	4.43	.914	.835
Decision Making	93	1	5	4.39	.794	.631
Open-mindedness	93	2	5	4.32	.810	.656
Systemic thinking	93	2	5	4.29	.879	.773
Empathy	93	1	5	4.28	.982	.964

Participation	93	2	5	4.26	.793	.628
Flexibility/adaptability	93	2	5	4.26	.779	.607
Collaboration	93	1	5	4.25	.928	.862
Learn to learn	93	1	5	4.18	1.042	1.086
Teamwork	93	1	5	4.15	.966	.934
Self-direction/ Self-management	93	2	5	4.05	.889	.791
Ethic/compromise	93	1	5	4.02	.944	.891
Judgement	93	1	5	3.69	1.063	1.130
Leadership	93	1	5	3.52	1.028	1.057
Entrepreneurship	92	1	5	3.27	1.178	1.387
Valid N (listwise)	92					

4 DISCUSSION

The research results show that teachers ranked the soft skills with high rates for the design practice. Among the 20 skills, none received an average ranking lower than 3. Only three skills received an average rating lower than 4 (Judging, Leadership and Entrepreneurship).

Concerning skills that emerge as significant contributors to design courses, there is the prevalence of cognitive and individual skills (in detriment of social and collective ones). Critical Thinking, Creativity, Problem Solving and Curiosity appear between second and fifth place. In the first place, Communication skills seem to be unanimous, as it also came first in the previous systematic review. Despite this, we identified an inconsistency in the teachers' discourse regarding the Team-working competence, which appeared in the average ranking in 15th place, but emerged in second place in the subjective answers.

The teaching practices identified by teachers as enabling the development of soft skills point to constructivist-based pedagogies, student-centred and active methodologies. In order to improve the systematisation of knowledge about soft skills, we propose a classification of competences. This classification was created from the establishment of 2 sets: Skills that are performed mostly collectively versus skills performed mostly individually; we call this set Collective\ Individual. The other classification was Cognitive/Metacognitive skills and Interpersonal/Social skills. In both groups, we also identified the need to create two sub-groups: The Gateway Competences group and the High-order Competences group. The first group is composed of prior, initial skills which are necessary for the development of more elaborate, complex skills.

Based on these four types of classification, we have proposed the construction of a conceptual map, intending to clarify the sets, as well as the relationships identified between the skills in a visual way.

4.1 Relations between skills

The literature review carried out revealed an interconnection between the competencies. By analysing the definitions, it was possible to establish links and interconnect them. The first link that can be indicated results from the definitions of Curiosity, Research and Exploration, Judgment, Decision Making, Open-Mindedness, Creativity, Flexibility, Systematic Thinking and Critical Thinking. Some authors demonstrate the sequential and conditional character of some of these competencies. [5] [6]. It is possible to establish sets and, from those sets, to realise that for the development of the competence of Critical Thinking, it is essential to have previously developed the other competencies mentioned above. In this argumentative direction, we defend that Critical Thinking is a more complex competence and needs the development of other skills, because the development of Critical Thinking occurs or is made possible by the development of previous skills. Critical Thinking enjoys a prominent status in contemporary educational goals and ideals and is considered a fundamental model and underlying objective of Western education [7]. This can explain why this competence has been widely mentioned by educators, as well as the previous or related competences. Critical Thinking has also a direct relationship with Creativity and is a necessary competence for Creativity to be realised [7].

It is possible to establish the relationships between Flexibility, a necessary competence for Creativity, Curiosity, and Open-Mindedness (OM), the latter one is a timely and valuable competence for divergent thinking. From Socrates to contemporary education theorists, OM competence is considered essential for learning [8]. More recent researchers argue that OM is critical to assessing the mental models of individuals, which are deeply held beliefs or conceptions that can confine them to familiar patterns of thinking and acting.

It is also possible to create the relationship between Systematic Thinking, Creativity, and Problem Solving, bearing in mind that systematic thinking is ultimately aimed at understanding problems. Systemic thinking draws from diverse disciplines to provide a holistic method for dealing with problems in any discipline. It is scientifically grounded in systems theory and a wide variety of transdisciplinary supporting principles providing a discipline-agnostic approach to address messes [9].
The competence of Research and Exploration is also preceded by the competence of Curiosity, so they are "Gateway Competencies"[10], i.e., introductory competences that induces others. Exploration and research, for example, derive from Curiosity [11]. The competence of research and the capacity to explore also seem to have this characteristic to lead to other competencies, such as Trial, Decision Making and Critical Thinking. It is not easy to separate these competencies objectively because they seem to be deeply intertwined one to the other.
The relationship between Ethics and Critical Thinking can also be established if we think that the construction of ethical thinking involves the cultivation of rational thinking since the competence of Ethics is realised as a construction of a critically reflexive morality [12].
Abut the cognitive self-regulatory skills, Learning to Learn and Self-Management skills are also related. Self-Management contains the Learning to Learn competence. Both benefit from Critical Thinking, which is a necessity for the development of Self-regulatory competence.
The competences that we call Social/Interpersonal also maintain relationships both with each other and with cognitive competences. The need for Critical Thinking and Ethics is unquestionable as "background" competencies for the optimal development of Communication, Empathy, Team-Working, Leadership, Entrepreneurship, Participation and Collaboration skills.
In this sense, it is possible to establish connections between Communication, Empathy, Collaboration, Participation and Team Working Skills. The ability to communicate well and develop listening skills can enhance Empathy skills. Consequently, being more empathetic makes it possible to be more inclined to the processes of collaboration and participation. Being able to communicate, listen, empathise, and collaborate allows to perform well in group work.
Finally, the skills that were assessed as less critical for Design were Leadership and Entrepreneurship. These skills also benefit from the above-mentioned competencies. It is expected that in the scope of Contemporary Design, which has a more collaborative character, leadership is a competence that has been assessed as less critical since the characteristic of collaboration is to be more horizontal and less hierarchical. Entrepreneurship also benefits from the competences, and a designer with this type of competence can act not only in his own business but also creating value, products, and services for society in a broad sense. This happens either through private business or through public services and social value, not driven by profit. It is likely that the very definition present in the common sense of these competencies influenced this result. Although they came in last place, the average rating of both was high at 3.54 and 3.46 respectively (out of a total of 5) which indicates an agreement on the contribution of these competencies to design of 70%.
Based on these reflections from the literature review, a conceptual map (Figure 1) was created as a way to understand the sets discussed here as well as some of their main visual relationships.

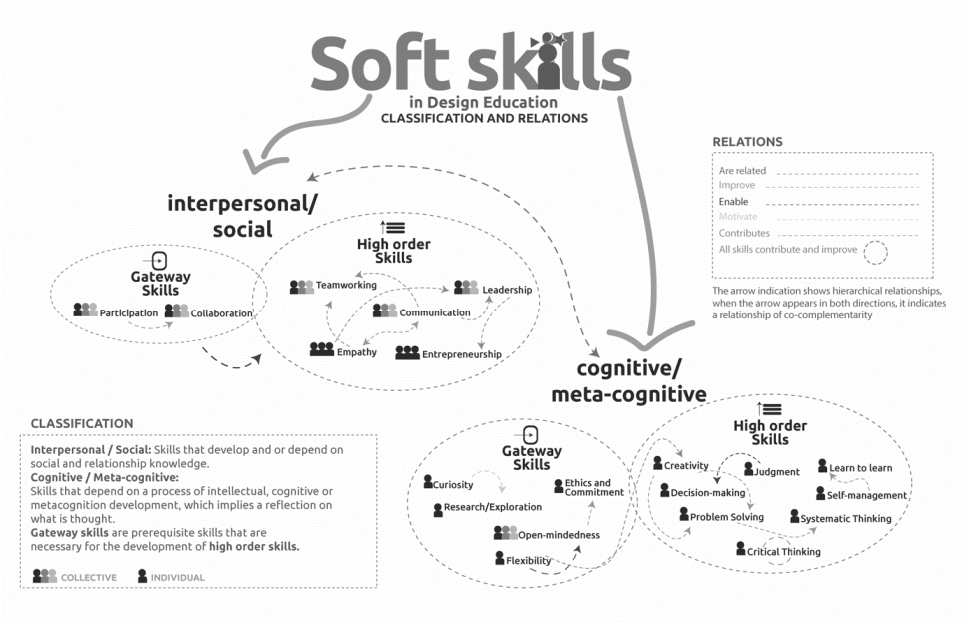

Figure 1. Concept Map: Soft Skills in Design Education

5 CONCLUSIONS

This research showed that the 20 soft skills identified in the systematic review have a high rate of importance for teachers in the areas where they work in Design. It was conceivable to determine the relationship and interconnection between the soft skills and to suggest, from the literature review and through the analysis of subjective responses, an interdependence between them.

The proposed classification, as well as the definition of the constructs projected in this article, may make it easier for teachers and students to identify the main soft skills in design education. It is possible to recognise which soft skills should be enhanced as initial skills in order to develop high-performance skills. This classification can be the initial way to indicate which methods can be applied and how to evaluate these skills according to the student's level of formation.

We are likely to develop strategies for teaching and to learn the gateways skills in the initial years, through the development of activities that can involve the students gradually and that increasingly require more skills in order to make them "scale-up" the soft skills of the conceptual map.

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HOW REMOTE/DISTANCE CLASS INSTRUCTION WHEN WORKING WITH INDUSTRY/INSTITUTIONAL PROJECT SPONSORS ON A STUDIO PROJECT CAN BE MANAGED TO PROVIDE A ROBUST EDUCATIONAL EXPERIENCE

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ABSTRACT
This paper will examine how remote communication tools such as "*BlueJeans*" or *Microsoft* "*Teams*" can be employed in a studio project to enhance the undergraduate educational experience in the context of remote class instruction.
Junior level students in the *School of Industrial Design* at the *Georgia Institute of Technology* take specific themed studio courses, one of which is "Health and Well Being" which is being taught in a "hybrid" delivery mode in response to COVID related concerns. Recognizing that remote instruction could compromise learning opportunities, the course was organized to follow a model used professionally by this author when managing multiple team projects as a design director.
Three projects championed by outside sponsors included (1) the design of paramedic equipment transport solutions; (2) systems to reduce the acuity of *Nexxspan* medical headwalls in behaviour health or end-of-life scenarios; (3) and development of a system for arterial dialysis. Sponsors included a former fireman/paramedic/alumni, a commercial company that offers a range of hospital equipment management products and a transplant surgeon with the *School of Medicine* at the *University of South Carolina.*
Sponsors pitched the projects to the students at the outset of the semester. Students formed teams of 3-4 students based on their affinity to individual projects; 5 teams being fielded out of a class of 20 students. Teams initially met in person or remotely with their project sponsors to better understand their chosen projects. Users and/or subject matter experts were interviewed remotely during the research process. Remote sessions were held twice weekly with each team to review progress and provide feedback/advice. Each team presented their work to sponsors and the class as a whole at three points during the semester using the *BlueJeans* application to summarize research, concept development and concept refinement/documentation.
In comparison with comparable projects conducted during previous semesters, it was observed that the option to participate remotely permitted outside sponsors to be MORE available to students with transportation and parking no longer being an impediment. Furthermore, by scheduling focused feedback/input to individual teams via a remote application, the effectiveness and efficiency of the instruction process was optimized for both the students and instructor. The drawbacks of this remote instruction relate more to issues of poor team dynamics or individual students lacking key design skills (which might be better addressed in person). Additionally, it has been observed that students not meeting face-face in studio limits peer-peer competition which decreases individual motivation for improvement in problematic students.

Keywords: Industrial design education, studio project, hybrid mode instruction, BlueJeans teleconferencing, health and well being

1 INTRODUCTION

Due to the COVID pandemic, the instruction delivery mode for many Industrial Design studio courses within the *School of Industrial Design* at *Georgia Tech* were necessarily modified to a remote or hybrid instruction format. In the case of the *ID 3031 Health Design Studio* offered during the Fall 2020

semester, instruction was modified to a primarily remote delivery format. (Such studio courses have historically been dependent on "in-person" instruction and "peer-peer" learning to help provide the "studio experience").

This author's approach to studio instruction for upper-level courses has been to coordinate projects with outside sponsors to provide students with the opportunity to work alongside professionals on "real world" projects and give them experience in dealing with marketing and manufacturing concerns. Towards this purpose, several outside entities were contacted to solicit projects for student engagement. 3 projects were identified including (1) the design of systems to reconfigure the acuity level of medical headwalls within "End of Life" (EOL) or "Behavioural Health" (BH) scenarios for a local medical equipment manufacturer; (2) the design of a storage and transport system for assisting EMT/Paramedics with moving lifesaving equipment to a patient's location during medical emergencies; (3) the design of an arterial-based dialysis solution proposed by a transplant surgeon from a regional medical school.

These projects were pitched to the students early in the semester through a series of online sessions. Students formed teams of 3-4 based on project affinity and individual student skills and interests. Virtual meetings were set up with each team during each class period throughout the semester to check on progress and advise. Students were able to set up virtual interviews with project sponsors to address questions/concerns or to get feedback on their ideas. Similar sessions permitted student teams to query subject matter experts. Formal review/presentations were scheduled at three points throughout the semester where students were able to present their research, initial design concepts and final designs to the class and project sponsors via screen sharing.

2 BACKGROUND

With the onset of COVID-19, extensive use of remote learning was suddenly required for health and safety. It accelerated the need to implement remote and blended strategies for delivering studio instruction. Design instruction is traditionally studio based where students investigate and solve open ended problems with one-on-one instruction. It is a peer learning environment with immediate feedback. It can be difficult to incorporate new technologies to enable online teaching while replicating this environment. While online instruction provides flexibility, disadvantages include reduced interaction, new obstacles to group work and lack of real time feedback during problem solving [1]. Previous work has shown that effective online/blended studio classes should include opportunities to receive instant peer feedback, ability to track progress, ability for in-context feedback and ability to annotate designs [2].

Effective methods of delivering studio instruction can also be helpful in reducing the gap between learning and practice. The role of a designer is continually updating with remote collaborative tools being increasingly employed [3]. A way to bring this into the classroom is to employ realistic projects with budgets and time constraints to give students a chance to remotely problem solve with peers, instructors, and industry partners [4]. At the same time instructors must re-evaluate how students are assessed. Evidence indicates that some behaviour typically considered as passive, such as viewing other students' work show equal or stronger correlation to student success compared to behaviours traditionally considered as active [5].

This paper presents observations of virtual learning implemented in a design studio class, how it was able to provide more opportunities for project sponsors to interact with students, and how abbreviated team meetings can provide a mechanism for effective and efficient instruction for students.

3 METHOD

Three sponsored projects were pitched to the students through a series of online sessions. Students formed teams of 3-4 based on their enthusiasm for a particular project and individual student skills and interests. Each project sponsor provided detail on key project stakeholders, existing competitive and age compensatory solutions, user demographics, key "pinch points" and design opportunities. Email contacts were shared with students. Virtual meetings were set up with each team twice weekly to check on progress and advise them on where further effort might be needed. Students were able to set up virtual interviews with project sponsors to address questions/concerns or to get feedback on their ideas. Students were also able to set up interviews with subject matter experts using remote conferencing applications such as *BlueJeans* or *Microsoft Teams*. Formal review/presentations were scheduled at three points throughout the semester where students were able to present their research, design concepts and final designs to the class and project sponsors via screen sharing.

Several teams made use of idea sharing applications such as *Figma* (www.figma.com) which permitted them to share information and ideas in real-time, as well as facilitating reporting of team progress. This proved to be more effective than more traditional virtual file sharing tools such as *Google Drive.*

Teams initially presented background research in order to get buy in from project sponsors, ensuring that they adequately understood the problem, user needs and state of the art of available solutions. These presentations included infographics relating stakeholders, user personas representing significant portions of the user population, journey maps detailing how users currently address the chosen problems, matrices outlining current available solutions and how they compare against various determining parameters. Of particular interest was information regarding compensatory solutions that are currently used by users to address the problem. Similarly, students explored information regarding related technologies that might be employed in proposed solutions.

Once the problem scope had been adequately understood, using a visual ideation technique, each team produced a range of ideas in a thumbnail sketch format. Concept proposals were mapped using morphological matrices. Each team developed 3-4 concepts using a combination of analogue and digital tools. Each concept was represented in a series of images showing appearance, organizational detail, assembly detail, general scale and dimensional information and proposed use methodologies.

Consensus was solicited from fellow classmates, project sponsors and the course instructor regarding the relative merit of these initial concepts. In most instances, teams were able to proceed with refining a final direction based on feedback received in the concept review. The teams addressing the paramedic/EMT storage/transport solution required additional time to work more closely with the project sponsor to develop solutions that were deemed to be both realistic and creative. The ability to conference directly with the sponsor facilitated additional brainstorming and concept review.

Each team refined their chosen design concepts using CAD – specifically *SolidWorks* or *Fusion360*. Final concepts were represented by detailed CAD models presented in a series of static images and/or animations that detailed how the solution could be assembled, used, and operated. The industry partners were pleased with the final team results, particularly the sponsors of the Dialysis and Headwall related projects.

Table 1. Comparison and Explanation of Team Output

Team Makeup:	**General Quality of Output:**	**Possible Explanation:**
Team # 1 *(Headwall Project)* *3 Students*	*High quality output well received by Sponsor*	+ *Good team makeup* + *Effective team communications*
Team # 2 *(EMT/Paramedic Transport Project)* *4 Students*	*Mixed level output needing further development* *Not well received by Sponsor*	- *Persistent team dynamic issues* - *Skill weaknesses* - *Team stopped communicating with Sponsor, Instructor or one another* - *Sponsor was GT ID alumni who may have had higher-than-usual expectations*

Team # 3 *(EMT/Paramedic Transport Project)* *4 Students*	*Good quality output needing further development* *Well received by Sponsor*	+ *Team made extensive use of Figma to manage group effort* - *Sponsor was GT ID alumni who may have had higher-than-usual expectations* + *Effective team communications*
Team # 4 *(Headwall Project)* *3 Students*	*High quality output well received by Sponsor*	+ *Good team makeup* + *Effective team communications*
Team # 5 *(Arterial Dialysis Project)* *4 Students*	*Exceptionally high-quality output well received by Sponsor*	+ *Effective team networking with Subject Matter experts* + *Effective team communications* + *Highly skilled and motivated team leader*

4 RESULTS AND DISCUSSION

It was observed that scheduled online review/coaching sessions with each team permitted pertinent details to be shared without wasting the time of other students. Although each team was comprised of 3-4 students, the ability to interact with them individually as well as collectively to provide regular feedback and input without requiring everyone involved to be located in one place made the process less cumbersome and more efficient.

This virtual approach permitted sponsors and subject matter experts to interact with teams on a more regular basis as it did not involve the time, transportation or parking logistics normally associated with typical in-person campus collaboration. As such, outside sponsors were MORE available to the student teams than they would typically have been under normal circumstances.

Table 2. Advantages and Disadvantages associated with Virtual Interaction in Comparison with Traditional Face to Face Classroom Interaction

Comparison Criteria:	**Traditional Face to Face Interaction:**	**Virtual Sponsor Participation:**
Willingness of Sponsor or "Project Champion" to field project:	*Varies depending on sponsor and project*	+ *More likely due to reduced logistical hurdles (time/transportation/parking)* + *Sponsors can participate from anywhere* + *Reduced Time/Cost of participation* + *Involvement can be more "casual"* - *Potential for reduced sponsor "commitment" due to inherent "distance" of interaction*

Initial Project Introduction by Sponsors:	*Typically done In-Person* *+ Increased respect for sponsors by students when meeting sponsors face to face* *+ Increased respect for sponsors that may result from actual site visit to sponsoring entity*	*+ Easier due to reduced logistical Hurdles (time/transportation/parking)* *- Lack of face to face meeting may lead to less respect for sponsors by students and vice versa* *+ Students, instructors, and sponsors can participate from anywhere*
Student Project Management:	*Typically done in studio or via email or text*	*+ Use of virtual conferencing provides ability to share 2D/3D work in real-time* *+ Use of file sharing technologies helps coordinate efforts of group and provides more peer-peer synergy*
Ongoing Project Input and Feedback from Instructor and Sponsors:	*Typically sponsor input and feedback is done via email* *- Often sponsor responses are not responsive or timely* *- Inability for sponsors to review 2D or 3D student work (aside from email attachments)*	*+ Increased frequency due to reduced logistical hurdles (time/transportation/parking)* *+ Ability to share 2D and 3D work in real time with sponsors via screen sharing* *+ Nature of virtual sessions makes Q and A more responsive and timely in comparison with email* *+ Sponsors are potentially more responsive and flexible due to reduced logistical hurdles (time/transportation/parking)* *+ Students, instructors, and sponsors can participate from anywhere* *- Possibly reduced perceived importance of virtual meetings due to lack of direct personal contact* *- Potential opportunity for reduced attention due to virtual format on part of both students and sponsors* *+ Ability to easily meet with individual students/ teams increases overall efficiency of class since "waiting for your turn" is eliminated.*
Sponsor Participation in Project Reviews and Presentations:	*Typically done In-Person* *- Availability of sponsors can vary widely depending on company/institution scheduling*	*+ Increased potential for participation of additional sponsor representatives due to reduced logistical hurdles. (time/transportation/parking)*

Use of idea sharing applications such as *Figma* allowed students to better coordinate their efforts as it was possible for all involved to review the work of classmates on a continuing basis, as opposed to seeing the work of fellow students only periodically. Certainly, it permitted more synergy to take place where the work of one student could more readily be leveraged and developed further by another.

5 CONCLUSIONS AND RECOMMENDATIONS

Although the observations made in this paper are anecdotal, based upon a single semester's work and all assessment of the results is admittedly qualitative (as opposed to quantitative), it appears that virtual conferencing with students/project sponsors can offer substantial advantages over traditional face-face interactions when implemented effectively. There seems to be a great opportunity for layering this virtual instruction onto traditional face-to-face techniques to achieve a robust studio experience.

Whether or not pandemic circumstances dictate that social distancing and virtual learning continue to be the rule, online conferencing should continue to be used to achieve more effective and efficient communication with students and project sponsors. Leveraging this technique with face-face instruction should provide the best of both worlds in terms of instructor input/feedback while still permitting regular and efficient review of individual and/or teamwork. It also provides a relatively pain-free way for outside sponsors and subject matter experts to interact with students. As such, it should expand opportunities for the participation of these individuals to provide input and feedback on a much more regular basis as well as the sponsorship of such real-world projects in the first place.

Specifically, it is recommended that future studio courses featuring design projects conducted with outside sponsors be organized so as to leverage virtual communications (1) in place of or (2) in addition to traditional face-face interaction to maximize the value of such relationships. It is also recommended that course instruction be structured to include both (1) traditional classroom instruction (large group basis); (2) and more focused support of individual students or project teams (small group basis) using virtual communications in order to maximize input/feedback & overall class efficiency.

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CIRCLING ROUND CIRCULAR CHANGE

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ABSTRACT
In the EU, a programme for implementing a circular approach to the Lifestyle and Fashion Industry dealing with the resource challenges of the massive textile-production has been launched. Thus, the industry faces a need for circular and closed-loop approaches and will be challenged in developing and recruiting internal competencies for making the transition from linear to circular production possible. This article explores the assumption of an existing gap between academia - (the fashion designer's roles and potential theories and models) and compares it with the actual practice of the designer's roles in circular transitional processes in the industry. Using a mixed-method approach, combining quantitative with qualitative research methods, this study investigates the actual roles; practice, reality, and performance of the designers in the field of circular design (CD) practice, its relation to the educational background and the designer's circular competences. It reveals huge gaps between theory and practice and an accumulated frustration among the designers on both having a) a lack of mandate order to execute the circular economy (CE) principles, and b) a need for new competences in the business. The paper finally suggests how to use the research when developing Education for Sustainable Development with a focus on design.

Keywords: Circular fashion, educations for sustainable development (ESD), design education, circular economy, role of the fashion designer

1 THE CHALLENGE - INTRODUCTION

The fashion industry has a substantial contribution to climate change, exercising a high negative environmental and social impact [1, 2, 3]. Design can have a meaningful positive contribution as it is estimated that up to 80% of the environmental impact of a product is determined at the design stage [4, 5]. Therefore, designers can be seen as "Agents of Change", yet so far, their contribution within companies in the transition towards circularity has been limited. In academia and reports surrounding the research the designers are often identified to be one of the key-professions which could mitigate the immense impacts of the industry and help reduce the impact of the industry through pollution and waste elimination, keeping products and materials in circulation and focusing on regenerating natural systems [6, 7]. Moreover, circularity requires designers to design for multiple life cycles which in turn appoints numerous new responsibilities [8, 9, 6]. Therefore, the number of responsibilities put on the designer has grown over the past decade. But new studies addressing the performances of fashion designers in CE-transitions show large gaps in circular competences, organisational confusion of roles and tensions in organisations trying to handle the transition [8, 10]. Other studies show designers lack fundamental sustainable competencies and understanding of challenges in complex systems and a need for re-focusing the curricula at design schools in order to enhance the performances of the designers [11, 12, 8, 13]. This study wishes to investigate *if and how* fashion designers try to handle the new roles and how their performances in the fashion industry are influenced by surrounding challenges.

2 THE APPOINTED RESPONSIBLE ROLES IN THE DESIGN-PROCESS

In fashion, the design process describes the phase in which a piece of clothing or apparel undergoes a wide range of decisive priorities and considerations. The process is considered to contain at least five levels: research, defining the design, prototyping, testing, production, and launch. [7, 14] These phases include crucial decisions deriving from a large number of aspects which are all intertwined and have an impact on the environmental, social, and economic challenges that the final product faces. In the field of circular fashion both non-academic branch-reports, academic research, governmental reports, and

NGOs tend to consider the designers of the future and present (fast)fashion to be one of the key-point for a new transition towards circular fashion [14, 15].
In a CE, the designer's roles include that the designer carries the capacity and competences to handle responsibilities spanning from resource flows, materials use, fibres, chemicals, water usage, lifespan, or lifecycle; end of life processes as well as knowledge about the potential business models for sales, customer use, take back, recycling or reuse [7, 10]. Furthermore, as a previous study shows through the ORFDCE model (Organisational Roles of Fashion Designers for Circular Economy) (see Figure 1) the designer can work and possibly interact in different roles in organisations transitioning to a CE, where the designer can have the role of *preventing*, the role of *facilitating* and the role of *advising*, which again should be strategically integrated throughout the different organisational levels [16]. In a CE, organisational systemic changes need to occur in order to enable circularity. [10, 16]. In order for the designer to be aware of and act on some of the above roles, several organisational systemic factors need to be considered: new knowledge on design and context on the part of the designer; dynamic capabilities of the organisation (the company's ability to build, integrate and reconfigure internal and external competences to deal with fast changing surroundings); an improved design management (DM); and a balanced power structure (i.e. the designers' social power as this will largely influence if they have the necessary standing to implement the assigned roles) [16]. Furthermore, as a circular approach relies on collaboration with internal and external stakeholders, sustainability accountability cannot be confined to a single profession [9, 17]. Moreover, as power within the company must be met as well, creating a new occupational mandate for the designer as Agent of sustainable Change is necessary [18].

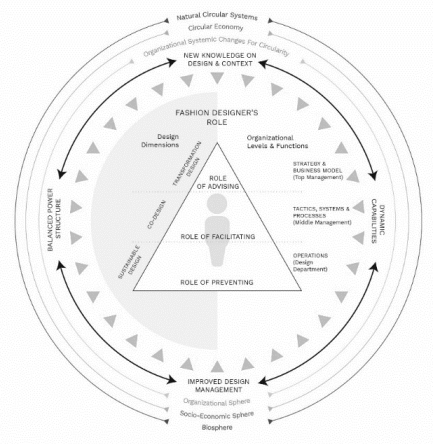

Figure 1. The ORFDCE model, Dan & Østergaard 2020

3 PARADOXES AND NEEDS FOR MANAGERIAL ACTIONS

The challenge of creating a mandate for the designers also calls for a revision of the managerial context in which the designer works. Values and ethos become the centre of attention. When addressing sustainability within organisations, the designer's objectives can be blurred due to organisational tensions and strategic dissonance. Hahn et al. (2014) outlined the inconsideration of organisational tensions and conflicts that contrasted with the convoluted nature of corporate sustainability.[19] Hahn's work emphasized that many businesses today seek simultaneously distinctive sustainability goals even though they can be antagonistic, as formulating a solution to one challenge could be unfavourable to another. As such, the lack of consensus regarding sustainable design not only relates to the lack of knowledge on the designer's part but also the lack of setting a clear set of objectives at the organisational level that are aligned to the company's sustainable vision and mission [20]. Hahn advocates for a transparent managerial approach to corporate sustainability issues, not giving one point of view more value than the other - but persisting on the differences of opinion and thereby generating an "Acceptance Strategy" that can transform existing tensions into "creative tension". This would allow for participation and a more agile open dialogue across the functions in the organisations and the management [19]. Also, Karell and Niinimäki (2020) conclude that designers more or less are struggling with the challenges of

"business tensions" and uncertainty of mandates, roles, and functions. But unfortunately, this knowledge has not been included in the industry's practices.

4 METHODOLOGY

The intention of this article is on one hand to explore the assumption of an existing gap between academia - (fashion designer roles and potential theories and models) and the actual practice of the designer's roles in circular transitional processes in the industry. By using a mixed-method approach, this study combines quantitative (surveys) with qualitative research methods (semi structured interviews). [21] Data analysis was conducted in two stages. Firstly, a survey was sent to 20 fashion designers working in sustainable-minded medium-sized Danish companies, of which nine responded. As the survey contained mostly open-ended questions, the analysis was conducted through qualitative content analysis where common themes were identified and coded. In the second stage of the sequential mixed method exploratory strategy [22, 21] five semi-structured in-depth interviews were conducted with five fashion designers working for sustainable-minded fashion companies in Denmark. This was done in order to gain closer insight into the challenges of the roles, mandates, and appointed responsibilities of the designer. The data was analysed through thematic analysis which allowed to identify common and/or varying patterns of practices. Then, the interview results were compared to those of the survey. In order to zoom out in perspective on the inputs from the data, two supplementary in-depth interviews with CE branch experts were conducted.

Table 1. The occupation, company type and experiences of the interviewed designers and experts

Occupation	Company Type	Experience
Designer 1	SME - Fashion Brand	10+ years of experience
Designer 2	SME - Fashion Brand	20 years of experience
Designer 3	Large international Fashion Brand	7 years of experience
Designer 4	Start Up Brand	2-3 years of experience
Designer 5	SME - Fashion Brand	2-3 years of experience
Expert 1	National Lifestyle & Fashion CE and Innovation Cluster	8 years CE responsibility & experience
Expert 2	CE Designer & private CE Fashion Consultant	20 years + sustainability experience

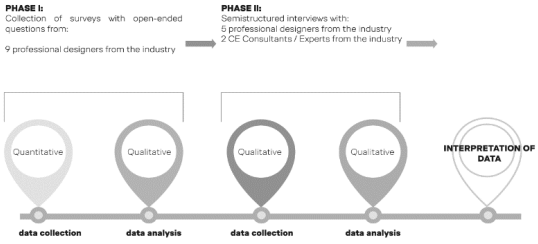

Figure 2. Sequential exploratory study strategy

The designers from both research stages were identified and contacted through and in collaboration with the national Danish Hub for Innovation in the Textile Sector; the Lifestyle and Design Cluster (LD-Cluster) for a more precise selection of respondents. But, as this study also shows, similar to other studies made by Karell, E. & Niinimäki (2020) it can be really difficult to find designers who are willing to a; spend the time on the interview, and b; commit themselves to a longer lasting relationship to research. [22, 21]. Therefore, the study has certain limitations and would have benefitted from more interviews and survey responses that would have enriched and brought more nuance to the data.

5 FINDINGS

Both interviews and surveys had the primary objective of identifying challenges of the roles, mandates, and appointed responsibilities of the designer within organisations that are sustainable-minded. The questions asked were similar for both interviews and surveys and addressed: experience with CE and CD and competencies, obstacles they encountered in implementing CD, support, and opportunity within the company to exercise real changes in relation to sustainable development and CE, new roles and responsibilities, organisational challenges, and tensions. Three thematic clusters were identified below:

5.1 Roles

Outlining main findings, all but one designer confirmed that the company they work with has started working with CE and themselves with CD, but they are only in the incipient stage. When asked, if the designers have the skills to work with CE and CD today, six respondents of the survey said they were poorly prepared and pointed at the need for new knowledge and life-long learning opportunities; but also the need for new cross-departmental collaborations between the design department and the purchasers and management. When asked; "Do you feel that the designer has been given more responsibilities in connection with sustainable production and CE?" replies showed new areas of responsibility have emerged over to the designer's field. On the other hand, more than half of the respondents still replied their roles were unchanged and their influence rather limited. In the designer's area, managerial decisions and interests are still key. When questioned if the designers felt they had a substantial influence on making the companies more sustainable the replies differed, but most described a limited discussion with the management. Only a couple of the designers saw themselves as leaders towards circular economy in their companies. The three main obstacles to implementing CD in their business or industry were: poor communication of strategies and communication between departments in the business, followed by a lack of competences and finally uncertainty of roles and mandates in decision making. In the in-depth interviews, the designers pointed at a sense of being "left alone" - or considered to be an idealist, as the CE and sustainable aims were not integrated into the practice of all the business departments. Moreover, due to lack of time allocation, there is a considerable gap in the designer's CE and CD knowledge. Furthermore, as one designer pointed out: *"the designer can do something today, but once we work with systemic interventions, there is a need for the designer to be part of broad interdisciplinary teams in the companies"*.

5.2 Mandate

When asked if the designers felt they have the right "mandate" - that is, a legitimate opportunity to act and launch real changes in sustainable development and the circular economy strategy within the company, the replies differed. Only two of the respondents replied with a full "yes" - whereas most of the respondents said they lacked mandate to act, as the communication between the design department and the management level was poor. As one designer stated, *"I have in principle the mandate to work with CE but lack support from procurement and management"*.

More than a quarter of the respondents found it crucial that candidates from the design schools are trained in CE-competences with half of them saying it is crucial for hiring them and four of them saying it is definitively important for hiring them. A majority of the interviewed designers from the in-depth sessions stated that there is a) a lack of true commitment from the management towards sustainability and in particular CE., b) there is a lack of understanding of what sustainability is more than just a buzz-word or marketing effect amongst the management, c) there is a lack of genuine interest in transforming the present business models, sourcing techniques, value chains or materials in use from the management, as the legislation still is fairly vague and encourages the present fast-fashion linear production.

5.3 Organisational tensions

All survey respondents and interviewees recognize tensions within the organisations they work in as CE begins to be integrated within the company including management level. As designers call out several aspects when asked if sustainability and CE can create tensions between different departments and actors in the company: *"Yes, many and great tensions between Design and Economy", "Greatly. Sustainable production challenges our value chain and our entire design."*

6 DISCUSSION

On one hand, the in-depth interviews with the designers showed how prior research on the potential of the designers' roles are dependent on the organisational levels and design dimensions and the power that the designer is offered or able to use [16]. When asked if the designer could see a role as "adviser" on organisational, managerial level, the role of facilitator on a systemic and processual level or the role of preventing on an operational level only few of the interviewed found they had the time, the competences, and mandates to act accordingly. But to the designers these roles could be relevant and of importance, dependent on radical organisational changes, involving all the departments of the business. So, the necessity of a holistic approach for both understanding the organisational system and the external influences on the designer's role is obvious.

Moreover, this study is in accordance with the previous research made by Sumter et al. 2020 and Karell and Niinimäki (2020) showing organisational confusion of roles and tensions in organisations trying to handle the transition [8, 10], but it also reveals the need for new research on other levels of the fashion organisations: management, purchasing, marketing, sourcing, economy, and investment strategies and how these silos in the organisations can collaborate. These types of interactions and breaking of silos should firstly start to appear within the curricula of design educational institutions, setting an example and direction for future practices within organisations.[12] Moreover, the study shows the fashion industry has stalled and probably will not deliver the expected reduction on the impact of the industry, unless political and legislative initiatives become reality.

Corporate tensions in the organisations between designers and other departments showed to be widely spread, with very different aims and approaches to sustainability and circular economy in practice. The commercial sales team and the marketing team in a company, are, according to the designers, not necessarily interested or concerned with sustainable issues at the same level as the design department. In these areas of the business, sustainability is often considered, treated, and communicated as a "trend" - or a strong sales promotion and thereby confusing the overall intention of sustainable products or circular initiatives even more.[19]

The interviewed designers expressed a clear need for leadership but also a profound confusion on who has the mandate to generate change and who is actually responsible. Again, and again the designers pointed at other areas in the company than the design department as the decision making, strategy making or financially decisive. More than half of the interviewees stated their roles had not changed over the past 5-10 years and that their roles still relied on traditional non-sustainable design virtues.

Finally, the educational aspects on CE-competences appear to be crucial for new fashion design organisational positions as they begin to include a circular mandate. And here some of the key answers to why the industry lacks to change is maybe to be found. Here we seem to find a pattern of connections.

7 CONCLUSIONS

The intention of this pilot-study has been to try to help identify and bridge the perspectives of academia within the field of circular economy and sustainable development with the fashion industry's current practice, in a mutually beneficial way.

This pilot-study shows a series of gaps between the designer's perception of their roles and the cultural and organisational norms that surround them. And this may be in contrast to the picture of the designer as potentially "Agent of Change". The interviewed designers have been far away from research and academia for some years, and most of them were not aware of the expected roles in CE or CD. The dominating business structures of fast fashion and organisational power, restrains the designers within the conditions they work. The following points were repeated by the interviewed designers: *a) need for radical political and industrial legislative action* - legislation is lacking and if the change towards a circular fashion industry is to take place, management will only commit if there are legal requirements and clear regulations on the industry; *b) competencies, knowledge and transparency* - competences and knowledge about sustainability and circularity is evidently something most of the designers have made on their own, mostly unaware of existing tools and with limited time to research further into the capacities of these models. Hence, the competences and knowledge are far away from the level of the present academia. It became clear that some of the designers, even if they are adapting circular or sustainable design principles, still rely strongly on a linear production value-chain. The designers also expressed a basic need for knowledge, inputs, and cross-disciplinary collaboration from and with specialists and researchers within materials, chemistry, engineering, technology, and circular business models; *c) time and the provision of Sustainable Collaborative teams* - time was a recurring theme for the interviewed participants and a significant challenge in order to enhance change. So, the mere thought of adding more circular responsibilities to the present tasks seemed unrealistic. In this way, the picture of the designer as the central organisational circular hub is crashing. Building new organisational structures that facilitate the creation of new teams relying on different skills and competences may on one hand provide an opportunity to identify and distribute circular tasks and add interdisciplinarity to the teams, but also require huge investments and re-organisations of the industry. And, finally, a closer, trustful, and continuous collaboration with research and academia is needed, in order to learn from, share and analyse the practices and potentials of the sector.

If the society surrounding the fashion industry has had the hope of the designer as the potential Agent of Change, this study stresses the overall need for education at all organisational levels in the fashion

industry. Right now, it appears there are only a few agents of change and no agents of the community, but a dominant level of agents of profit. This calls for new research on educational practices.

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H.I.I.T. HIGH INTENSITY IDEATION TRAINING - FACILITATING GROUP DESIGN IDEATION IN A DIGITAL TEACHING SPACE

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ABSTRACT
2020/21 has been a challenging experience across Higher Education. Within the Product Design Department at NTU, these challenges have created opportunities to expand teaching methods and explore innovative alternatives. Utilizing these challenges to adapt to an online environment this paper provides an early adopter route into digital ideation training, whilst providing a clear roadmap to a future Blended Learning approach. Collaborative ideation is key to facilitating peer learning amongst 1st year design students, allowing them to build key Designer skills whilst fostering an environment of inclusivity and creativity. This is a recurrent challenge when transitioning to Higher Education, with the effect of COVID-19 only amplifying this. In 2021, many 1st year students had been out of education for 6 months before beginning University, rendering the challenge even greater. In response to the challenge, this paper proposes a new approach to collaboration, actively using the flexibility of online workspaces to create a new ideation paradigm.
Using the fundamental principles of Lotus Blossom Ideation approximately 100 students participated in High Intensity Ideation Training (HIIT) using Miro, an Online Visual Collaboration Platform.
This paper postulates that implementing this method online is not only highly successful but presents potential for more collaborative and creative rapid ideation. The method provides students with a range of creative tools, enhancing strength of communication, whilst removing some existing barriers to learning. Recommendations can be made for improved implementation of sessions and the paper provides and outline template for anyone wishing to adopt the process.

Keywords: Ideation, online, pedagogy, collaboration, HIIT

1 CONTEXT

The 2021/21 Academic year has brought challenges to education and design that have never been experienced before. Hands on, practical courses have been adapted to 100% online learning, and the issue of engagement and student success has never been more difficult to manage. It has not been without its opportunities however, as the rapid move to online teaching has brought to light innovative solutions to age old problems. One of these opportunities is the potential for the integration of Blended Learning to Product Design degrees. The mixed media approach provides potential to integrate with a wider group of learners and develop rich online content. One area that has had difficulty transitioning however is the application of group ideation sessions within an online teaching environment. Is it possible to foster creativity and inclusion when Design students are spread across the globe? Can students be taught to build on each other designs and actively participate without using paper and pens? The authors believe this is possible, and this paper proposes a solution to the challenge. Here we provide an early adopter route into online digital ideation methods and considering whether this is purely an emergency remote teaching method [2] or whether there is scope for a meaningful alternative to in person group studio ideation.

2 METHODOLOGY

Using the fundamental principles of Lotus Blossom Ideation [1] approximately 100 students participated in High Intensity Ideation Training (HIIT) using an Online Visual Collaboration Platform (Miro). Divided into small virtual groups, students completed a warm-up task, before moving into larger groups to build upon ideas and collaborate with peers. The Design Thinking method of 'How Might We'

(HMW)[3] positional questions was used to drive the group ideation in a targeted direction. The intention was to see if it was possible to create new digital interactions by using existing in-person techniques in an innovative way, hoping that these new innovations can then be applied in a more blended approach once teaching in person returns.

2.1 Framework

An outline framework of the process used is described in Table 1 below. The process outlined was employed for several reasons. Drawing from existing literature around online interaction we found that '*when designing tasks, instructors should make assignments challenging, varied, active, multidimensional, and relevant. During the course, instructors should take steps to minimize students' anxiety, use effective evaluation and feedback, and promote interaction.'* [4]. The framework was developed with these specific criteria considered to ensure students remained motivated throughout the process.

Table 1. HIIT Online Session Framework

Stage	Description	Duration
Set Up	Single online meeting utilizing chat function. This allows single Tutor to control session overall & issue instructions, with support Tutors divided across group Miro boards.	
30 Apples	Using pre created Miro boards the groups begin to ideate around the concept of 30 different apples. Allow familiarization with Miro & tools	10 minutes
HMW Themes	5 statements spread across groups, with 4 groups (25 students per group) working on the same statement. Ensure briefs are not related to current project. Example themes- How might we carry water? How might we light a room? Etc. Task is to think of 8 themes within HMW statements as a group. An unrelated example is provided to demonstrate concept. Each Miro board has the brief in the middle to allow group to surround it with themes. This board is utilized for ideas in the next two exercises.	10 minutes
Idea Rotation	Each group member picks a theme and has 5 minutes to draw as many ideas as possible on the Miro board. After 5 min move to the next theme and rotate until all themes are complete. Encourage drawing and being loose with ideas. Ideally 40 ideas per theme are generated.	45 minutes
	BREAK	
Cluster Rumble	As a group, the students cluster their ideas within each theme highlighting shared characteristics. Encourage all to participate in discussion.	30 minutes
	BREAK	
Decision Point	Groups select 8 ideas they think have the potential to be explored further. Ideas developed into more defined concepts and shared across cohort.	15 minutes
Cool Down	Presentation of concepts for each brief, tutor and student comments and reflection. Participants highlight areas of interest.	15 minutes

2.2 30 Apples

The 30 apples ideation process was employed for two reasons. Firstly, as stated by the Creators *'The purpose of this simple exercise is to demonstrate three key principles useful for creativity and idea generation: quantity is a condition for quality; building on the ideas of others; the ideas we come up with are usually all the same.'* [5]. Secondly, the process acts as an ice breaking activity, allowing students to not only become accustomed with Miro and its tools, but also to begin to 'lose the ego' surround drawing quality. All participant skills are limited to the basic tools provided by Miro, therefore drawing quality is less of a factor.

2.3 HIIT

The HIIT session itself allows the students to build on the outlined themes individually whilst working as part of a larger team. This concept of 'alone-together' helps to promote a feeling of belonging within the virtual group, without the need for verbal communication.

The outlined themes are driven from the HMW questioning method using How Might We statements to "*explore further aspects of a given problem, so that there is an appropriate problem for the subsequent Design Thinking processes.*."[3] By framing the initial question as a HMW statement, students can ideate divergently within a theme, whilst not being restricted by it. This ensures everything that is created is meaningful and on task.

Building upon the ideas of the Lotus Blossom Ideation Method [1] the HIIT session allows ideas to be displayed visually, whilst remaining connected to the core theme. The process and layout of Lotus quickly highlights the quality of ideas (based on the number of concepts generated within that theme) and allows for rapid group decision making on which themes hold the most promise, or where more focus needs to be spent. The visual nature of the process also allows a visual narrative of ideas to form, showing the inception of an idea, and how the group have worked to iterate around that initial design.

Developing on from these principles, HIIT employs a further area of idea development using a 'Cluster Rumble.' Here ideas are grouped together to form ideas with shared characteristics that have potential for development. As a group within the Cluster Rumble, the students take these grouped ideas and begin to form more solid concepts from them. These are eventually filtered down to a select 8 which become the key concepts from the ideation activity.

The HIIT method of ideation is built around the idea of high intensity interval training in exercise. The short bursts of high intensity workouts have been shown to improve fitness, and the same can also be said for ideation. Drawing upon other task management styles such as Pomodoro [6] HIIT breaks down sections into rapid areas of activity, followed by breaks. This framework is outlined in Figure 1 below.

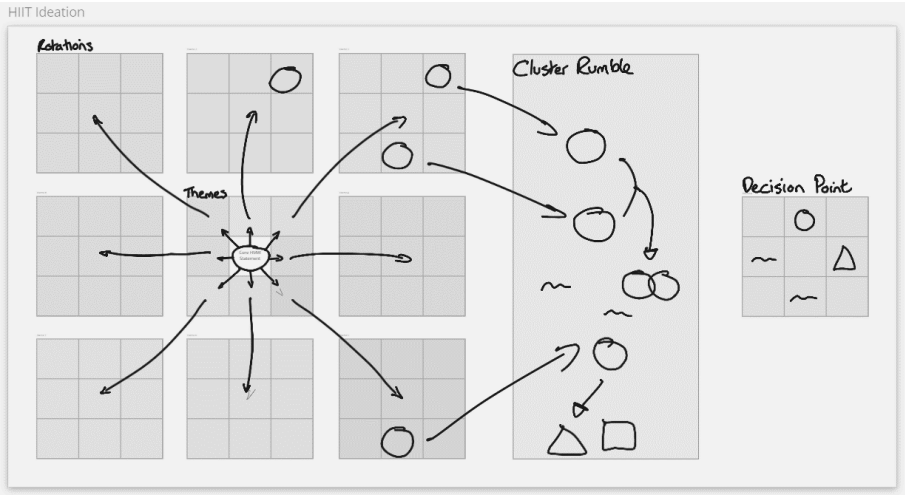

Figure 1. HIIT Framework

3 FINDINGS

3.1 HIIT

The High Intensity Ideation Training format was successful, with students engaging with the process to a greater degree than previously seen in on-site teaching. This paper postulates that implementing this method using an online setting is not only possible but presents potential for more collaborative and creative rapid ideation. Utilizing HIIT provides students with a range of creative tools, enhancing and developing strength of communication using colour, text, and reference images. Additionally, the use of Miro levels out ability by encouraging sketching through a computer mouse or trackpad, giving students with lower ability more confidence. Most promising is that students were observed to build upon each other's ideas, giving feedback, collaborating, and developing concepts as teams. HIIT helps to develop active, participatory student-centred learning environments that promotes instructor-student collaborations. [7] Existing barriers to learning still exist in this space, with a lower uptake from less

engaged students and those who lack confidence. There is also a challenge in ensuring more confident students do not dominate the space, allowing students to contribute equally.

3.2 30 Apples

The use of 30 Apples as a warmup activity was highly successful, as it encourages participation without worry of failure, and ensured the participants were comfortable with the tools before commencing the activity. (Figure 2)

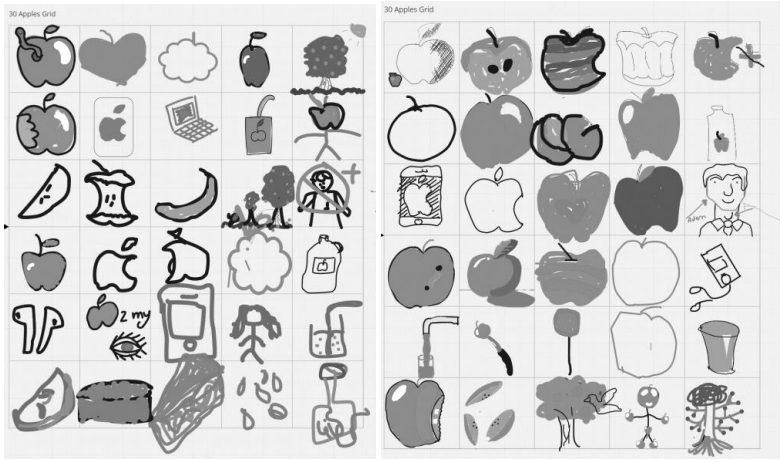

Figure 2. Warm up activity example

30 Apples also provides another function, as the tools within Miro can become a distraction and students can easily derail sessions if not closely monitored. Rapid ideation and collaboration are integral to the HIIT framework, but if not closely monitored they can result in off topic creativity. By providing a space for this creativity, HIIT sessions can be run more effectively by encouraging rapid ideation and collaboration without disruption. Careful considerations and monitoring by Tutors are needed within the task to ensure students do not become side-tracked.

3.3 Cluster Rumble

Cluster Rumble instils a feeling of shared ownership within the concepts, where students build on each other decisions to develop a concept greater than the sum of its parts. It also provides a granularity to the process, allowing iteration within ideas (a key skill often lacking in first year Design students,) rather than ideating with a fully formed concept from inception. The shared ownership of designs ensures students do not feel protective of their initial idea, as others have built upon it without the knowledge of the fully formed concept it was devised from.

3.4 Anonymity

Miro can be used anonymously, and most students opt for this posing both challenges and opportunities within HIIT workshops.

The positive impacts of anonymity within HIIT include increased confidence and willingness for collaboration. In remaining anonymous, it was observed that students are much quicker to collaborate with each other from the outset of the activity compared to in-person sessions. East[8] reports that anonymity gives students confidence to contribute, stating that participation "*without the belief that they'd be identified as asking a stupid question, but 'someone' asking a stupid question.*" In building self-esteem among student cohorts, HIIT ideation sessions can remain short and sharp, with more ideas shared. East's [8] students reported that anonymity levelled the playing field amongst cohorts, and where students were not confident speaking within in-person sessions they were able to voice their opinions, questions, and thoughts through these online platforms more easily. In HIIT workshops, it was observed that anonymity provided a more level playing field, encouraging less confident students to participate in collaborative activity.

As expected, one limitation of anonymous participation is that less engaged or less confident students can avoid participation. However, it should be noted that had the HIIT session been in person these students would have missed out completely due to non-attendance. With the HIIT sessions being online these students are still able to observe sessions even if they choose not to actively engage, therefore suggesting that the reach of HIIT online has a wider positive impact on students.

3.5 Shared Ownership

The aim of HIIT is rapid ideation, giving students a breadth of ideas to build from. When applying the Lotus Blossom Method to in-person sessions, it is observed that students often work individually on ideas before sharing with a wider group. This can be attributed to two key factors; students wanting to take individual ownership of ideas, or students lacking confidence in their own sketching ability, spending more time on the quality of the sketch itself rather than the quality of the idea. This often leads to a disconnect within a group and the collaborative element of Lotus Blossom is lost.

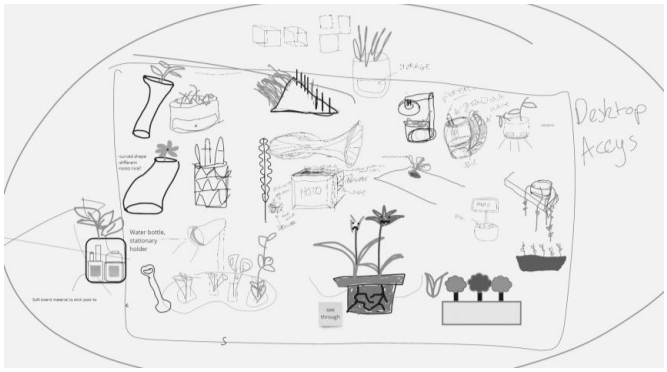

Figure 3. Example of Student Idea Collaboration

Miro helps to improve on this in several ways. Firstly, it allows all participants to see the actions of one another in real time, meaning multiple participants can work on the same idea synchronously. This early collaboration within a session encourages shared ownership of ideas from the outset (Figure 3). Furthermore, the tools within Miro level the playing field in terms of sketch ability, with most students sketching ideas using a computer mouse. Whilst the depth of detail that can be achieved with a mouse may be challenging, the basic function means that sketch ability plays less of a role in the generation of ideas. This allows students to ideate in a simple, less precise way and therefore builds confidence in those that are less comfortable with sketching. This leads to more rapid ideation and allows HIIT sessions to run in short creative bursts, allowing students to be more collaborative and take shared ownership of ideas.

3.6 Tools for Creativity

The tools available within Miro allow for more creativity within HIIT sessions. Typically, students come to in-person sessions with one pen or pencil, relying heavily on sketch ability to communicate ideas. Miro provides a variety of tools to better facilitate ideation. A range of pen colours, line thicknesses, shapes, and stickers aid in the communication of ideas by allowing students to give context without relying on a variety of physical equipment. In using the tools that Miro offers, students can express ideas creatively, allowing for quick collaboration and exploration of concepts. Furthermore, ideas can be better contextualised using existing images and media, which can be quickly copied into Miro. This adds a potential for greater depth of creativity as inspiration and reference points are integrated within ideation. Integration allows others to build upon concepts with a shared understanding of their origin.

3.7 Measuring Success

The success of HIIT can be measured through observation of student work in comparison to previous cohorts, with students that participated in HIIT having an increased ability in rapid ideation. This improved ideation ability is demonstrated through later projects and assessed work, with students

producing a greater range of ideas compared to that previously expected of students from an A-Level background.

4 CONCLUSIONS

Overall, the experience of applying HIIT to an online learning environment was a positive one, with student collaboration and rapid ideation skills both being put into practise. A combination of anonymity and a level playing field in sketch ability allowed for enhanced confidence amongst the cohort, encouraging collaborative work and allowing students to build on and rapidly share ideas within the workspace. Furthermore, the availability of tools within Miro allows students to express ideas creatively, leading to a positive experience and giving students an opportunity to take shared ownership of work.

For optimum future implementation it is proposed that HIIT sessions be run as a blended learning experience, where students engage in an online collaborative space whilst in the same real-world environment. This would allow for shared benefits of digital collaboration across a cohort whilst promoting face to face interaction amongst peer groups. With a tutor driving the direction of HIIT, small student groups can collaborate in a real studio setting by contributing to a Miro board on a large screen, with participants highlighting key areas of innovation in real time. In doing so, students will benefit from the digitally collaborative aspects of Miro whilst building a real-world community.

Overall, the Authors found the application of HIIT sessions highly beneficial to students' creativity and learning, proving that collaboration amongst design students is possible even when working remotely. The hope is that with ever decreasing pandemic restrictions HIIT sessions develop and grow to become highly successful ideation sessions that utilise the benefits of online teaching, without being restricted by it.

5 RECOMMENDATIONS

Recommendations can always be made for implementing sessions and improving on their quality. The initial planning and setup of HIIT was time consuming. To reduce this initial set up time, we suggest utilising the Miro template provided in Figure 1 (available on request,) and for facilitators to follow the workshop framework outlined in Table 1. In following these guidelines, sessions should run smoothly with all staff having clarity on process and desired outcome, thus allowing more time for collaboration and on task learning. HIIT sessions are more successful with larger student groups of mixed ability and confidence, promoting collaboration and fostering a free-flowing environment.

Naturally, consideration needs to be given to technical difficulties that result from all versions of online teaching. During HIIT sessions, this can be tackled through splitting the cohort across Miro boards rather than aiming to have all students on one board. Whilst it is acknowledged that the session does work better with larger groups, technical limitations need to be taken into consideration to ensure the smooth running of the sessions.

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IN PURSUIT OF MEANINGFUL INSIGHT; COVID REMOTE COLLABORATION AND DESIGN AS PROVOCATION

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ABSTRACT
Conducted from June 2020 until the time of writing, this design research activity was conducted as part of the 3 year, H2020, Pan European TInnGO project which aims to create a sustainable paradigm shift in gender and diversity mainstreaming in transport. Such a shift is needed due to the lack of sex disaggregated gender data, gender gaps in employment and decision making and women in STE(A)M able to rise to leadership positions. This lack of diversity at all levels of transport, together with difficulties in engaging 'hard to reach groups' in transport planning, means that transport services and innovation continue to fail to consider gender and diversity. This would also encourage design input into future transport.
A central concept of TInnGO was to use design activities as provocations and ways to engage with people in new ways – e.g., through visualizations, vignettes and cocreation activities – to develop greater insights into mobility problems and drive gender and diversity sensitive smart mobility solutions. Led by Coventry University, it was anticipated that this would entail management and leadership of codesign sessions in 10 Pan-European hubs.
The Covid-19 pandemic significantly disrupted plans, making travel, physical co-design and contact with vulnerable groups impossible. The paper discusses strategies developed to work with placement students to develop gender and diversity sensitive smart mobility design provocations based on information provided by national hubs, and the technological challenges computer supported co-operative design posed.

Keywords: Codesign, computer supported co-operative design, teamwork, student learning, transport

1 INTRODUCTION

The application of visual design (and other creative media) to present concepts or working ideas is a widely accepted methodology in industry and design education. Using design to induce a response, that can break down barriers to discussion is less common outside of design studios or education where citizen insight is highly prized. Transport planners and local authorities still find citizen engagement difficult, especially with traditionally hard to reach groups. As such, the views of those groups may not be considered. Breaking this cycle is important if future transport is to be inclusive.
The TInnGO project sought to demonstrate the value of collaborative or participatory design, in breaking down barriers, engaging new and different dialogues centred around the conceptual design of gender and diversity-sensitive smart-mobility products based on local needs. A portfolio of design concepts would demonstrate the role of design thinking in a technology and science led sector.
TInnGO's co-design model centred around 10 national EU hubs, recruiting and training citizen scientists meeting in local 'design studios' where they could discuss mobility problems, turn initial ideas into briefs or mind maps which could be transformed into sketches, by designers from the UK hub shared via our Open Innovation Platform (OIP)[1] – a web-based gallery and forum. These could be presented back to the group and other interested parties as design provocations to elicit further, deeper insights based on collective mobility experience, progressing an iterative design cycle. The concepts, termed as

[1] https://oip.transportgenderobservatory.eu/

‘design provocations’, are used to ‘initiate critical reflection on issues that are often overlooked, obscured or accepted as natural practice’ [1].

From March 2020, Europe-wide rolling lockdowns made it impossible to follow the original plans. Rather than active engagement (including visits to European hubs, street interviews and focus groups with vulnerable transport users) we worked remotely with TInnGO’s non-design partners, who tried to generate design briefs using their understanding of local users and situations (gained from initial project research) and comment on initial sketches, acting as proxies for end users.

Our distributed student design team (based in Indonesia, Spain, and India) had to develop empathy/envisage the problems of vulnerable user groups in different European cities based on (a)synchronous communication via MS Teams, Mural and Zoom. Design provocations were uploaded on to the OIP for comment by the wider ‘nondesign’ TInnGO community, using a discussion-board format who mostly have no design background.

Students denied access to the university premises (design studios, equipment and modelling) worked asynchronously at a distance supported by online tutorials and weekly critiques using ‘MS Teams’. The initial brainstorming stage relied on Microsoft Teams, Zoom and Mural – all of which can become disjointed, due to bandwidth lag, working across different time zones, and isolated activity. Working with the limits of our devices (none of which were designed to support continuous remote working), we have noticed how the technology interferes with the organic free flow of ideas that might occur when co-located. Based on our 10 months experience we discuss the insights/barriers we have faced in relation to 1) communication with non-designers, 2) extent to which IT solutions can accommodate design activities, 3) development of empathy at a distance, 4) design skills gap 5) design as a provocation to encourage deeper thinking and engagement.

2 COMMUNICATION WITH NON-DESIGNERS

It is important to clarify the meaning of ‘non-designer’ in the context of TInnGO. The project is formed from a large multidisciplinary EU-wide team comprising of academics, local authorities, transport organisations and SMEs brought together to create a paradigm shift in gender and diversity in the field of smart mobility. The project requires a number of designed outcomes, informed by the collective experiential problems of hard to reach citizens who experience mobility problems. The term ‘non-designers’ refers to anyone not trained in design language and methods of communication used by design teams. It does not mean that citizens or project members are not designers.

Ideally design challenges should originate from citizens, for whom illustrating a concept or visualizations may be unfamiliar and lack of design literacy may prevent contribution. Design literacy refers to the ‘basic skills that are well within the full range of everyone’s cognitive capabilities and serve our everyday needs’ [2, p9]. Therefore, a lack of formal design training is not seen as an inhibitor to expressing ideas. We aimed to experiment with how the medium of design could enable different flows of communication and insights – as opposed to more traditional, verbal, or written forms of citizen engagement, surveys and focus groups. In the process outlined above ‘non design colleagues’ acted as informants, clients, co-designers and critics. Difficulties arose in relation to:

- Articulation of a design problem – generally in relation to lack of preparation, so generic images were downloaded from the internet to provide context (e.g., a city street).
- Lack of understanding or ability to convey the mobility problem in sufficient detail for design activity to be meaningful.
- Reluctance to share an idea visually, instead referring to typed text or in conversation.
- Preoccupation with the operation of the software, spelling/typos rather than generating ideas.
- Lack of ability/willingness to provide feedback to young designers or understanding the importance of this engagement for moving out of conceptual design phases.
- Learning how to express their issue or idea, objectively, without personal experience bias.

From the perspective of the student designers, additional difficulties related to:

- Communicating with experts in other fields e.g., engineering, computing, human factors AND those from admin, evaluation in different language.
- Understanding how their visual design communications, varying in scale and context would not be obvious to someone unfamiliar with drawing conventions used by designers.
- Needing to move out of inexperience and comfort zones to respond to the needs of the user group, presented the difficulty of designing for the ‘actual other’ not ‘presumed other’ or self.

- Challenge the relevance of a design requirement
- Overprotectiveness and defensiveness over feedback which was experienced in isolation
- Not rushing straight to a design solution – but looking at a wider systems approach

Previously, the authors have positioned the role of future-responsible development as a hybrid, a combination of multiple needs into a cohesive whole [6]. This hybrid progresses the typical perception of users, or designers, or researcher; rather we are all these things, to a lesser or greater extent. Yet, when viewed through the lens of a global crisis and isolated working, restricted empathy compromises the sense of group spirit and leads to miscommunication or reluctance to contribute that ultimately harms the design process, a factor that impacts upon the students training since they are not receiving the visceral responses that would otherwise have been proffered.

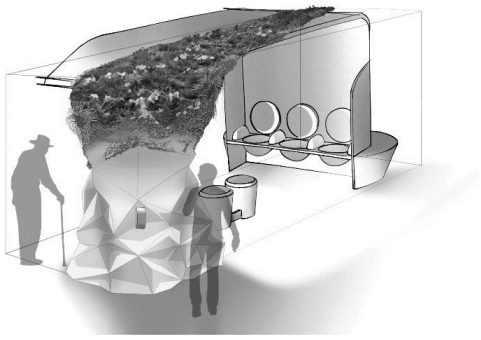

Figure 1. Bus Stop Information Panel, Solenza Lazar (2020)

3 DESIGN AS PROVOCATION TO ENCOURAGE DEEPER THINKING AND ENGAGEMENT

As a learning experience, we encouraged the interns to develop a naturalistic style of their own. When asked to provide feedback on the design communication from the design interns, non-designers found some material difficult to understand. We produced a variety of formats, from rough sketches to detailed 3D rendered views, referred to as 'design provocations', to stimulate debate. Figure 1 illustrates the type of concept generation that expresses an idea, not a finished design. The 'ghosted-in' figures are intended to illustrate scale, whilst text annotations describe the concept. The design intentionally introduces a different aesthetic to the existing waiting stop design and the combination of different styles shown in Fig 1 are intended to provoke a viewer response. The annotations are often written in 1st person, lacking business language, in a social media form that requires significant editing. Indeed, this informality is present when speaking with partner hubs, in emails and during weekly design review meetings. This tendency has almost certainly resulted from restricted contact with external parties. When artwork is posted on the OIP we noticed reluctance from others to comment, critically or constructively, about an image that is observed 'online' rather than witnessed in person, where subjectivity would normally have enabled viewers to construct meaningful feedback.

It is not uncommon for design sketches to exaggerate form, but we have been mindful to show work with the minimum of extraneous communication. It is unclear whether the reluctance is attributable to inexperience or whether the current trend for hyperrealism (i.e., Pixar etc.) in rendered images (Fig 3) has in some way skewed the expectation for a 'designed' output. In this case, our experience of an in-person, 2D sketch and 3D sketch model are more powerful media with which to communicate in context and for viewers to evaluate a solution to real world problems. Visual narratives can convey the user experience (UX) of a design concept, and indeed the storyboard technique in Fig 2 shows how viewers can be guided through steps of that design. In contrast, a semi-realistic design provocation, perhaps erroneously suggests that feedback was unnecessary.

We have previously stated the high value of co-creating understanding and collectively seeking solutions, as a more meaningful and inclusive means to prevent stigma. The system around the problem and solution convergence differs to the traditional elitism of the creative arts, thus enabling the capability of experience to improve futures. So, fundamentally things have changed when we are all

designers/hypothesizers/creators. Glancing to design history, acclaimed Industrial Designer, Raymond Loewy, sums up design as *"a simple exercise; a little logic, a little taste, and the will to co-operate."*[2] That was at the height of the excitement of a new machine age. Is design perceived differently today? User values may be similar, when we venture past the glamour and excitement of the new; essentially a solution should, in some way, improve our lives, to paraphrase, one potato peeler at a time[3] even if assistive technology status can become a commercial paradox.

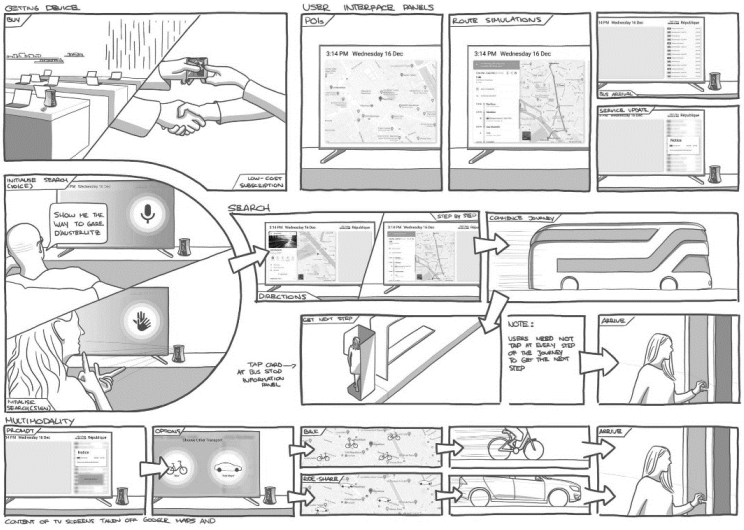

Figure 2. Story boarding, Ronald Jurianto (2020)

Perception then, remains of high importance to a consumer and since design students will ultimately be faced with the notion of commercially acceptable solutions, their ability to move beyond novice skills is paramount. Agile design education can address gaps which may have long lasting impacts. Intern designers are novices using design education as their 'window' to a dynamic industry, that to be fully representative needs the behaviour found in industry. Our experience shows that the COVID-19 pandemic has impacted on design student's exposure to training, and they have had to learn to shift to a predominantly self-directed methodology outside of the usual design studio culture; it is remarkable that the students have adapted and led the development of new methodology but there will be experiential gaps that are hard to fill.

4 EXTENT TO WHICH IT. SOLUTIONS ACCOMMODATE DESIGN DISCUSSION

During lockdown many have become accustomed to, and reliant upon, videoconferencing as a normal way of working or more generally communicating. In this section we look at some issues related to using Microsoft Teams as a means of discussing/critiquing concept designs with students. Here the limitations of internet connectivity, hardware and software have significant effects when working with a small, globally distributed team. Rushing into lock down no one had a perfect, state-of-the art system; no one was a technical expert; everyone had to manage their own local connection. Students (and staff) had to learn to transfer their sketches into a format which could be seen and understood on a shared screen. Confining the medium to this 'window' on thinking may have affected mark making, annotations and what they chose to show. It became harder to understand design progression, than if looking over a sketch book, or mock-up models and objects.

[2]https://www.raymondloewy.com/about/quotes/
[3]OXO,https://www.fastcompany.com/90239156/the-untold-story-of-the-vegetable-peeler-that-changed-the-world

Connection stability has been an issue. In prioritizing the need to hear the students, see the designs in a larger format and reduce lag, cameras and sometimes microphones were turned off. This effectively reduced telepresence - facial expression, tone of voice and other aspects of presence, such as clothing; face-to-face communication is rich because it includes deictic elements and objects, which are visible to all participants [3,4]. The fact that we were not in the design studios, surrounded by design ephemera was a clear disadvantage.

We had to experiment to find solutions which worked for us. Previous research [5] has looked at the social factors in teleconferencing in educational environments. The TInnGO design team comprised of lecturers and student designers, so student learning was a key element. [5] stressed that the educator is essentially "responsible" for the group's bonding, guidance, and progress of the learning process; and emphasized that the development of social skills is more easily fostered though direct communication.

In our work, collaboration differed to that of lecture or tutorial delivery. There was therefore a big learning curve. Students and staff needed to cohere as a unit, develop trust and understand the nature of the work (i.e., to develop gender and diversity smart mobility concepts). We then had to present design 'provocations' in a short period of time which could be used by other members of the project. [5] found evidence of awkwardness, anxiety and stress as people start to become familiar with each other and the technology and highlighted the role of the educator in creating atmosphere around interaction and performance. In our small group, the students were initially shy and reticent – learning how to present designs within the technology; their first experience of contributing to a project, of which they did not retain control. Although we set individual projects, over the course of a couple of months they started to work together and defend each other's designs. This was unexpected and does not have a direct equivalent when we have conducted local internships. This may indicate a protective instinct over their remote social group and development of remote social skills as a future skill for designers, who need to empathise with subjects and benefit from intra-empathy, which may differ to collaboration when in local competition.

Figure 3. Bus stop design, Sanjeevi Suganthi Pugazhenthi (2021)

Are we seeing the limitation of telepresence as a creative tool? Stability aside, the digital methods did not match the analogue activity of a post-it on a wall or the cardboard sketch-model. We are of the shared opinion that there is no substitute for the large roll of paper – it can be drawn on, cut up, things stuck to it - not just digitally observed. Digitally capturing and recording the flow of design ideas is difficult. For design research it is important to see ideas – in any form. In a physical studio there would have been more of a sense of immediacy, materiality, and ownership and of seeing ideas emerge and blossom. This sharing and sense of achievement was missing. Lack of group copresence has severely hampered spreading design insights and understanding the value added of design.

5 EMPATHY AT A DISTANCE AND DESIGN SKILLS GAP

Development of empathy is a challenging task and typically comes with maturity and experience. Design students are frequently required to design for others, which requires clarity, rather than biases from limited life-experience preconceptions. On reflection, a number of normal activities that have been unavailable due to lockdown impacted the student experience due to:

- Lack of tactile modelling – students are reluctant to make models or have no local facility in which to 'make'. Feedback gained from interacting with prototypes and sketch models is lost.
- Lack of self-motivation and speed, without the sense of 'competition' found in studios.
- Lack of visible body language with cameras turned off, that would allow designers to adjust their 'pitch'. Establishing the skill to read the audience is vital for professional practice and interviews.
- Lack of access to end users, who are able to define their needs and preferences.

Design education endeavours to provide a broad enough design knowledge so that graduates may reasonably design for the masses, and essentially be employable, Design as an industry still struggling with the paradox of designing for all [7]. We have sought to alleviate the issue of miscommunication of need, and misinterpretation of solution requirements that are endemic of working with young people for whom limited life experience limit understanding and typically concludes with partially suitable solutions for older/marginalised people. The classic undergraduate response is to develop an app as a solution to everything – yet digitalization may further exclude certain groups.

We have embedded empathy as a tool for enlightenment and reflected on its value from both perspectives. Not only have the students not had contact with end users, but they have also been in lock down, with few opportunities to observe travel behaviour. We have used journey maps, experiential maps, and personas. Interestingly, students who have developed personas during this period have tended to dwell on the negative aspects of existence to a larger extent than we have previously noticed, creating scenarios full of grief and despair when trying to understand the holistic experience from someone from a marginalised group.

6 SUMMARIES

The social skill of empathy remains at the core to improving the future. Based on our experience thus far, the social aspect of empathy needs further highlight, and its importance in remote collaboration is at least equal to that of visual communication training. In fairness, the team involved in this research have adapted during difficult and uncertain times. The level of coherence has been commendable, especially that of the student's support of one another. It has required a concerted effort to maintain progress, respectful communication, and an appropriate sense of the group hierarchy. Training of next generation empathic-hybrids as solution-facilitators and generation of a Post-pandemic design language may help to ensure the influence of perception results in solutions that serve us all.

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DESIGNING FOR TRUST IN EMERGING TECHNOLOGIES IN THE HEALTH SECTOR

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ABSTRACT
Design as an academic discipline requires a good deal of practice-based research and learning. To facilitate cross-pollination of design theory and practice, this article discusses the connection of a literature study and the development of a designer tool to employ theoretical insights in trust in emerging technologies in the health sector for practice. The ubiquitous spread of emerging technologies (ET) has created opportunities that profoundly impact sectors such as policymaking, administration, economy, science, and health sectors, and ET products, and systems services might alter society as a whole. The dilemma that while technologies are becoming smarter and more connected, they are seemingly getting more obscure and ambiguous too, raising some important questions related to trust. Considering that trust is a highly dynamic and complex phenomenon, for example considering aspects such as risk and uncertainty, this article sketches out how trust can be theoretically revisited and practically strengthened in situations, where both risk and uncertainty are bound to be involved. Following the introduction, the second part of the article investigates how trust in emerging technologies is reflected in current (design) literature and how its presence or lack can impact on an emergency response. The third part presents a design tool that facilitates to promote, integrate, and sustain trust. The conclusion in part 4 discussed the students' learning experiences on combining design research and practice in a master's course.

Keywords: Trust, emerging technologies, emergency health products and services

1 INTRODUCTION

Technology affects every aspect of life, society, and environment, and its development is constantly advancing and increasing in complexity. We have seen a boom of new and disruptive technologies, also known as emerging technologies, on the market, and it is predicted that these will impact almost every occupation within the next 10-20 years [1]. Everything is becoming smarter and more connected, and as a result, their opportunities, functionalities, and capabilities expand exponentially, way beyond traditional product boundaries [2]. Emerging technologies are creating many positive outcomes, such as healthcare technology improving patients' quality of life by predicting certain diseases with AI [3] or using blockchain to ensure that sensitive patient data is transferred securely between multiple parties [4]. However, given the increase of these technologies and the fact that their internal workings often are invisible and hard to comprehend, it is likely that trust in technology will change during the digital revolution.

1.1 Methodological approach and background of the study

The study presented in this article comprises a literature review and a practical project which are both parts of a master's course at the Department of Design at the Norwegian University of Technology in Trondheim (NTNU), Norway. The objectives of the course is to write a scientific article on a self-chosen topic to gain theoretical insights, to apply these insights in a project, which further explores the topic, and to present a design concept/solution. This article discusses literature trust concerning emerging technologies used in emergencies. Sources are reports, articles, and journals, that have been found mainly through Google Scholar, Scopus, and Oria. Keywords for the search were: Trust, digital trust, transparency, emerging technologies, health technology, and emergency technology. The project explored the practical side of conveying trust values and norms in emergency products. Author one and two worked with EGGs Design as partners and two supervisors from the Design Department at NTNU. The project resulted in a 'design-for-trust process' comprising a prototype of a workshop kit and an Instagram account for inspiration for designers.

2 TRUST, TECHNOLOGY TRUST AND TRUST IN EMERGENCY SITUATIONS

Trust is a highly dynamic and subjective phenomenon and certainly connected to risk: both the nature of the risk and the willingness to take on said risk. Many researchers go as far as to say that trust is only required in situations that are characterized by risk [5]. So, when there is an immediate risk to health, life, property, or environment, it seems reasonable to say that trust is fundamental - whether it is trust in oneself and one's abilities, in colleagues, in the equipment, or technological devices remains an issue that the following section will explore. Researchers have widely explored the concept of trust for the past 50 years, examining its role and implications in society. There exist several characterizations of trust [6] and McKnight provides one of the most cited and robust definitions: "*The willingness to take on risk and be vulnerable irrespective of the ability to control the outcome or trustee. All at once, it includes intentions, beliefs, behaviours, disposition, and institutions as part of a dynamic phenomenon which changes according to the nature of risk and interdependencies of a situation* [7]."

Historically, most literature has focused on interpersonal, dispositional, institutional, and inter-organizational trust, and the huge variety of definitions only contributes to the complexity of the concept. Technology trust relates to the belief that a product, service, or the underlying technology infrastructure performs accordingly to users and stakeholders' expectations and ideally adds value to the performance.

Historically, most literature has focused on interpersonal, dispositional, institutional, and inter-organizational trust, and the huge variety of definitions only contributes to the complexity of the concept. Technology trust relates to the belief that a product, service, or the underlying technology infrastructure performs accordingly to users and stakeholders' expectations and ideally adds value to the performance.

According to McKnight et. al. trust involves among principles of [8]

Functionality: having the capabilities to do a task [14]

Usability: ease of use [15] [16] [17]

Effectiveness: provide help when needed [18]

Reliability: operate consistently without failing [19].

Yet, when making the choice of trusting a product, one also chooses to trust the humans who created said artifact, and a designer should also get familiar with different aspects of trust depending on the product, device, or service and on the context of its use. For technology to become a mediator of trust between people and/ or organizations [20] a designer must convey trust via products and services. To become an intermediary of trust, a designer needs an understanding of why it is important to consider trust in a design process and how to facilitate trust-building.

2.1 Emerging products and trust

Examples for emerging technologies, are artificial intelligence (AI), 3D printing, augmented reality (AR), virtual reality (VR), robotics, drones, internet of things (IoT), blockchain, biometrics, and nanotechnology. In emerging technologies, trust issues get more complex. Many of these technologies are being used as buzzwords in media and throughout society, yet few users understand what these technologies do, or can do in the future. They often fall under the category of "black box solutions" which is defined as a complex system or device whose internal workings are hidden or not readily understood [9]. In recent decades various guidelines for identifying trust requirements in design processes related to specific domains have been developed, such as e-commerce [11], mobile vendors [12], or for establishing trust in Virtual Healthcare Communities [13].

Emergency situations, where emerging technologies are used have specific trust requirements. An emergency is defined as a "serious, unexpected, and often dangerous situation requiring immediate action". Emerging products and services imply special challenges e.g., related to the acute and oftentimes chaotic scenes of the situation. Risk and uncertainty are bound to be involved, and this makes trust issues especially interesting for designers developing these products and services. In recent years researchers have investigated what influences trust in emerging technologies [10]. Both trust and accurate, accessible, and timely information are essential for the coordination of emergencies. Proper training combined with the skills and knowledge of all professionals involved in an emergency situation are important aspects for appropriate emergency response and a designer should be knowledgeable of these factors.

3 RESULTS

The practice project lasted for 4 months and included approximately 50 participants, designers, peers, and supervisors from the department. It was connected to a specific emergency product, 'Insta-Patch'. Author 1 and 2 analysed the product related to the factors above and investigated the context of its use. Insta-Patch is an instant injury assessment and monitoring patch for fast and efficient patient monitoring outside the hospital. Insta-Patch enables the assessment of an injured or ill person's condition in any medical emergency and makes it possible to determine the priority of the patient's treatment, based on the severity of their condition - also known as triage. This product is in an early development stage and the inventors of lnsta-Patch were asking questions such as: 'Would you have dared more if a small patch from the first aid kit could tell you what condition the injured person is in?' This question indicates that daring to use this kind of patch to save lives has a comparatively high threshold and that strengthening the confidence, or trust, in the product – might lower this threshold.

Insta-Patch is supposed to convey vital parameters, detected by sensors in the patch, on the screen of the patch, or through an app. The connection between the patch and the app is based on a Bluetooth connection, as well as a QR-code for identification, which is not unproblematic since Bluetooth is a comparatively old technology, introduced in 1989. Although the technology has improved considerably since then, many people still associate problems with connection, for instance to speakers or headsets, with Bluetooth. According to the guideline above, a relevant question is: What happens if a medical care worker uses valuable time failing to connect, while lives or health are at stake?

The app and the patch are connected to ensure patient triage and communication of vital parameters. The app algorithm triages patients in red, yellow, and green zones, depending on their injuries. Triage is usually done manually, by assessing some defined parameters such as pulse and respiratory frequency and attaching paper tags on each patient. The algorithm does not necessarily present a trust problem, but the connotation of 'algorithm' is associated with something abstract and obscure by laypersons. Furthermore, people might distrust that the sensors in the patch read the data correctly. What if it is not attached correctly? Will it manage to take vitals correctly if there is a lot of blood spillage?

Besides the need for flawless technology, Insta-Patch must be introduced understandably and realistically to the users. This is particularly relevant in the context of an emergency because first responders (often lay people) must be knowledgeable to trust an unfamiliar (sometimes emerging) technology to assess and/or treat a potentially life-threatening condition that they are unlikely to have encountered before. Findings from the product analysis and the interviews pointed towards supplementing functionality- usability-, effectiveness- and reliability principles with intersubjective components to facilitate trust between people and organizations. When promoting and implementing a product or a service it is among others important to consider users' privacy, security, and transparency of information. Moreover, a product that users can handle with confidence and trust, is related to encouragement and inclusion.

3.1 The designers trust kit

Trust is subjective, relational, and contextual simultaneously, and the extent to which users trust a product or system is a consequence of both their individuality, the characteristics of the system, and the context of use. Project findings from above led to a greater human-centred design focus and changed the goal: from improving trust in one specific product shifted to developing a trust kit comprising of tools that should make it easier for designers to understand and improve trust in their projects, to "melt" trust into the designer's current ways of working. Author 1 and 2 conducted 10 semi-structured interviews with EGGs designers and 2 workshops EGGs designers, other practicing designers, peers, and supervisors. The result is a concept comprising three phases and three levels, where trust can be included in product service and systems design, shown in Figure 1 below. Figure 2 shows the 3 trust tools for the consideration phase. Each phase 'consideration', 'development' and 'implementation' includes tools. In the project, only the tools for the 'consideration' phase were developed, due to time constraints. The phases represent basic steps in the design process, the levels and tools were selected by the EGGs designers, who also decided by vote which tools they would like to use. Based on the voting three trust tools were created:

01 TRUSTSPIRATION an Instagram Account (IG)
02 A Workshop kit for consideration phase. (WS)
03 A prototype of a Design for trust app.

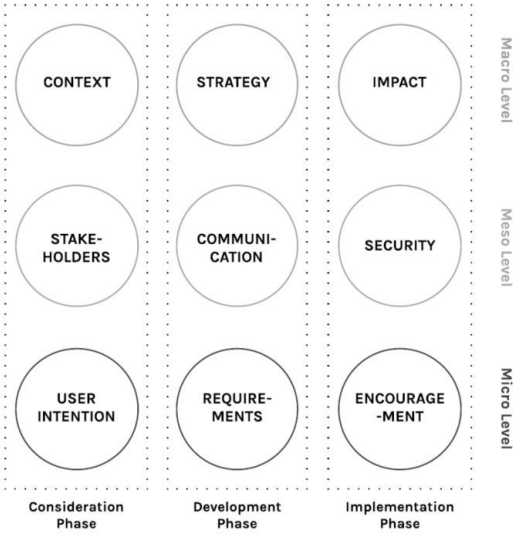

Figure 1. Trust phases and levels

01 Trustspiration

Trustspiration is an instagram account that shares a new perspective on the complex and dynamic phenomena of trust. By channeling the knowledge and insights we had collected throughout research and literature in a low threshold way, we hoped to give designers the tools and inspiration they need to incorporate and strengthen trust in their projects.

02 Design for Trust Workshop kits 1, 2 and 3 (prototype)

This solution consists of 3 unique kits designed for each phase of the innovation process; Research, Development and Implementation. By sorting the knowledge we had collected throughout research and literature in three separate phases, we hoped to be able to give designers the appropriate advice at the best fitting time.

03 Design for Trust app (prototype)

The Design for Trust APP is an open collection of tools and advice that helps designers take trust into account with just a click. The app should display insights we had collected throughout research and literature through an easy to use app, where it should be possible to customize trust-tips according to where in the design process the designer was.

Figure 2. Suggestions for three tools in the trust kit consideration phase

4 CONCLUSIONS

The exploratory research on trust and the development, the design of the trust kit presented in this paper is a work in progress and has become the topic of the master's thesis of the first two authors in spring 2021. The mentors at EGGS and NTNU agree that trust is a worthwhile subject to pursue and encourage the students in analysing the Design-for-trust-process further. Even though the project has changed its direction along the way, its connection to literature and theory has remained. This has given the students valid arguments to refine their Trust-kit concept.

The students, who are the first two authors of this article, assign the combination of theory and practice in the master's curriculum a great learning effect: "… we have learned to not be afraid of digging deep into theory, even though it might seem scary. We have been frustrated and confused at times and we have felt limited - but we have also seen that exploring theories and relating them to a project, actually opens up a world of infinite possibilities - that are highly motivational to work with. The designers and engineers, who develop and transform technologies, products, businesses or services, may express values and norms through what they make, which again might influence the behaviour of individuals or even the practices of society. We have realized that when making the choice of trusting something, one simultaneously chooses to trust the someone who created it. In this sense, what we as designers craft, becomes a mediator of trust between people or organizations."

Trust in technology is a topic that is rarely discussed in design curricula, yet it relates strongly to students' capacity building, especially in the light of emerging technologies and related roles and responsibilities of professionals. The master's course at NTNU provides students with the opportunity to explore non-technical issues and connect them with technical designer skills, thereby contributing to a more holistic engineering design education.

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LESSONS LEARNED IN THE DEVELOPMENT OF AN ONLINE 6-3-5 DIGITAL DESIGN TOOL FOR DISTRIBUTED IDEA GENERATION

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ABSTRACT
In a year, which has observed a change towards more online teaching and learning, there is still a limited number of online collaborative design tools which can support distributed design activities. A prototype online tool to support 6-3-5 (known as the 6-3-5 method or brainwriting) was developed, at the Department of Design, Manufacturing and Engineering Management (DMEM), University of Strathclyde, to support idea generation. The software is accessed through a web browser and guides through the 6-3-5 method. Students can conduct the activity in a synchronous mode (live) supported by text or video chat, or in an asynchronous mode. This paper discusses the design and development of the online 6-3-5 tool and key requirements for its further development including its suitability for both use by distributed design teams and as an educational tool. The outcomes of this research are the lessons learnt in developing the prototype online tool, its evaluation and the identification of further creative methods that could be digitised in the future.

Keywords: Distributed design, design activity, creative design methods, 6-3-5 method, design tools

1 INTRODUCTION

Design methods allow for the creation of design ideas using recognised processes. Design methods are well established, used in industry and education to achieve a particular goal to meet outcomes. While collaboration and communication tools have developed with new computer technologies, there appears to be fewer digital/online creative design methods compared to physical creative methods.

Digital design methods support design activities and involve using computer devices, allowing for design ideation to occur. This can be collocated or distributed. One of the most common online tools is the digital whiteboard, where many users can contribute ideas as reported in papers such as Vidovics et al [1]. Design activities conducted on a digital whiteboard tend to replicate those on a physical whiteboard in a collocated space. This realisation can be compared to many of the digital design online tools using existing web 2.0 functionality. They manage and capture the design process, e.g., storing design documentation in a prescribed way or recoding and digitising design outputs. Several developments on a shared whiteboard have emerged and are commonly used by design teams including Miro (miro.com), Mural (mural.co), Sketchboard (sketchboard.io) and others. Some include specific templates for designers including decision making frameworks or ideation brainwriting.

There are many case studies reported in the literature of distributed design teams conducting design activities as online technology capabilities grow, including synchronous CAD [2], social network sites [3], collaborative document editors [4], learning management systems [5], and video conference [6] for a range of design activities including design review meetings, democratic decision making (voting/polling), annotating concepts, CAD development and a range of design methods including TRIZ, design alternatives, market research and feedback from stakeholders.

Over time, there have been novel developments of design methods and tools which are inspired by computer functionality. ICR (Inform, Create, Reflect) is a digital design activity using Microsoft OneNote, which enables design teams to collaborate on the development of ideas by passing and adding information to concepts [7]. The ICR method supports more complex and developed ideas compared to other design methods such as 6-3-5. However, the novelty of the concepts is questionable and significantly less concepts are generated by team members than with physical 6-3-5. Sketchy [8] is a

digital design tool that allows designers to draw ideas on their own mobile or computer device individually, but they can be inspired by other collaborators using a 'peek' feature. 'Peek' allows a design team member to quickly watch another team member who is also drawing in real-time. The designer then can update their own ideas based on inspiration from others.

1.1 Experiences of the 6-3-5 Method

6-3-5 is a design activity similar to brainstorming but with more benefits, including extended thinking time for participants and reduced impact of dominant team members [9]. The 6-3-5 method has been attributed to encouraging more creative concepts, especially for students who have skills in longer concept generation projects, such as mechanical engineering students [10]. For educators, 6-3-5 is simple enough to explain, conduct, discuss and reflect upon during a typical tutorial session [11] which perhaps explains its popularity within an educational setting. Furthermore, students are more likely to apply design methods in the future when they learn by experiencing the technique within exercises or workshops [11].

At DMEM, University of Strathclyde, students utilise computer technology to support distributed collaboration when physical collaboration is impossible. The design method which is most commonly and successfully used to generate ideas, face-to-face, has been the 6-3-5 design method, where six team members are challenged to draw three ideas in five minutes. After the five minutes, the team members swap drawings, develop the other team members ideas for another five minutes, and so on for six rounds. In a distributed environment, students typically facilitate this design method by drawing their own three ideas and then photographing or scanning the ideas and sending them to their fellow team members. This is complex and time-consuming; however, students appreciate the systematic nature of this design process.

Due to successful use of the 6-3-5 tool within distributed collaboration projects, there was a motivation to investigate if an online version of 6-3-5 could be developed that supports online idea generation and also educators in teaching the method. In this paper, the requirements of an online 6-3-5 tool are described, the development of a prototype online 6-3-5 tool is documented and an evaluation of its use in a student design class is reported. This paper shares the considerations of building the online 6-3-5 design tool, the process undertaken to develop the tool and the lessons learnt which may influence others who are considering developing online creative design tools.

2 BUILDING AN ONLINE DISTRIBUTED TOOL TO SUPPORT 6-3-5

The online 6-3-5 tool was inspired by the game Drawful™ (jackboxgames.com/drawful) and subsequent versions of the game by developer Jackbox Games. In this game, players draw an image on a mobile device based on a prompt. All players then vote on the 'best' image, which meets the prompt. This has analogies with creative design methods where designers generate ideas based on a brief, by drawing concepts and then selecting the most suitable idea based on user requirements. As Drawful™ is a party game that is often played with friends, it was considered that a similar tool could be developed which supports the creative design process. A design method was required that enabled individuals to generate many ideas by drawing. This is where the success of 6-3-5 within DMEM and the implementation of a drawing design method came together. The success of the 6-3-5 in classes to produce numerous ideas and the playfulness of the online party game were the basis of the requirements of the 6-3-5 online tool.

2.1 Requirements of the 6-3-5 tool

Requirements for a digital creative design tool cover a range of categories, including functional, data, environmental and contextual, user-centred and usability [7]. The authors used this work to establish the requirements of the 6-3-5 online tool (see table 1).

The requirements identified a need for the host of the instance (in other words a 6.3.5 session) to alter the rules of 6-3-5 based upon the number of participants. Also, there is a need for the participant to be guided through the 6-3-5 method if they are new to the tool. This led to the realisation that this digital tool could be a useful educational resource for students and others who are new to the 6-3-5 method of generating ideas. The requirements of this tool were established as:

1. Based upon the established requirements for an online 6-3-5 tool, a user journey was created to communicate the sequence of events to the programmer to set up and conduct a digital 6-3-5 activity. This included five critical areas of the digital tool: A 'Start' page where a host could setup the instance or a participant can join.
2. A 'New instance' page featured a setting for the number of participants, time per round and number of rounds. The User can enter the 'theme' of the drawing ideas at this time.
3. A 'Joining information' page where the User can join a digital 6-3-5 instance.
4. A 'Drawing' page where the User draws their ideas, with subsequent pages for each round.
5. A 'View and download/ screen for all ideas generated.

Pages from the visual user journey document are illustrated in *Figure **1***.

Table 1. Requirements for an online 6-3-5 tool

Functional	The User should be limited by the rules of 6-3-5. The host should be able to change the rules-based upon the requirements of the task (e.g., more time, less participants etc).
Data	The User and the host can view all drawings digitally and download each drawing.
Environmental and contextual	The system should be easy to access on a computer device. The system should allow drawing with a mouse or touchscreen.
User-centred	Instructions should be easy to follow, including for those who have never conducted a 6-3-5 before.
Usability	The User should be guided through the 6-3-5 process.

From discussions with the programmer, a methodology was agreed for the creation of the online tool. Due to the complexity of developing a web app and mobile app, the programmer suggested working on a prototype web app first, to ensure a working prototype.

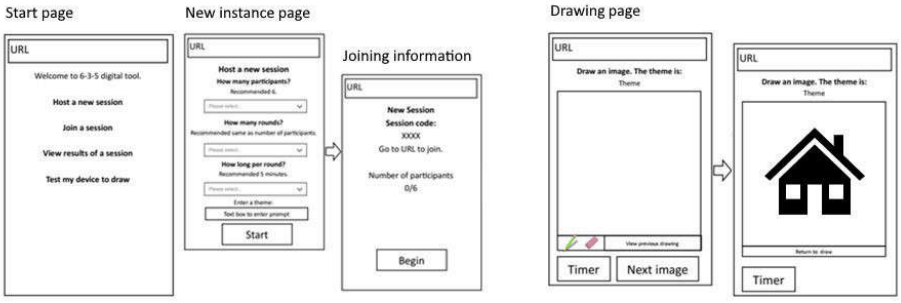

Figure 1. Example pages from the visual user journey document

2.2 Coding the prototype 6-3-5 online tool and its functionality

The 6-3-5 online software was written in PHP, Smarty and JavaScript, and stores its data in a MySQL database. The software allows a number of participants to be specified for the activity from a pool of registered users by the instance owner. When an owner starts an instance, the database is populated with a unique identifier for the input drawing for each User, for each round, of the entire 6-3-5 instance – this is achieved by an algorithm that iterates over arrays of users, and their position in each round. This algorithm can accept a variable number of users, as required for each instance.

As users complete drawing tasks and submit them back to the system (as base64-encoded image data along with encoded identifiers and metadata), it records the completion of an individual drawing and then creates links for users in their 'to-do' list of drawing tasks. Users can only begin their drawings when the prerequisite input drawing is available. The required drawing functionality for the 6-3-5 task is generated via a drawing module modified from an open-source painting package named miniPaint (available at: github.com/viliusle/miniPaint).

Depending on the round and number of participants, at any given instant, each participant can have different amounts of drawing tasks available for them to perform, and those drawing tasks can be from

several different rounds of the overall instance. A user can participate in any number of 6-3-5 instances concurrently. Owners of a 6-3-5 instance can see all drawings from all participants at any time. Participants can see all drawings in all 6-3-5 instances they have participated in only when that instance has concluded, or the owner has ended it.

3 USING THE 6-3-5 ONLINE TOOL WITHIN AN EDUCATIONAL SETTING

With a prototype created, the next step was to evaluate the prototype 6-3-5 online tool in its initial form. To support the evaluation, a framework was developed with university students, some who had used 6-3-5 before and others who were learning to use 6-3-5 for the first time.

3.1 Research Methodology

The prototype 6-3-5 online tool was introduced to third year students of the DM306 Product Development class at DMEM. There are 95 students in this class, working in teams of 5. Students had two-year's experience with design methods and were new to the 6-3-5 method. Students were introduced to the 6-3-5 paper-based method and then introduced to the prototype 6-3-5 online tool. The class was hosted on Zoom (due to Coronavirus) and utilised breakout rooms to allow each team to complete the 6-3-5 activity using the prototype 6-3-5 online tool. The prompt for the 6-3-5 activity differed across each team, based on the established problem areas they were investigating. Teams were supported by two class lecturers, two class tutors and a facilitator who led the workshop. Staff switched between breakout rooms to ensure students could use the prototype 6-3-5 online tool and understood the 6-3-5 method as they progressed. A survey was created to capture the students' opinions. It queried the prototype 6-3-5 online tool and comparisons with paper based 6-3-5 and requested suggestions for improvement.

3.2 Survey Results

29 students responded to the survey, two of whom had experience with the 6-3-5 method before.
One of the aims of the 6-3-5 online tool was to guide students through the 6-3-5 method to educate them on how the method works. Students were asked if, in their opinion, the prototype 6-3-5 online tool guided them through the method. 15 Students said, 'yes, they were guided' and 14 students said, 'no, they were not guided'.

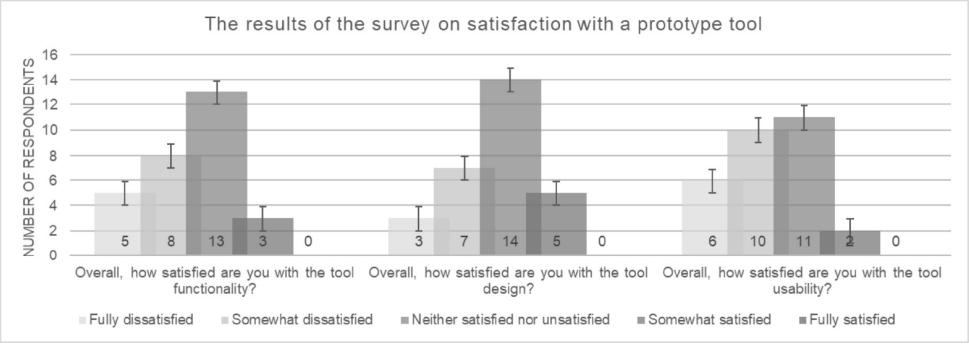

Figure 2. Results of a survey on satisfaction of the functionality, design and usability

On a scale of 1-5 from not satisfied to fully satisfied, students were asked three questions: (1) Overall, how satisfied are you with the 6-3-5 online tool functionality? (2) Overall, how satisfied are you with the 6-3-5 tool design? (3) Overall, how satisfied are you with the 6-3-5 online tool usability? Responses can be seen in Figure 2 including error bars of the sample of respondents (29) against the population of the class (95) with standard deviation of ±0.911. For each of the questions, the most popular response was 3 (neither satisfied nor unsatisfied) - 13 responses for functionality, 14 for design and 11 for usability. Responses were slightly more positive towards satisfaction for design and less favourable for usability. The two students who had experienced 6-3-5 before preferred the paper-based 6-3-5 method and noted that they would use paper based in the future.

4 DISCUSSION

The development of the prototype 6-3-5 online tool came out of a necessity to move to working/studying online. It was difficult to conduct a 6-3-5 creative activity online during class, and so a tool that guided the students through the 6-3-5 process was developed. Based upon the response from students, there were some issues with the prototype 6-3-5 online tool. Only 51% of the students said that the prototype 6-3-5 online tool guided them through the 6-3-5 process. Student feedback suggested some functionality improvements, such as more informative instructions

The students did not 'learn by doing' whilst using the new online tool. When conducting 6-3-5 on paper, students needed to fully understand the process. Across Zoom, explanation was confusing for students as there was no practical activity to support understanding. When conducting the 6-3-5 method using the prototype 6-3-5 online tool, the automated mode diminished their understanding. This should be cautioned against within an educational environment.

The students found issues which may have influenced their scores, including team members names being missed and overcomplexity of the drawing tool. These were not expected to influence opinions of the prototype 6-3-5 online tool as much as they did. This proved to be good initial feedback.

However, these were not the main issues with the response to the satisfaction questions. In terms of functionality, students considered the prototype 6-3-5 online tool satisfactory. Students noted that functionally was complex. For example, the drawing module offered too many drawing options. The drawing module was as complex as a photoshop clone when all that was required was a pen tool and an eraser tool. The drawing module responded in ways that the students were not expecting. For example, students anticipated drawings would be saved automatically; the default colour was green rather than black, and it was not easy to delete or erase parts of the drawing. These aspects influenced the student's evaluation of the prototype 6-3-5 online tool but can be fixed easily with a simpler drawing module. Usability scored lower for similar reasons.

Another concern based on the survey results was the fact two students who used 6-3-5 before preferred a paper-based 6-3-5 mode, even if improvements were made. This was based on students' dissatisfaction with digital capabilities and the complexity of a digital tool compared to paper. This was unexpected as the tool had been based on the Drawful™ game. It could be considered that without enjoyment, the digital tool no longer becomes an attractive alternative to physical drawing. It should be noted that the sample size of two is not significant enough to make meaningful decisions about the development of the prototype 6-3-5 online tool but is an indication to investigate further.

overall, considering the requirements in The requirements identified a need for the host of the instance (in other words a 6.3.5 session) to alter the rules of 6-3-5 based upon the number of participants. Also, there is a need for the participant to be guided through the 6-3-5 method if they are new to the tool. This led to the realisation that this digital tool could be a useful educational resource for students and others who are new to the 6-3-5 method of generating ideas. The requirements of this tool were established as:

6. Based upon the established requirements for an online 6-3-5 tool, a user journey was created to communicate the sequence of events to the programmer to set up and conduct a digital 6-3-5 activity. This included five critical areas of the digital tool: A 'Start' page where a host could setup the instance or a participant can join.
7. A 'New instance' page featured a setting for the number of participants, time per round and number of rounds. The User can enter the 'theme' of the drawing ideas at this time.
8. A 'Joining information' page where the User can join a digital 6-3-5 instance.
9. A 'Drawing' page where the User draws their ideas, with subsequent pages for each round.
10. A 'View and download/ screen for all ideas generated.

Pages from the visual user journey document are illustrated in ***Figure 1***.

Table 1, the majority of students are satisfied with the prototype 6-3-5 online tool. In terms of Functionality the 6-3-5 rules have been implemented and the host can change the rules. This indicated that the 6-3-5 method can be transferred to a digital platform. In relation to Data and the User, the host of an instance can view and download all drawing ideas. Regarding Environmental and Contextual issues, the system was easy to access through a URL, and allowed for drawing with a mouse. Other drawing methods such as touchscreen of digital pen should be investigated. To improve user-centred design aspects, the instructions will be made easier to follow on-screen with a more intuitive process. Finally, usability requires some significant changes to allow the participants to conduct a 6-3-5 online and to be guided through the process more readily.

4.1 Future development of the 6-3-5 online tool

The prototype was a significant first step as a proof of concept, but highlighted areas critical to the development which were not considered within the initial requirements. The first change is to simplify the introduction of the 6-3-5 online tool and the instructions on how to use the system. Information on what to do should be delivered as it is required. This will improve its use as an educational tool. The second change is to simplify the 6-3-5 online tool to remove unnecessary functionality. This change will simplify the drawing experience to allow quick ideas to be generated. The third change is to make the 6-3-5 online tool more enjoyable to use. Indeed, the change of input. from mouse to digital pen or touchscreen would be a first step. It is reported that mood and visual stimulus can affect the creativity of outcomes from a 6-3-5 activity [8], and the suggested changes would encourage more creative outcomes.

The low sample size of the students who had used 6-3-5 before impacted the results. A further study with students experienced in 6-3-5 will reveal accurate results supporting the next version of the 6-3-5 online tool. There is also a need to conduct further studies with those unfamiliar with 6-3-5 to determine the level of simplicity required to help with student understanding of the method.

5 CONCLUSIONS

This paper documents the early development and evaluation of a prototype 6-3-5 online tool to support distributed idea generation. The reporting of this tool's development and data on how students responded to its use is novel. The need for a 6-3-5 online tool was established from observations of a distributed design class where the 6-3-5 method of producing concepts was successful in supporting global design. The inspiration for the 6-3-5 online tool came from a party videogame that influenced the tool's design. These factors generated requirements for the 6-3-5 online tool and created a user journey map. The web app was coded to the rules of the 6-3-5 method and the requirement to allow multiple instances at once. To evaluate the tool, students were asked to use it within distributed design teams. The results highlighted several areas for improvement and identified educational aspects such as understanding of the 6-3-5 method and the comparison of the digital tool to pen and paper. Aspects in the development of the 6-3-5 online tool, which were expected to be entertaining, conversely added complexity to the method and require simplifying and increasing engagement. The next development of the 6-3-5 online tool will be undertaken in the 2021-22 DMEM classes.

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ETHICS IN DESIGN EDUCATION, BUT DIFFERENT; PRACTICING THE PRACTICAL TURN

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ABSTRACT
Design education has looked for different approaches to teaching ethics and ethical behaviour. In this paper I want to add an approach that is coming from the collaboration between design research and philosophy of technology. Philosophy of Technology has produced a substantive number of theories and reflections about the impacts of technology and innovations on our daily lives and social behaviours. To make the reflections from philosophy of technology more tangible for design engineering students we experimented over the years with different tools and practical approaches in order to integrate these perspectives directly in the design process. In analogy with the empirical turn before, we named this closer integration with design 'the Practical Turn in Philosophy of Technology'. My argument now is that by using these insights, one can cultivate ethical reflection with design engineering students by directly informing their design process in what I call 'practicing the practical turn'.
In this paper I will show this approach alongside the results of a one week workshop with a group of students from the University of Antwerp in the context of responsible design for public space.

Keywords: Ethical reflection, practical turn, philosophy of technology, social design, responsible design

1 INTRODUCTION

Industrial Design Engineers have social responsibility by the very nature of their activities; bringing new products and services into the world of the user [1]. This responsibility calls for ethical awareness in the education of future design engineers, as they will be influencing the impacts of technology on people and society for better or worse. In our curriculum at the University of Twente we approach this responsibility from the perspective of human-technology relations on three different levels [2]. The first level is the individual relation between a user and product, where we want to emphasize that good design starts with understanding and designing the intended relation, before shaping the actual technology. At the second level we look at how products can influence and shape relations between people; the social level. The highest level is the societal level; where design can address issues like sustainability, healthiness, and inclusivity. In order to show how responsibility and responsible behaviour in this context should be understood we developed the framework of Responsible Design [3, 4] where three different strands provide for practical tools and theories in; (1) designers acting responsibly, (2) enabling others in society to act responsibly, and (3) producing things that do not destroy the world. The first strand is mainly informed by human centred design. The second and third strand are in our context heavily informed by philosophy of technology.

2 DESIGN, ETHICS, AND PHILOSOPHY OF TECHNOLOGY

Philosophy of technology has produced a substantive number of theories and reflections about the impacts of technology and innovations on our daily lives and social behaviours. Collaboration between design research and philosophy of technology for responsible design is therefore very promising. The reflective, philosophical perspective brings the societal implications of design to the fore. Since the philosophy of technology in the current of the 'empirical turn' aims to study concrete technologies and contexts, contributions from philosophy to design have become all the more feasible. Design research can use the frameworks of philosophers to theorize the findings from practice, to make sense of the past, and for ethical reflection on the impacts of design and the moral responsibilities of designers. Or, still more practical, philosophical insights in the relationships between humans and technology can contribute to design for usability and design for behaviour change [5]. On the other hand, the practice

of designing actual things provides a laboratory for putting philosophical frameworks to the test and to use in the real world [6]. A clear example of the use of philosophy of technology in the development of ethical awareness is the concept of ethics in technology by Verbeek [7]. Moreover, Verbeek coined the idea of "technology design as experimental ethics" [5] and argues that by carefully assessing, anticipating, and eventually shaping the influences of technology, designers can take responsibility for the inevitable changes (for better or worse) they will bring to the lives of individual users, the dynamics of social groups, and society at large.

One can critique however with Sonneveld that "ethical reflection in design, considering values such as wellbeing, safety, autonomy, responsibility, and so on, is often a theoretical perspective: focussed on abstract users and abstract use situations […] Although illustrated with concrete examples, the theory remains theoretical, searching for a general position a designer should develop towards users." [8] One way to overcome this is to focus on the development of the designer as a person and promoting the awareness of both professional and personal values [9, 10]. I recognise this is highly valuable, however also want to advocate a complementary approach here.

To make the reflections from philosophy of technology more tangible for design engineering students we experimented over the years with different tools and practical approaches [11-13] in order to integrate these perspectives directly in the design process. In analogy with the empirical turn before, we named this closer integration with design 'the Practical Turn in Philosophy of Technology' [14]. My argument now is that by using these insights, one can cultivate ethical reflection with design engineering students by directly informing their design process in what we call 'practicing the practical turn' [15].

3 PRACTICING THE PRACTICAL TURN

In this paper I will explore this approach, based on the experiences with a one-week Industrial Design Workshop at the University of Antwerp. Here, 17 second and third year bachelor students executed a conceptual design project for the improvement of public space. During the process they experienced and applied tools and theories we developed in the context of the Practical Turn. A total of three different tools an theories were explored, respectively *Utopian Technology* [16], the *Product Impact Tool* [17], and *Open Script Design* [18]. Within a total of five design projects the results ranged from an open electric bike-sharing system to a bus-stop that fosters ethical discussion.

4 WORKSHOP WEEK 'RESPONSIBLE DESIGN'

The actual workshop was based on the concept of responsible design. The word "responsibility" contains the verb "to respond". One can therefore interpret responsible design quite literally by responding to the needs of society. The workshop was meant to explore this by researching the concept of Open Script design, as developed by Stam [19]. Open script design means that some designs are more open for interpretation by the user than others. Think of LEGO bricks versus a Barbie Doll. In theory, an open script will also delegate the responsibility from the designer to the user and therefore enable them to 'act responsibly' [4].

4.1 Set up of the workshop

-- Introduction + "Valuable Object"	Modernism/Post-Modernism + Utopian Design	Mediation Theory + Finding Product/situation/ service to redesign + Documenting/PIT	Concept design	Preparation of Exhibit Feedback on Results
Setting up first part of Exhibition	Finding Utopian Design Examples + Setting up second part of Exhibition	"Opening-up the script"	Prototyping	Setting up final part of Exhibition Exhibition and Drinks

Figure 1. Set-up of the one-week (Monday-Friday) workshop with morning (top) and afternoon (bottom) sessions

Figure 1 shows the full program of the workshop. It started Monday morning with a sort of warming up round around the question of value of products and ended with the presentation of the workshop results in a physical exhibition at Friday afternoon. The students had to bring (a picture of) an object that was valuable to them and then explain each other why this was the case. The students then set up the first part of the exhibition, showing the results of their discussions. Adhering to the central theme of "responsibility", the students had to find out themselves (and negotiate together) how to do this best. In the meantime, the participating students were divided in 5 groups according to their own liking. These groups stayed together throughout the rest of the week. On the second day we looked into the concept of Utopian Design and on Wednesday the groups had to formulate themselves a design challenge in the form of a specific public space (problem or challenge) to redesign.

4.2 Results of the workshop

Utopian Technology is a philosophy of technology perspective on design by Dorrestijn [20], based on the notion that in design history, several periods and accompanying movements are distinguishable that envisioned to radically change society through design. In the approach he uses Arts & Crafts, Modernism, Late modernism, and Postmodernism as possible guiding principles. These four periods then respectively lead to a 'restorative', a 'socially-functionalistic', a 'technology-at-a-human-scale', and a 'diversity-of-lifestyles' utopian vision on design. After a thorough explanation of these concepts, the students were sent out to find examples of designs and situations that could reflect these different visions in public space. Figure 2 shows some examples of images that the students presented after this exercise. The café-table with raw planks is a typical example of a restorative utopia where the connection with nature stands for honesty in material use and craftsmanship, resulting in what is supposed to be an improved experience of 'being human'. The public bike sharing system on the right is a fine example of the socially-functionalistic perspective on society; all the bikes are the same and the user has to obey to the system (taking out and putting back the bike in a pre-defined place) to make it work. The electric scooters in the middle are part of a sharing system without docking stations. The latter is improving the user experience on an individual human scale, however the students also recognised that the individual behaviour of users was a cause of collective nuisance, because of discarded or abandoned scooters scattering around the streets. This led the student group to rethink and redesign the system in the second part of the workshop.

Figure 2. Examples of Utopian Design that were collected outside the classroom by the students: restorative, technology-at-human-scale, and socially-functionalistic

"Opening up the script" means that you can reconsider products, designs, or situations to be more open to the preferences of the user. This openness can both be applied to the functionality as well as to the meaning of an artefact. A picnic blanket can for instance also be used as a cover for protection against the rain. The same blanket can also be both protective ("this is my spot") as well as inviting ("come sit over here"). Openness can also mean that there is room for a contribution of the user, for instance when you are decorating the picnic blanket yourself.

In the exercise the students were asked to think of aspects that were related to their design challenge and find out how they could be more 'open' or 'closed'. Figure 3 shows an example of opening up the script of an amphitheatre by the student group that set themselves to redesign public playgrounds. The openness of the script in the redesign was about functionality; the amphitheatre could also be used as stepping stones or obstacle course. Interestingly, the redesign also showed a counteracting effect as the audience in the traditional amphitheatre setting would have more possibilities to sit together.

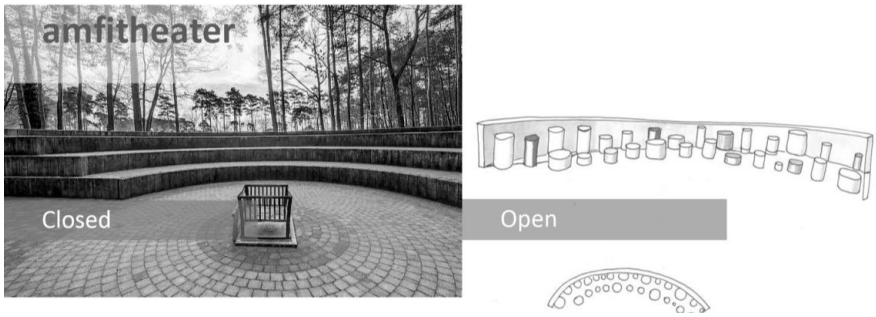

Figure 3. Example of open-script and closed-script comparison and ideation of a student group (by Janne Caenen, Lotte Van Hoofstat & Salma Yachchou)

The Product Impact Tool is a framework, derived from Philosophy of Technology and User Centred design that addresses the multitude of impact types that technologies have on humans and human behaviour [17]. It offers a repertoire of exemplary types of impact, presented as different sides or different levels of affection. The impacts, or influences are categorized in four quadrants, named *before-the-eye, to-the-hand, behind-the-back, and above-the-head.* The student groups had to use the worksheet to analyse their design challenge and ideate problems and solutions within all the four quadrants (figure 4). The interesting thing is that the tool forces to also think of the less obvious and sometimes hidden effects of technology. By making several 'rounds' through the four quadrants, these often unwanted side effects come to the fore [12]. The positive side-effect of the exercise itself is that it naturally becomes apparent that solutions can also come from all four quadrants.

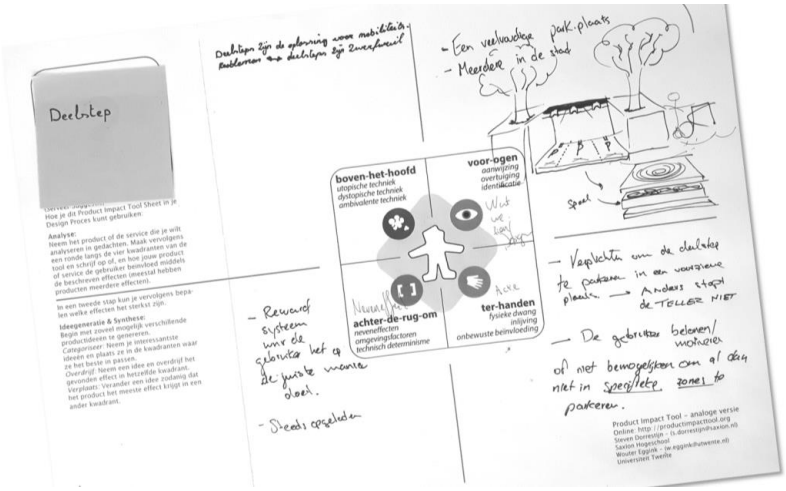

Figure 4. Example of Product Impact Tool analysis and ideation (steps project) of a student group (by Kobe Baudewijns, Emile Cognie, Pieter De Beucker & 1 other student)

After the documentation phase and the analysis and ideation with the product impact tool, the students had to develop their concepts and present them at the end of the day. Some examples of the ideas presented by the student group working at the electric scooter system are shown in figure 5. One might say that due to the priming exercises with utopian design and opening up the script, the presented solutions differed heavily. The first solution, depicted on the right is based on the principle that the scooter system itself will not allow to discard them in an unwanted place (the red areas). This can be seen as a correction on the technology-at-a-human-scale solution, where the responsible behaviour is build-in in the technology itself. The students recognised that this is then actually also a movement in the direction of the socially-functionalistic utopia because the user has to obey to the system. Also, problems may arise when the system is not absolutely clear in communicating the 'forbidden' areas.

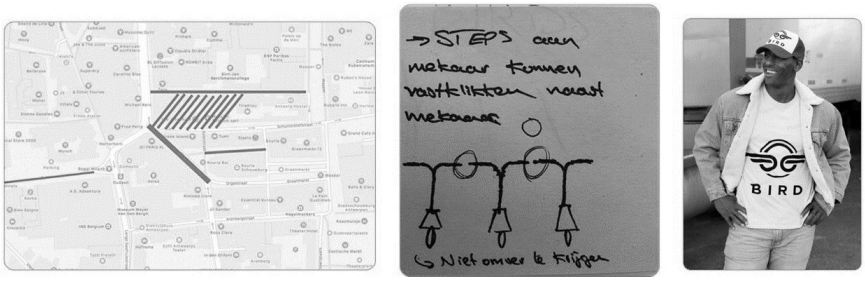

Figure 5. Visuals of ideation for solutions on the problem of nuisance by an electric step sharing system (by Kobe Baudewijns, Emile Cognie, Pieter De Beucker & 1 other student)

The second solution, sketched in the middle was geared towards cooperation. The scooters could only be discarded by connecting them to another scooter, thus resulting naturally in the socially-functionalistic ideal of 'neat' rows of scooters. This would also prevent them from falling over, which was unwantedly associating them with rubbish. The last solution depicted here was based on stimulating preferable behaviour by incentives. The 'good' user would be rewarded with specific merchandise. This is very much related to the diversity-of-lifestyles utopia, where the user remains totally free to choose their behaviour. The idea was also that the users behaving properly would become natural ambassadors for the scooter system. This led eventually to a new discussion whether this was desirable. By being connected to the brand, the ambassadors could also become held accountable for the misuse of others.
This paper leaves no room to show all the results of the five student groups and the associated exhibition, however I hope that I have shown how the different philosophy of technology inspired exercises stimulated the ethical reflection among the students in a natural and practical way. This by showing them the dilemmas connected to design, coming directly from their own results in practice.

5 DISCUSSION

Apart from having interesting design results, the project shows how design can make tangible the inherent dilemmas and conflicts in designing for public space, where collective responsibilities and individual concerns often collide. Supported by the exercises and presented theories, this led to both a high amount and a high level of ethical discussions during the week. In my opinion it did not so much lead to better designs in the sense that they would be readily applicable, however the students were in the end very profound in explaining the dilemmas around their designs and in defending their decisions. In interpreting the positive results of the different tools, one should however take into account a possible bias in the group of students as they all applied voluntarily for a workshop about responsible design. So, one might expect that they were also more than averagely interested in ethics in design. However, there was no mentioning ethics in the first place. It is that with the practicing of responsible design, the ethical discussions come naturally to the fore.
In the end, the experiences were more interesting than the results, although the experiences could not have been so interesting without the intermediate design results. This is what we call the reciprocal effect of the combination of design with philosophy of technology [15]. The conceptual designs are informed by the reflective analyses of the philosophical tools, while in turn, the ethical reflections are informed by the practical examples of the concrete design proposals.

6 CONCLUSIONS

The experiences -even more than the results- during the one-week workshop make a case for the Practical Turn, that shows an inherent reciprocal effect. Through the materialization and visualization of ethical and social issues with design -based on the ethical reflection from the philosophical tools and theories- the ethical reflection in its turn is explicated. By practicing the practical turn, students can experiment with and 'feel' the ethical dilemmas and conflicts of their future profession in a way that is very closely related to their design practice.

ACKNOWLEDGEMENTS

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THE ONLINE PBL (PROJECT-BASED LEARNING) EDUCATION SYSTEM USING AI (ARTIFICIAL INTELLIGENCE)

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ABSTRACT
This paper proposes the project-based learning (PBL) education system which uses Artificial Intelligence (AI) instead of teachers' direct instruction. Kanazawa Institute of Technology (KIT) applies PBL to its design and engineering programme as Project Design (PD) Programme. Students form small groups to discuss real-life problems and sometimes collaborate with local communities. However, in order to prevent COVID-19 infection, students cannot go to school. Instead, e-Syllabus and the web meeting Zoom (videoconferencing software) are used to take lectures at home. Adding to the PBL class implementation experience under the impact of COVID-19 and to the review results of the progress of digital technology, the outline, and the feature of the on-line PBL education system using chatbot and AI is proposed. Although the system is still under development, some of the components are introduced.

Keywords: PBI, Artificial Intelligence (AI), COVID-19, online, e-learning, chatbot, text mining

1 INTRODUCTION

The importance of problem-based learning and project-based learning (both abbreviated to PBL) is perceived in engineering education and in addressing the Sustainable Development Goals (SDGs). Kanazawa Institute of Technology (KIT) applies PBL to its design and engineering programme as Project Design Programme (PD). The programme aims to grow up independently minded, actively engaged engineers. PD consists of 5 compulsory courses which are held in 12 departments in all four colleges: College of Engineering, College of Informatics and Human Communication, College of Architecture, and College of Bioscience and Chemistry. The focus of this programme is the use of the design process to solve the problems, and at the same time, to enhance students' innovation skills rather than specific engineering theories. Each project team in each PD course consist of four to six students and sets up their own project theme. That means more than 250 projects are set up in each PD course every year [1]. Students form small groups to discuss real-life problems, find out solution cooperatively and learn practical knowledge through PBL. PBL should be collaborative, constructive, contextual, and self-directed. They sometimes collaborate with local communities [2].

However, in order to prevent COVID-19 infection, the Japanese government issued the state of emergency on the metropolitan area on April 7 and expanded it all over the country on April 16, 2020. The state of emergency lasted about a month until it was completely lifted nationwide in May 25 [3]. Students cannot go to school or take lectures in classrooms. Instead, most universities used the web meeting tools such as Zoom and WebEx for their students to take lectures at home. In KIT, classes started as on-line on April 20. Group discussion in the classroom indispensable for PBL became impossible.

To advance an educational reform, introduction of the digitalized education system and the learning management system (LMS) have been promoted. We dealt with the classes using our LMS, e-Syllabus which were launched in 2016 [4]. However, there were comments in the questionnaires after the classes which described the dissatisfaction to PBL activity. Furthermore, the work loads of on-line PBL to teachers were larger than the usual PBL in the present LMS.

Through the system survey focused on the artificial intelligence (AI) we have recognized that chatbots which combine text-mining technology and AI have come to be utilized in many companies. Chatbots are used increasingly to reply to questions automatically using AI technology. There are many free

communication and collaboration tools: students use SNS more than e-mail. It is required to utilize the Information and Communication Technology (ICT) further and to improve LMS. The authors are investigating the online PBL education system which uses AI instead of teachers' direct instruction or TA's (Teaching Assistant's) support. We propose the on-line PBL education system using Slack and chatbots with AI.

The rest of the paper is organized as follows. Section 2 elaborates on the experience of the on-line PBL and the results of PD2 which were held in 2020 spring semester. In section 3, we review new digital technologies and trends of application of AI to education fields. Section 4 proposes the new on-line PBL education system which uses chatbot and AI. Although the system is still under the development phase, some of the system components will be introduced.

2 PD2 COURSES IN COVID-19

Out of five Project Design Programme (PD) courses PD Introduction and PD2 are held in Spring Semester and PD1 and PDIO are held in Fall Semester. Before 2019 meaning before COVUD-19 pandemic, all courses were carried out in classrooms divided in groups. Sophomores in 2020 took PD1 in classrooms in 2019 and PD2 on-line. They could compare PD course in classrooms and that on-line. First, we explain e-Syllabus System used on-line classes, then we review the results of PD2 courses in COVID-19.

2.1 e-Syllabus System in KIT

Since KIT launched the e-Syllabus in 2016, the teachers have been utilizing the e-Syllabus as one of communication tools with students. Some of them have been using the e- Syllabus when carrying out flipped learning and active learning [5].

E-Syllabus is a powerful tool when carrying out flipped learning and active learning. It was used as the main platform of the on-line education under the state of emergency of COVID-19. An example of e-Syllabus of a PD2 class is shown in Figure 1.

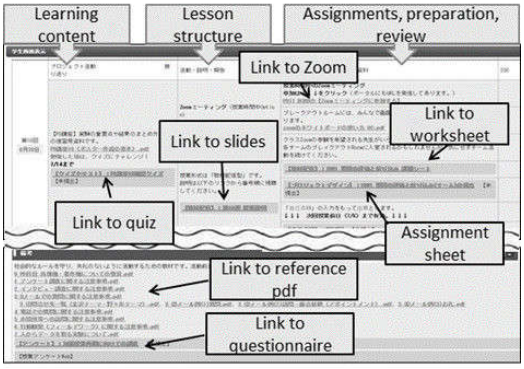

Figure 1. The example of e-Syllabus of a PD2 class

E-Syllabus is displayed, if a student logs in to his page from the portal site, opens his list of courses and click the course. E-Syllabus displays the contents of learning of weekly classes with the guide of learning targets, scholastic evaluation method, and preferred achievement, etc. The teacher in charge can upload preparation teaching materials and worksheets before the class and gives assignments. Students prepare their lessons by e-Syllabus and participate in the Zoom on-line class in the school hour. After an introductory lecture, students are divided in groups and work in Zoom Breakout Rooms. The teacher does the quiz which confirms learning results of the week, receives questions from students or guides discussion by students. He or she can carry out quiz and questionnaires by e-Syllabus in school hours and can confirm degree of comprehension on the scene. Reference materials can be uploaded so that students can use as reference materials during group discussions.

2.2 Results of PD2 courses in COVID-19

At the end of the semester, in order to carry out self-valuation of the degree of achievement of students' study target, the questionnaire survey was carried out using e-Syllabus. The questionnaires were designed to answer the achievement level of study targets by percentage: from 100% meaning completely well achieved to 0% meaning not at all. The survey also asked free comments about the on-line learning.

We compared the questionnaire results of the on-line PD2 class in 2020 with the questionnaire results of the PD2 class carried out in the classroom in 2019. 896 students answered the questionnaires in 2020 and 1,442 students answered in 2019. The number of replies of questionnaires are different because 2020 questionnaires were carried out on-line while 2019 questionnaires were carried out in classrooms. The on-line response rate became lower than that carried out in classrooms.

Although two questionnaires were not the same, some questions were the same. What were compared are the degree of achievement of problem discovery capability, team activity, logical thinking, and the degree of satisfaction of the class. The result is shown in Figure 2. The explanatory note A of the graph indicates 100% of the degree of achievement or satisfaction, B indicates more than 80% achievement or satisfactory enough, C indicates more than 60% achievement or not enough satisfactory, and D to F indicate less achievement or dissatisfaction.

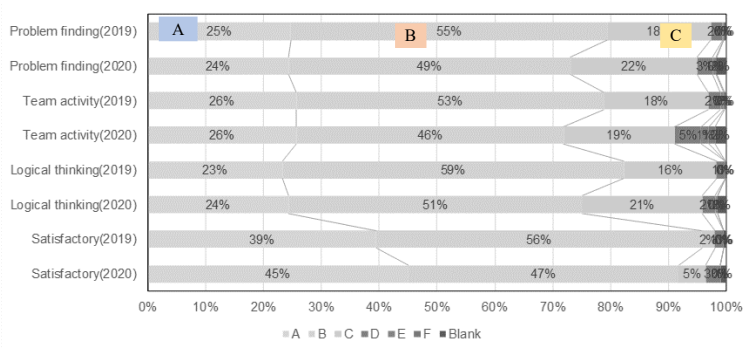

Figure 2. Comparison of questionnaires

For the degree of achievement of problem discovery capability, team activity and logical thinking, the percentage of A+B+C (the total rate of more than 60% achievement) of 2020 is lower than that of 2019 while the percentage of A (100% achievement) is almost the same. That indicates that whether the class is on-line or in a classroom does not influence the learning results for high performers. The students of the achievement ratio of 80% or less need suitable instruction at on-line classes. Students did mutual learning by group work in classrooms or after class in 2019. However mutual learning for which students gather became impossible in 2020.

For the satisfactory level, the satisfaction rate is higher in 2020 than that in 2019 while A+B is lower in 2020 than that in 2019. In free descriptions, while there are comments affirmative about the on-line class as it is easier to review the learning contents later, there are also comments that it is hard to do group activity on-line. It is hard to cause the motivation of low students of greediness for learning by on-line learning. There are some comments that there are many assignments, some of them are difficult and it is hard to do them online. Some students need easy to understand explanation to assignments. There are also comments that it is hard to question the teacher in the on-line class.

3 DIGITAL TECHNOLOGIES IN EDUCATION

The education / learning methods are changing with progress in ICT. The Education Reform Committee of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) considered the innovation of the education corresponding to progress of technology. The Committee has proposed the following to the Cabinet; innovation for collaborative and interactive lectures utilizing group studies and ICT, as well as cooperation between schools and families/communities should be promoted, along with the implementation of the new Course of Study [6].

Furthermore, the trial which uses AI and chatbot for education is studied. The application of AI has accomplished remarkable development recently and attracts attention as the 3rd boom. There are many articles published about AI applications in education. We can consult much literature on websites.

3.1 Intelligent tutoring system

Intelligent tutoring system (ITS) is an outgrowth of the computer-aided instruction (CAI) [7]. ITS analyses students' responses to specific questions and changes learning contents based on the answers. For example, Media5 corporation provides learning materials for high school students which use AI to support best learning methods for each student [8]. Students answer some questions before learning video materials, and AI navigates best learning methods to improve their learning scores. It analyses the past problem and creates mock problems. It also manages a student's learning schedule.

3.2 Text mining

The second example of the recent application of AI is the text mining. Text mining transforms unstructured text into structured words and extracts meaningful patterns. It can explore and discover new meanings in the text data. Peculiar processing and ICT technology were required for the text mining before. Nowadays there are some commercial based text mining tools available that can be used to analyse voices of customers from surveys or social media. We have used Mieruka-Engine™ for analysing the free descriptive answers of students who took PD courses. Some results were reported in 2018 [9]. Mieruka-Engine™ claims as No.1 text mining tool in Japan (Mieruka-Engine™ is a registered trademark of Plus Alpha Consulting Co., Ltd.) [10].

3.3 Chatbot

Another example of application of AI is the chatbot in question-answering. The chatbot is a software that can chat (converse) through websites or messaging applications. It is like the interaction between humans and robots. Robin Singh wrote an article on Chatbots Magazine in 2018 [11]. In the article he pointed that chatbot with AI technology can be used to teach the students by turning a lecture in a series of messages to make it look like a standardized chat conversation. Areeba Khan announced Chatbot makers utilize artificial intelligence and the latest conversational design to create bots that can communicate with students as well as teach them [12].

For the purpose of the increase in efficiency of corresponding to questions from customers (or students), the automatic inquiry systems which utilized AI are commercialized. They are used not only for business use but for education. Kindai University in Japan has introduced "Virtual TA for Slack" using manaBrain® (manaBrain® is the registered trademark of SCSK Corporation) [13].

3.4 Speech recognition and image recognition

As the use of AI, speech recognition and image recognition are performed widely. Speech recognition is used for the translation machine. Image recognition is the technology indispensable to development of automatic driving. These AI technologies can also be used for the education area.

4 ON-LINE PBL EDUCATION SYSTEM

Taking advantage of the rich instructional materials, students' deliverables, and questionnaire results of KIT PBL courses, the authors are investigating the online PBL education system which uses AI instead of instructors. Based on the on-line PD2 experience and the survey of AI systems, we propose the on-line PBL education system which combines PBL and digitalized learning. In PBL education, the role of the teacher as a facilitator is important and the bidirectional communication between the teacher and students is needed. There are many subjects to be solved in the systems configuration: how to prepare teaching materials, teacher know-how, and an ICT system and how to utilize AI in the system.

The composition of the education system under plan is shown in Figure 3. Students access to the digital platform e-Syllabus and work on their project team database (DB). The AI engine communicates with students on the digital platform and acts as the facilitator. Text mining and chatbot serve as main components of the AI engine. It uses the course materials and know-how database as a reference to answer students' questions. Some components are already prepared and there are some programmes and linkages under investigation.

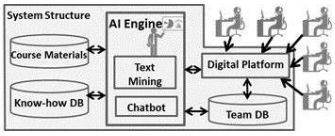

Figure 3. Composition of the on-line PBL education system

4.1 Digital Platform

The e-Syllabus system is used as the LMS platform in KIT. As mentioned in 2.1, teachers and students use it as on-line course tools. Students can access Zoom Breakout Rooms and chatbot via e-Syllabus. As students get used and are familiar with communication by social networking service (SNS), they perform group activities and group discussion there. A "Channel" can be set up for each project and project members communicate and work in the channel. All of the conversation and produced data can be recorded as a searchable team data.

4.2 Course Materials and Know-how Database

The AI engine accesses course materials and the know-how database and instruct students. More than 6,500 reports of the four Project Design Programme courses from 2012 to 2018 are stored in the database: about 1,500 PD Introduction experiment reports, 1,700 PD1 design reports, 2,000 PD2 implementation documents and 1,400 PDIO project repots. The students taking PD courses can search the documents related to their theme from the database. There is also the database which teachers prepared the principles and laws of physics and chemistry. Teachers' instruction materials including PowerPoint class slides are also on the e-Syllabus and the web server as shown in 2.1.

4.3 AI Engine

The mascot character of KIT, Drever, acts as the PBL teacher using the AI engine as shown in Figure 4. It can reduce teachers' workload of replying to students' question and facilitates project activities instead of teachers. During on-line PBL classes students ask many questions by mail or chat not only the class hours but even midnight when students do their homework. Some students hesitate questioning teachers even during class hours. Instead, students can ask Drever questions through the digital platform. Although it is necessary to prepare the questions and answer (Q&A) data beforehand, Drever answers questions and accumulates what are asked from students and feedbacks to answers. The teacher in charge analyses Q&A log data and modifies Q&A data. As the AI engine of Q&A chatbot, manaBrain® can be used.

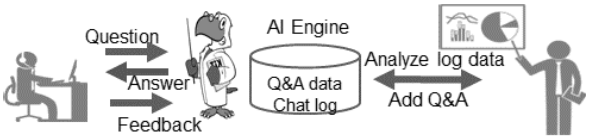

Figure 4. Drever and the AI chatbot for Q&A

The AI also analyses students' documents and the participating situation of the students to group activities using speech recognition and warns the low students of willingness to learn. It behaves like the facilitator who takes charge of the projects.

4.4 Pros and Cons of the System

It is the key to the system to prepare enough Q&A data. Once the questions and answer (Q&A) data are adequately prepared, students can perform project activities on-line. They can chat using SNS and Drever facilitates anytime. Teachers do not need to work late in order to reply to students' questions. Teachers' roles change to analyse students' activities and to give feedback through Drever.

However as mentioned in 2.2, it is hard to cause the motivation for learning by on-line learning. The mechanism of cultivating students' mutual learning is required. Occasionally idle talk with teachers may be effective for motivating students. It will take some time for AI to do idle talk with students.

5 CONCLUSIONS

PBL classes were carried out on-line using e-Syllabus during the state of emergency caused by COVID-19 and continued through the spring semester in 2020. Some problems were revealed from the questionnaire survey at the end of the semester. Mutual learning for which students gather became impossible and it was hard to cause the motivation of low students of greediness for learning. While there are comments affirmative about the on-line class, there are also comments that it is hard to do group activities on-line.

From the survey of digitization and development of AI, we propose the on-line PBL education system, which consists of the digital platform, the team database, the AI engine, the course materials, and know-how database. As students get used and are familiar with communication by SNS, adding to our e-Syllabus system, the on-line PBL education system using Slack and chatbot is proposed. Text mining and chatbot serve as main components of AI engine. There are several tools which can be available as the AI engine, and the on-line PBL education system can be constructed by combining them. The PBL teacher using AI can be realized to support PBL instead of teachers' direct instruction. The system is still in the development phase. Furthermore, many works are required including the valuation method of project activities besides chatbot programme creation.

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USING NARRATIVE ENQUIRY TO INVESTIGATE THE DEVELOPMENT OF STUDENTS' ENGINEERING IDENTITY IN A DEGREE APPRENTICESHIP

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University of Bath

ABSTRACT
Every year, around 35% of engineering graduates (mainly female and ethnic minority graduates) in the UK choose roles outside engineering (EngineeringUK 2019) [1]. Given that engineering as a profession struggles to attract recruits, this represents a significant loss of qualified talent the profession can ill afford. A possible reason why engineers choose not to practise after qualifying may be that they have not developed a professional engineering identity during their engineering education. Eliot and Turns (2011) [2] define professional identity as "personal identification with the duties, responsibilities, and knowledge associated with a professional role". Engineering identity is the extent to which students identify themselves as engineers. Research shows that engineering identity is an important indicator of persistence in both engineering education and the engineering profession (Godwin, 2016) [3] (Beam et al 2009) [4] (Cech et al 2011) [5]. The purpose of this research is to find ways of reducing the number of engineers who graduate and then do not practise, by identifying ways in which they can better develop their engineering identity during their studies. The findings presented in this paper are surprising in that they seem to indicate that the four years of a degree apprenticeship have had little impact on students who already had either low or high identification with engineering. Engineering educators should consider how the development of an engineering identity can be supported in engineering degrees.

Keywords: Engineering identity, engineering education, identity theory, degree apprenticeships

1 INTRODUCTION

Education in the UK is devolved to its four nations, so this paper will focus on engineering education in England, where there are two routes to qualifying as an engineer: an academic route via a university degree and a work-based route via an apprenticeship degree. The students in this study are apprentices studying two days per week for a BEng in Engineering and working three days per week in engineering teams for a technology company. This research will explore how these students develop their engineering identity during the four years of their education and the impact of their engineering identity in how they envision their future – inside or outside engineering.

Identity theory provides a useful lens for the study of professional engineering identity. If we believe that "Identities are the meanings that individuals hold for themselves – "what it means to be who they are" (Burke, 2003) [6] then a methodology that uses the tools of social science to study personal meaning, narrative enquiry, seems well suited to the study of identity (Goodson & Sikes 2001) [7]. This methodology is rarely used in engineering education (Foor, Walden & Trytten, 2007, p. 104) [8]. This paper explores the identity theory literature, the use of narrative enquiry as a research method and findings from pilot trials.

2 IDENTITY IN ENGINEERING EDUCATION

Admissions processes for engineering programmes tend to focus on finding candidates who are good at sciences, mathematics, and physics in particular. However, the success of those candidates in the engineering profession is closely linked to their identities. Whilst formally all a student needs to become a professional is to graduate from the appropriate institution, as Costello's research shows, "a certified professional school graduate who cannot "walk the walk and talk the talk" will not seem like a true professional to others and will not be successful" (Costello, C.Y. 2005, p. 23) [9] Acquiring engineering knowledge and skills is clearly an important part in becoming an engineer but it is not enough; to become

engineers, students must develop an engineering identity (Brickhouse et al, 2000) [10]. Many authors have looked at engineering identity, however, identity theory as a conceptual model has been largely overlooked. This article seeks to address that gap. Identity theory is rooted in the work of the American sociologist George Herbert Mead (1934) [11], who theorized that the self-arises from social interaction. Blumer (1962) [12] coined the term "symbolic interaction" to highlight that behaviours are symbols that carry meaning; what is important is not so much how we behave but how we and others interpret our behaviour. We operate within the structures in our society and our behaviour is shaped by those structures; this is what Stryker (1980) [13] means when he refers to "structural symbolic interactionism" (SSI). Those structures include class, gender, ethnicity, profession, etc.

Stryker and Burke (2000, p. 284) [14] define identity as "the meanings that persons attach to the multiple roles they typically play in highly differentiated contemporary societies". The basic premise of SSI is that identity emerges through interpersonal interaction and that these interactions are shaped by social structure; the social structure defines what behaviours are appropriate for each role. As we internalize those expectations, we are setting up the basis for our identity in that particular role. Stryker emphasized the role played by social structures in shaping human behaviour, recognizing the reciprocal nature of these relationships: "society shapes self, which shapes social interaction" (Stryker and Burke (2000, p. 231) [15]. He defines identity as the "internalized positional designation" linked to each role a person has in society (Stryker, 1980 (2002) p. 60) [16]. He understands those positions to be relatively stable and built into the structure of a given society. Individuals within a society label each other and themselves, according to the positions they occupy, i.e., teacher or student. As individuals internalize those identities, they also internalize the meanings and behaviours that are expected of those identities and occupy their position in the social structure as well as the symbols and shared perceptions associated to an identity, in this case engineering identity. For engineering students, this means embracing the personal characteristics associated with the engineering profession, such as a logical approach to problem solving, attention to detail and tough-mindedness for instance (Williamson et al, 2013) [17]. They must also be perceived as an engineer by their peers and colleagues.

A central premise in identity theory is that "people seek ways to establish and maintain those social situations and relationships in which their identities are verified." (Burke and Stets, 1999 p. 351) [18]. As engineering educators, we probably have a sense that this is the case and indeed, research shows that difficulties in verifying an engineering identity can cause students to abandon their studies (Pierrakos et al. 2009) [19] (Patrick, Borrego & Prybutok 2018) [20]. Burke (2009) [21] proposes that identities operate as a continuous feedback loop, managing the meanings perceived in a given situation, with the objective of maintaining self-meaning within a comfortable range. When the perceived meaning (our interpretation of how others see us) matches our own self-meaning, our identities are verified. Identity verification leads to increased trust, commitment, and emotional attachment towards those who are verifying our identity and in turn, those feelings increase our sense of belonging to that particular group (Burke and Stets 1999. P 351) [22]. A person's identity becomes stronger when it is verified repeatedly. Lack of identity verification generates negative emotions linked to feelings of low self-esteem and low mastery (Cast and Burke, 2002) [23].

It would be too easy to assume that a student who does well in her engineering studies, obtaining good academic results, would have her engineering identity validated. However, grades may not be enough, as being an engineering student invokes more than one single identity. Identity theory proposes that there are three different types of identities: role, group, and person identities. Burke and Stets (2009, p. 114) [24] define role identity as "the internalized meaning of a role that individuals apply to themselves." As different people will internalize meaning in a different way, the same role identity may have different meanings for different individuals. This is clearly the case in engineering, as there is a lack of clarity as to what it means to be an engineer. Group identity relates to how individuals identify themselves with a social group, in this case the engineering profession and finally, person identity is "the set of meanings that define the person as a unique individual rather than as a role-holder or group member" (Burke and Stets 2009, p. 124) [25]. Going back to our engineering student, for her engineering identity to be validated she needs to see herself as an engineer, but she also needs others (the classmates, lecturers, colleagues in the workplace, etc.) to see her as one. When someone validates our identity, we respond by generating trust in that person and over time, this fosters greater commitment to the relationship (Burke and Stets, 1999) [26]. Identity verification of a role identity generates feelings of mastery and efficacy. Verification of a group identity generates feelings of self-esteem and integration (Burke and Stets, 1998) [27]. The discussion outlined above led the researcher to hypothesize that:

Students with a strong engineering identity are more likely to have experienced trust in a formative relationship.
Students with a stronger engineering identity are more likely to be committed to a future in engineering.

3 RESEARCH METHODOLOGY

The researcher's interest in the study of identity led her to explore life stories as a possible methodology for this research. Narrative enquiry uses personal stories as data and particularly since the 1990s, has become a widely used methodology for "understanding the meaning of human experience" (Merriam and Tisdell, 2016, p. 34) [28] although as a research methodology, it has been rarely used in engineering education (Foor, Walden & Trytten, 2007, p. 104) [29]. It is, however, particularly well suited to the study of identity (Goodson & Sikes 2001) [30] as in retelling their stories, individuals are constructing their identities (Chaitin, 2004) [31]. Life story interviews allow individuals to tell their life story in their own way, charting the path that has taken them to where they are today. Those stories are not set in stone; as we tell our stories, we choose what is important at a given point in time, in a particular setting and with a specific audience. Narrative enquiry as a methodology offers a way of interpreting someone's experience (Atkinson 2012, p. 16) [32]. Following a narrative approach, semi structured interviews were conducted using a modified version of The Life Story Interview, an instrument developed by Dan McAdams (1995/2008) [33] at the Foley Centre for the Study of Lives at Northwestern University. In narrative research, the relationship between the researcher and the researched has epistemological implications that shape the way in which the research is conducted. The role of the researcher is particularly important because "the researcher is the instrument of both data collection and data interpretation" (Patton 1990, P. 54) [34].
Purposeful sampling was used to select research participants. Purposeful sampling is a technique widely used in qualitative research in which researchers select a sample "from which the most can be learnt" (Merriam & Tisdell, 2016, p. 96) [35]. The researcher looked for participants who were willing to participate and were good communicators, as recommended by Palinkas (2015 p. 534) [36] who highlights the importance of selecting research participants who have "the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner." Purposeful sampling requires in depth knowledge of the individual students to be selected. As the researcher did not personally know the students, she asked for help from the Student Support Advisor for each year group in order to identify students who they felt may be interested to contribute to this research. Out of the shortlist provided, one male and one female participant from years one and four of the degree apprenticeship were randomly selected for interview.
As an internal researcher i.e., employed by the institution in which this pilot study has been conducted, it is important to be aware of the "hidden ethical and methodological dilemmas of insiderness" (Labaree, 2002, p. 109) [37]. Hammersley's view that "there are no overwhelming advantages to being an insider or an outsider. Each position has advantages and disadvantages, though these will take on slightly different weights depending on the particular circumstances and purposes of the research" (Hammersley, 1993, p. 219) [38] seems particularly relevant.

4 DATA COLLECTION AND ANALYSIS

The Covid-19 pandemic and subsequent lockdowns and restrictions in England meant that interviews had to be conducted using MS Teams rather than in person. Research on the use of computer mediated interviews seems to indicate that they can be a "viable alternative to the face-to-face interview" (Curasi 2001, p. 372) [39] and the researcher feels confident that this research has not suffered as a result of having to conduct interviews online. What is harder to predict, however, is the impact that online teaching during the pandemic, and therefore reduced levels of personal interaction with classmates and faculty, may have on the development of engineering identity for the class of 2020 and this is something that may need to be revisited in this research. Four ninety-minute interviews with students enrolled on the same engineering degree apprenticeship in England were conducted; two were in their first year and two in their fourth and final year. In each year group, one student was male, and one was female. Each video interview generated around seventeen pages of interview transcripts. Transcripts were analysed manually, reading them several times, seeking to reduce the data inductively, looking for themes in the different stories. Three out of the four undergraduates identified themselves with the engineering profession and saw their future as engineers; the fourth student was not so sure. Contrary to what may have been expected, the students with a strong engineering identity already had it by the time they started

their apprenticeship and the nearly four years of their degree apprenticeship, offering exposure to an engineering workplace as well as academic study, had only served to clarify in the students' mind what aspects of engineering they enjoyed more than others. The fourth student started her engineering studies unsure about engineering as a career and remained unsured as the end of the degree apprenticeship loomed: *"I'm kind of currently at the stage where I am deciding whether to stay… in engineering or whether to just change completely, going to like investment banking".* The three students who identified themselves with engineering had attended different schools in different parts of the country, came from different socioeconomic backgrounds and had different interests. However, their stories had one thing in common: all three had built trusted relationships with an adult whilst at school (a teacher in two cases, a scholarship mentor in the third) who had encouraged them to consider engineering as a profession before they had thought about it themselves. A first-year student said: *"The (scholarship) mentor pushed me to apply, despite my response being that I was convinced maths was for me and that I was really unsure about engineering. He told me that strong mathematicians that loved problem solving were exactly what they were looking for and that getting the scholarship could open a wide array of opportunities for me. He convinced me that there was nothing to lose … I'm definitely indebted to him for doing so, I wouldn't have had that platform for industry connections and insights. Without that I think I would really have struggled to break down the misconceptions that I had of engineering."* For another student, it as a teacher: *"My DT teacher… I spent an immense amount of time with him… and I started getting recognized within the classroom as the DT guy that everybody came to for…".* A year-four student commented: "*My physics teacher, …, he kind of pushed me a little bit more towards engineering. And that's when I flipped from physics to mechanical engineering*". Through those relationships, the students had been encouraged to push their boundaries and go beyond their academic curriculum, and this resulted in the three students having more or less formal teaching roles with their peers and, in one case, students at other colleges. These activities can be interpreted as a form of Peer Assisted Learning, defined as "the acquisition of knowledge and skill through active help and support among status equals" which has been found to enhance cooperative learning and communication skills as well as improving the student's understanding of the subject under study (Gazula et al, 2017) [40]. By seeing their potential and encouraging them to do more, those adults had validated the students' identity and by trusting them with additional responsibility, they had reinforced that identity. According to identity theory, the validation of role and group identities generate different results: whist doing well in a class would generate feelings of self-efficacy, helping others to learn would also have a positive impact on the students' self-esteem. As the students had opportunities to do more of this, a positive feedback loop was established that lead to greater trust and commitment. One of the students in the first year often referred to herself and to her classmates as engineers: *"sitting down in the kitchen with five other engineers I've never met before of my age and immediately you just have that 'click'."* In contrast, despite being close to graduation, the fourth-year student who did not identify with engineering, never referred to herself as an engineer during the interview: "*I know I can do engineering and I can be an engineer … it's just not necessarily where I see myself going 100%".*

5 CONCLUSIONS

Degree apprenticeships expose students to academic learning in engineering disciplines and give them the opportunity to work in an engineering setting for the four years of the program, engaging students in multiple projects and working with different engineering teams. It would be reasonable to expect that such exposure would have an impact on the engineering identity of degree apprentices. However, this pilot study seems to indicate that may not be the case and that students' engineering identity was already set by the time they started their degree apprenticeship. The students interviewed who arrived with a strong engineering identity maintained it and the one who did not, failed to develop it. The findings of this pilot study seem to confirm the two hypothesis I outlined above, highlighting the importance of relationships with teachers and mentors in fostering an engineering identity. The findings also seem to confirm that students with a strong engineering identity see their future in engineering. These findings would suggest that engineering educators need to build opportunities for students to validate their engineering identities into their programs. This can be achieved by getting to know their students better and developing closer relationships with them and by creating opportunities for students to get involved in Peer Assisted Learning. Supportive personal relationships in an engineering setting develop trust which in turn develops commitment towards engineering as a profession. These are the findings of a pilot study that focused on degree apprentices. This research will be expanded by include students

enrolled on a conventional engineering degree at a university in England, and to conduct a larger number of interviews with both cohorts of university students and degree apprentices. The larger sample will also enable further comparison between the early and later year students. The openness showed by the students who participated in the pilot study and the depth of the insights they shared begins to throw new light into this fascinating topic.

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ADAPTING SOCIAL DESIGN RESEARCH METHODS FOR SOCIALLY DISTANCED PRACTICE

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ABSTRACT
Social Design Research, due to its interactive and democratic nature, typically requires access to participants at all stages of the Design process (enquiry, insight gathering, ideation, and testing). This ensures that the designers' practice is informed with contextual knowledge gained through relationship-building and ethnography, which are key features of Social Design Research [1]. Due to the impact of the COVID-19 pandemic, the delivery of Design education, and the approaches taken by lecturers and students had to adapt. The methods, attitudes and approaches to Design research and practice have evolved due to these changes due to the use of newly adopted digital collaborative environments. This paper presents the adaptations to existing Social Design Research methods and new ones which have been generated by the students through the undertaking of a project aimed at designing for social value delivered to first year Product Design students at The University of Derby.

Keywords: Social design, design for social innovation, design research methods

1 INTRODUCTION

As designers, consultancies [2] and publicly funded design organisations [3] increasingly acknowledge the potential for Design to positively contribute toward social impact, Social Design is becoming an essential part of Product Design curriculums around the world to prepare students for evolving practice. The necessity to challenge values and attitudes to Design has been made more evident after the Social Turn [4] and its push for communities taking part in the creative process. The catalyst for this new emphasis on a more considered, holistic approach to Design can be viewed as a reaction to established paradigms which centralise market returns, user experience and the consumption of goods [5]. Over reliance on Design as a tool to fulfil immediate needs and wants, has led to unsustainable solutions, with negative implications for human beings and the environment. Therefore, designers sought to utilise Design to address the broader and more complex issues facing humanity and thus generate a new, more socially conscious approach to Design. Social Design is understood as Design both for and with society [3,5] and it requires designers to undertake thorough qualitative research which involves engagement, participation, and collaboration [5,6].

1.1 Social Design Research

The open and inclusive approach to research in a Social Design framework allows students to learn about the daily pattern of conduct of a community; how they might use their spaces (public/private); what kind of experiences might shape their daily lives and what challenges they face [6-10]. Social Design necessitates habituated practice, shaped and driven by knowledge of a group's shared experience as a driving factor in designing for greater value and impact. [10,12]. Social Design Research relies on primary qualitative research, which seeks to obtain and understand culturally specific information about the values, attitudes, opinions, and behaviours of a particular community/audience in its social context [13]. The advantage of this type of enquiry lies in its ability to provide multi-faceted descriptions of how people experience a given issue, situation, or circumstance. Social Design Research investigates and provides information about the 'social' side of an enquiry and focuses on experiential factors of a community; this includes lived, shared, and learned experience [10-13].

1.2 Effects of the 2019 COVID-19 pandemic on students' learning

With the implementation of national lockdowns, University curriculums had to quickly adapt to a digital learning environment. For Social Design modules this meant that all stages of the creative

process, which entails working for and in a community, was disrupted because they could no longer undertake primary face-to-face research. This moved students away from working in physical spaces with communities and consequently isolated them and the community participants to mainly virtual spaces. As part of the project undertaken by the Product Design year 1 students, they were briefed to co-design urban furniture for a local park which could be manufactured by members of the local communities with migration background, who would at the end of the project gain a skills certificate. Due to the collaborative nature of the project, students were required to undertake Design ethnography and work together to explore how to best address the needs of the park while retaining simplicity of their designs for the participants which will be making them. Realisation of the project would thus create a skill share initiative where both parties exchange knowledge and create a more welcoming and accessible environment at the park for migrant communities and the local student population.
As a result of the pandemic and social distancing regulations the university implemented a programme of blended learning. Blended learning is a mixture of online and face to face learning, occurring in an instructional based context both in the classroom and over digital meeting spaces [13].

2 RESEARCH METHODS

2.1 Social Design Research Methods

The main two research methods which students were encouraged to use for Social Design briefs at the university are Design Ethnography and Spatial Studies.

2.1.1 Design Ethnography

Ethnography as a method seeks to enable designers to understand the potential users of resulting designs, how they might perceive, access, and engage with them [14,15]. It grants designers in-depth, empathic knowledge of the lifestyle, routines and issues which matter most to the participants (See Figure 1 below). This enables designers to develop ideas whilst clearly understanding who they are designing for. Evolutions within this approach have taken it from participant observation to interaction, conversation, and Co-Design. Common ways of collecting data used within this method include 'Semi-Structured Surveys' and 'Interactive On-Site Enquiries'.

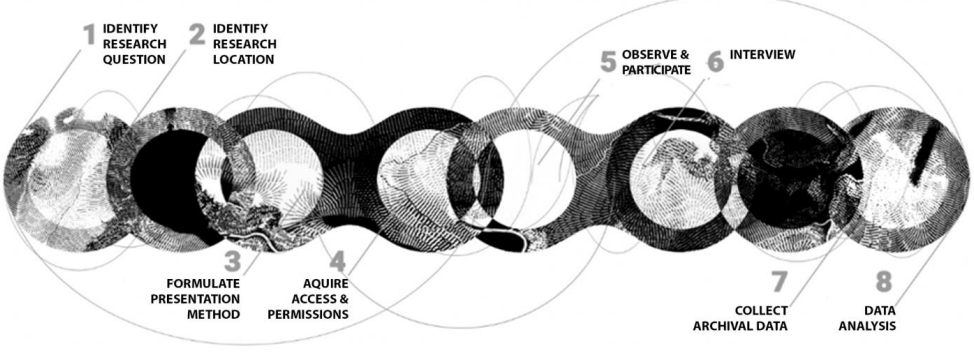

Figure 1. Ethnographic research model taught as part of Social Design modules.

Semi-Structured Surveys in Social Design Research are not used in their common form (e.g., questionnaires seeking a quantifiable set of data from participants), instead they are used in a semi-structured way, allowing for open conversation combined with fixed questions. As opposed to gaining a small subsection of data which translates broadly to a population, Social Design surveys are components of a carefully planned ethnography, helping Design researchers to understand specific communities.
Interactive On-Site Enquiry is a form of observation which requires being physically present in the setting or amongst the community. It can take the form of workshops, collaborative Design thinking

sessions and observations. It is a means of gathering primary data from an environment without doing a survey. The involved nature of this approach means that it needs to be evaluated within an interpretative framework as opposed to a scientific one.

2.1.2 Spatial Studies

Spatial Studies entails examining the geography and urban planning of a space [16]. In a Social Design brief, the data is typically collected in two ways; first by gathering the geographical data, e.g., obtaining the specific boundary statistics, understanding the relevant spaces and places where a community interacts. This type of data is often portrayed in descriptive forms such as maps and schematics. Furthermore, spatial data is used to examine patterns of behaviour, amalgamating spatial data into research analysis [16]. By using maps and schemes as tools for identifying patterns of behaviour and the interactions of a specific area with its surrounding environment, qualitative data can be systematically gathered and analysed, resulting in a better understanding of the social mapping of a community. Spatial data informs and supports ethnographic studies and allows designers to develop an illustrative, visual framework for community-environment interactions.

2.2 Adaptation of Research Methods for Socially Distanced Practice

2.2.1 Methods Deemed Unsuitable for Socially Distanced Research

The regulations for teaching during the pandemic and government enforced social distancing placed many difficulties on undertaking social research. All face-to-face enquiries were unable to go ahead due to health risks to both the public and students. Because there was no possibility to have interactive on-site enquiries at the park, which resulted in two major implications. Firstly, lockdown measures meant that students could only visit the park individually and not as groups, and they could not talk with visitors of the park. Secondly, it meant that students were unable to work with the community who live in the area, gain relationships, and begin to build an ethnographic profile of the people they were designing the products to be made by. Methods which were deemed unsuitable due to the pandemic included face-to-face interviews, field work which required students to meet up physically in groups, and on-site interactive structured and semi-structured surveys.

2.2.2 Adapted Methods

Whilst there were measures that completely prevented certain methods used in Social Design Research, it was possible to adapt others to fit the circumstances caused by the COVID-19 pandemic. For example, whilst it was impossible to perform surveys in-person, which can be more relational, it was possible to use digital tools to connect with the community and elicit responses from them which could be analysed. Participants were recruited this way, not through attending the park and asking in-person but using social media networks (such as Facebook). Starting with friends and peers, and then branching out to friends of friends, the students were able to gather a sufficient sample size of regular park visitors from which insights could be gathered.

For Design Probes, several access factors were considered, which utilised new technologies to ensure understanding for migrant participants context contemplating language/cultural barriers. Students co-ordinated the creation of their surveys using interactive schemes of the park and animations. Translations were made available using cognate software which guided the users around a graphic display of a map of the park, indicating areas which they were required to answer questions about. Through individual trips to the park students built up a bank of photos and clips, along with access to topographic maps, which were then compiled into a more visual engaging survey which could be accessed from any internet capable device (See Figure 2 below). This provided students with feedback through questions, but also through clicks, recognising the areas of the park the community wanted to 'interact' with the most, albeit through a digital interface.

In the concept selection phase, the students also switched A-B testing from being in-person, to utilising web-hosted 3-D CAD models so that people could orbit around them and zoom into details.

2.2.3 New Methods

While moving to online delivery has caused complexity, it has also resulted in innovations of new collaborative research methods. Alongside this shift, the student's experience of studio learning took on completely new forms which had positive impacts despite the irregularities associated with moving

promptly to online delivery. For example, students who might usually struggle to participate equally in group work in an on-campus environment, thrived when the burden of self-presentation was removed. Lecturers recognised these changes and value the democratisation of the groups, which can be a challenge in-person. To help facilitate their cohort relationships as peer designers, staff also encouraged the student groups to set up their own digital socialisation spaces. These took the form of digital 'Speakers' Corners', created on Microsoft Teams, Discord, Miro, and Mixer. Spaces like these, allowed students to contribute freely, collaborate and exact critique on each other's work, making sure that all students were involved, and the bond of the group was kept strong.

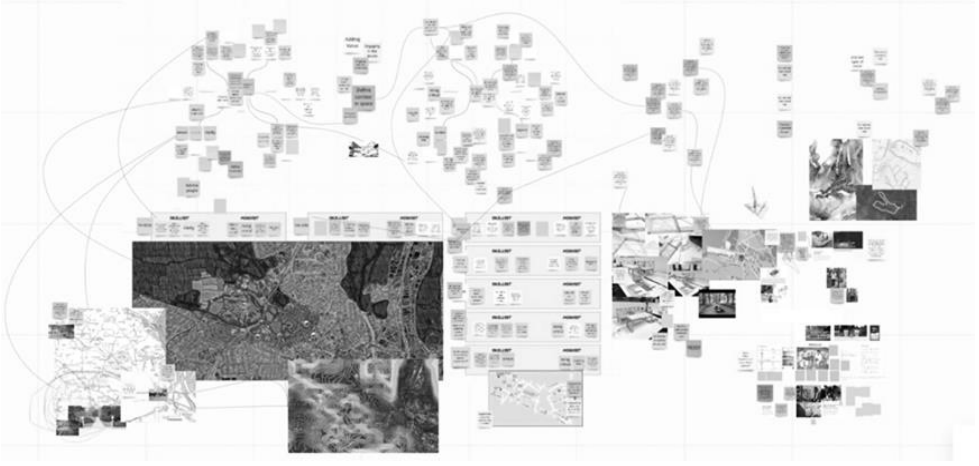

Figure 2. An example of digital collaborative spaces developed and utilised by students

Consequently, these formed an adapted method for their Social Design Research, which hereon is referred as 'Digital Speakers Corners', which allow for new ways of gathering data that still ensured integrity of research findings.

Another method which the students devised was a form of contextual enquiry where one team member acts as an "on-site navigator". The student carries a smartphone whilst in a video call to the other colleagues who are working from home who would record the site visit on their computers. This way the team-members who worked from their home-office could safely participate and enquire about the location without breaking social distancing rules, yet still be part of the directing of the gathering of information in real-time.

Alongside this, students also created hybrid methods for data mapping that relied on a blended enquiry, i.e., photographic, video evidence from the physical site and digital mapping data gathered from historic study libraries, satellite images and council databases.

3 OUTCOMES

3.1 Facilitator perspective

In response to the university's implementation of national health and safety measures, it is evident that some of the most innovative and effective rapid adaptations of Design Research methodologies and methods were generated by students. Upon the prompt adoption of digital workspaces, students adapted their approaches to undertaking, sharing, cross-evaluating, and working in groups. Each of these developments has created a push for a reconsideration and restructuring of teaching practice. As lecturers recognized that the break in physical socialization is impacting students' intrinsic and extrinsic motivations to learning, the need of digital spaces for socialization has become vital for healthy learning developments. First building blocks for these spaces were laid through real-time interactive online spaces such as Microsoft Teams collaboration channels and free online exhibition spaces. Once students started to use these spaces regularly as part of their online delivery and group research, the students themselves started to expand their digital social spaces through various gaming and Design platforms. The familiarity of these online spaces meant that students felt at ease to utilise these for broader

purposes, such as group research, ideation, debates, as well as testing. Once these spaces were established, student groups organized open digital research groups, where participants of the communities could join from their mobile devices and take part in the data gathering, discussions and co-Design.

Due to lockdowns the majority of students were residing secluded in dormitories or family homes which meant that students did not have enough space to create prototypes in or even fabricate more refined product proposals. Lecturers recognized that these constraints would impact on students' technical development, therefore all access to campus, which was already heavily restricted and rigorously monitored, was dedicated to safe technical sessions. This allowed students to access materials and tools to produce rapid product prototypes and proposals. However, problems arose when these technical skills could not be shared physically with the participating community, leaving one part of the brief unsolved; the mutual knowledge and skill-sharing elements that would happen on site was no longer possible. This opened up speculative reflections on how these problems could be solved in the future through potential blended digital/ on-site co-Design sessions and the rethinking and restructuring of public spaces.

3.2 Student perspective

Whilst the blended environment has proven difficult and challenging to manage, students have responded exceptionally positively well to all the transitioning stages of learning. Although this learning experience was not able to grant students the same learning and social experience, it has revealed the potential of new learning structures that allow for a more progressive democratic curriculum, in which students can participate in the shaping of pedagogy as well as peer-to-peer and peer-to-academic learning.

Overall enthusiasm initially showed signs of diminishing when the learning fully progressed to online-only delivery as students felt isolated from their peers and struggled to structure their learning without the aspects of having physically to visit the campus or public spaces or interact directly with users of the park or migrant communities. Students who would usually confidently present and communicate their ideas started to be withdrawn from the online conversations and shared their progress only in written formats where students who would normally struggle to present in-person excelled in digital communities which allowed them to freely communicate as equals.

Once circumstances were more settled and the students had adapted and generated their new appropriate research methods and recruited enough participants, they started to manage their individual and team workloads well. This also led to the flattening of the participation hierarchy, which subsequently resulted in an improved experience for all students compared to strictly on-site collaboration approaches.

4 FUTURE IMPLICATIONS

Reflecting on the adaptations to research methods that evolved from implications caused by the national lockdown and public health and safety measures, it was evident that students are adaptable and Social Design Research can still be undertaken during times of social distancing. The students demonstrated that participatory and interactive research and practices can still be executed, and that digital realms of engagement can provide sufficient insights. Furthermore, the adaptations done within the span of less than one academic year implied that if the methods were further refined, they could be bettered, and new methodologies and methods for Social Design practice would likely emerge. This has confirmed the fact that regardless of the obsoletion of social distancing rules in the future, digital hybrids of Social Design Research methods will continue to be encouraged in student work.

5 CONCLUSIONS

The findings in this research-informed project could potentially open the discourse for the development of 'Digital Social Design' practice which provides a greater level of openness, inclusivity, and accessibility. This notion was proven as an equitable proposition for Product Design students, who managed to further their thinking and making skills even without daily access to machinery, studios, or public spaces in general. From this it is clearly implied that these new types of adaptations to learning and interacting have the potential to become part of curriculums and hybrid pedagogies past pandemic restrictions. Delivering academic Product Design curriculums in this way would give students greater freedom in managing their time outside of university schedules and generate more sustainable financial

constraints that students face when having to travel to campus. Universities would have to consider supporting students with blended curriculums by providing technological support in forms of accessible machines and digital spaces of learning. Adaptations to blended learning have not just facilitated the development of new research methodologies in Social Design but also built up a new confidence within students that generated stronger comradery and congeniality. This has set a building block to a more sustainable community of learners that is increasingly tactful and resourceful with their time and abilities. Regardless of COVID-19 restrictions and their breakdown in the future, what was elucidated though this period is that students and lecturers were able to adapt to new circumstances which revealed the vulnerabilities of existing structures of Social Design Research.

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INTRODUCING DESIGN HEURISTICS FOR FURNITURE DESIGN IN A FURNITURE DESIGN COURSE

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ABSTRACT
Concept generation in the early design phase is a deciding factor in any design innovation process. And the magnitude of the concepts generated in the initial design phase is the measurable criteria for success. Experienced designers travel through their world of objects, observations, encoded information, and collection of prior experiences to externalize multiple concepts through different tools. However, novice designers experience difficulties exploring the problem space and fixate on the concepts with the initial features. Researchers suggested many formal tools or methods for concept generation in the early phases of design to overcome these issues. Many of these are difficult to use by novice designers and many of these are very generic to product design. This paper discusses a concept generation tool for novice furniture designers 'Design Heuristics for Furniture Design' (DHfFD) with special emphasis on the chair, which has been developed from the study and analysis of award-winning furniture (chair) and published compendium of well-known, successful designs. To understand how the DHfFD cards are perceived by novice designers in use, the tool was introduced in a furniture design course, and a qualitative study was performed with novice design students at the Department of Design, IIT Guwahati. It is observed from the study that the DHfFD tool helps to generate diverse concepts within a short duration of time. This research integrates design tools and cognition in design; accordingly, it recommends using 'Design Heuristics for Furniture Design' (DHfFD) in a furniture design course.

Keywords: Design Heuristics for Furniture Design, tool for concept generation, furniture design

1 INTRODUCTION

Research expounds that frequent unwanted design innovation project dissolution occurs at two points [1]: a) after concept generation and selection process, b) after the market introduction. Therefore, concept generation in the divergent phase of the creative problem-solving process has a decisive influence on the success of any innovation [2] [3], and statistically, the success of the concept generation is significantly co-related to the quantity of the concepts generated [4]. Although researchers proposed several formal methods [5], existing methods have the following issues: 1) unstructured or intuitive [6], 2) difficulty in acquisition [7], 3) difficulty in assessing the concepts [8], 4) lack of validation [9]. An empirical investigation shows that analogical problem solving [10], which is assisted by the solutions from past problems, is an effective tool for scaffolding in design education [11]. Thus, heuristics is a widely accepted tool for concept generation [12], as these are developed based on the principle of analogical problem-solving. The above factor motivated many researchers to develop heuristics for concept generation. Existing heuristics are industrial and product design-oriented and not much support for furniture designers specifically. This research discusses the impact of the tool DHfFD on novice designers.

2 AIM AND OBJECTIVE

Previous research related to the effectiveness of the different heuristics observed successful concept generation with heuristics. As the developed tool is from a completely different domain, it is thus necessary to confirm the impact and perception of the developed tool in practice. The research aims to investigate the tool's performance during concept generation and to understand how the tool is perceived. To achieve the desired aim, the tool was introduced in a furniture design course and a qualitative study was performed with novice design students at the Department of Design, IIT Guwahati, India.

3 HEURISTICS IN DESIGN

The heuristic is described in the literature as a rule of thumb, cognitive short-cut, engineering strategy, cognitive problem-solving tool, etc. A heuristic is defined as "a context-dependent directive, based on intuition, tacit knowledge, or experiential understanding, that provides design process direction to increase the likelihood of reaching a satisfactory but not necessarily optimal solution" [13]. Notwithstanding the limitation, heuristics are well accepted, as they help in divergent thinking. The existing heuristic approaches in design research are SCAMPER [14], TRIZ [15], SYNECTICS [16], 77 Design heuristics [17], Design heuristics for additive manufacturing [18], Transformation design theory [19], Portability design heuristics [20], Design heuristics set for assistive product design [21], Design aesthetic heuristics [22], Design heuristics for innovative packaging [23], Heuristics in ergonomic design of portable control devices for elderly [24] and new design heuristics for digital era [25] etc.

4 DESIGN HEURISTICS FOR FURNITURE DESIGN

The design heuristics above can be categorized into two [21]: 1) Comprehensive Design Heuristics (CDHs), which do not have any pre-specified purposes and may be useful across all design domains; example: TRIZ, 77 Design Heuristics, 2) Design heuristics for X, which do have pre-specified purposes and are useful in domain-specific problems; example: Design heuristics for assistive product design, Design heuristics for additive manufacturing. As there are no heuristics available for furniture design, in a previous work a collection of 66 heuristics were developed [26], which fall under the category of Design heuristics for X. The research was focused on the second category and the developed tool is called Design Heuristics for Furniture Design (DHfFD), which emphasizes chair design. The collection of heuristics was developed based on extensive study and analysis of existing furniture (chair) design analogy from Design award repertoire, published compendium, catalogue of leading furniture manufactures, and online design magazines. The existing pieces of furniture were grouped as suggested in the K-J method based on the form & structure and special features. Analysis and heuristic extraction of each group has been done, as indicated in literature [27].

5 EXPERIMENTAL APPROACH

5.1 Research Question

This research seeks to understand the effect of DHfFD on creative idea generation by novice designers in a furniture design course and sought to answer the following research questions:

1) Does using DHfFD result in more innovative furniture designs?
2) How do novice designers perceive DHfFD in use?

5.2 Participants

A total of 28 novice designers participated in the study from undergraduate and postgraduate design courses with no prior experience in furniture design and no idea about DHfFD.

5.3 Method

In this study, a longitudinal research approach was adopted. The same group of novice designers generated ideas before and after the introduction of the tool Design heuristics for furniture design. The main reason behind adopting a longitudinal research approach was to confirm the treatment effect on participants and register changes in individual participants.

The experiment was conducted in four phases, as illustrated in Figure 1. The four phases are the control treatment phase, the experimental treatment phase, the survey phase, and the evaluation phase. The control treatment phase began by asking participants to generate solutions without any tool being given. Participants got 30 minutes to complete the task. A gap of 30 days was there between phase I and phase II to avoid the pre-treatment assessment's effect on post-treatment. At the beginning of the experimental treatment phase, the DHfFD tool was introduced through a lecture. During the experimental treatment phase, students were asked to generate concepts within 30 minutes using DHfFD cards. In both phases I and II, the students were given an open-ended challenge and asked to produce as many ideas as possible in 30 minutes.

Brief: Design as many as possible indoor chairs for urban housing. There is no constraint of cost, material, and process.

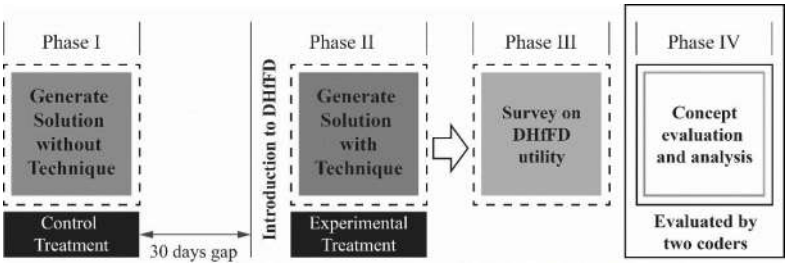

Figure 1. Experimental execution diagram

In this study at the experimental treatment phase, a total of 12 DHfFD cards were introduced. The cards were selected randomly from a set of 66 heuristic cards set. On a two-sided 80 x 100 mm card, each heuristic was presented. Design heuristics cards for furniture design have the following content in each card as shown in Figure 2: design heuristic number, design heuristic name, an abstract representation of the design heuristic through illustration, design heuristic description, instructions for designers, real examples associated with the heuristics.

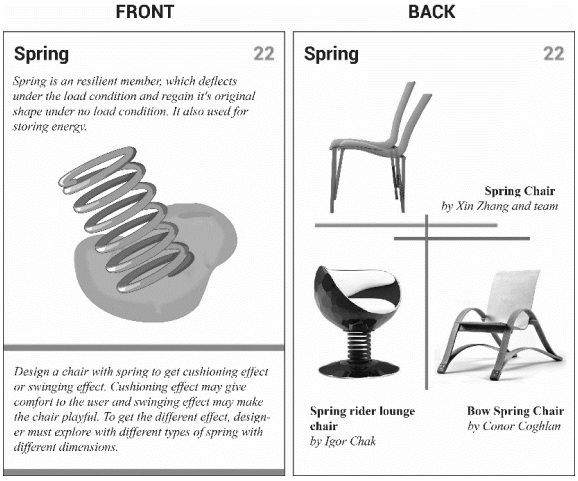

Figure 2. DHfFD card

Cards were not provided one at a time, in a standard order, as it may restrict the flexible use of the tool in more than one manner, and it may also create a problem for future acquisition of the tool. They were given the liberty to use the cards the way they wanted. The given card list is shown in Table 1.

Table 1. Set of 12 Heuristics Provided in Study

Cantilever	Wave surface	Spring
Wiggle	Tensegrity	Coil
Extension	Playful	Tensile surface structure
Collapsible	Comet structure	Science & Technology

In phase III, the participants were asked to respond to a series of questions on a Likert scale from 1 to 5. One-to-one discussions with students were also arranged to gather suggestions and understand the reason behind their perspective towards the tool. The students were asked the following questions in Table 2.

Table 2. Questions submitted to the students

Q#	Text of Questions	Scale
Q1	How effective was the tool in helping you to generate more concepts of a chair?	(1 = Not effective, 5 = Very effective)

Q2	How would you rate the appropriateness of the textual content of the tool?	(1 = Very poor, 5 = Very good)
Q3	How would you rate the appropriateness of the visual content of the tool?	(1 = Very poor, 5 = Very good)
Q4	How do you find the DHfFD for creative concept generation for chair design?	(1 = Not effective, 5 = Very effective)
Q5	Was there a need for an explanation of any basic's concepts during the application of the new tool?	(1 = Quite always, 5 = Not at all)
Q6	Was the tool useful to understand the types of form and structure of chairs?	(1 = Not effective, 5 = Very effective)

In phase IV, three coders were trained, and they evaluated the concepts generated in phase I and phase II based on the quantity, quality, novelty, and variety of ideas [28]. The coders also investigated the evidence of the use of DHfFD for the corresponding concepts generated by the participants in phase II. Coders were from the background of accessory design, applied arts, and architecture.

6 RESULTS & DISCUSSIONS

6.1 Major Findings from Phase I

In phase I, 28 participants generated 140 concepts within a range of 3 to 12. The concepts generated at phase I without any technique/tool have the following issues: 1) indistinguishable concepts presented, 2) existing ideas presented with minor modification, and 3) impractical concepts presented. Some of the examples are shown in Figure 3. Students in the sophomore years lack understanding of the form and structure of furniture (chair), which might be the primary reason behind the indistinguishable concepts. Impractical concepts resulted from a lack of experience and exposure of the participants. The scenario necessitates domain-specific support to scaffold novice designers for creative concept generation. Nevertheless, this phenomenon is not valid for all participants.

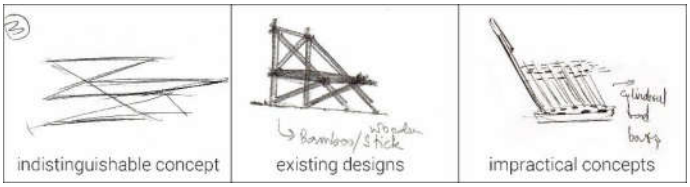

Figure 3. Concepts sketches from phase I

6.2 Major Findings from Phase II

In phase II, 28 participants generated 294 concepts within a range of 4 to 20. The concepts at phase II are substantially improved in comparison to the concepts at phase I. Concepts with high novelty scores were observed when few participants combined more than one DHfFD card. Some examples of concepts with evident DHfFD heuristics are shown in Figure 4.

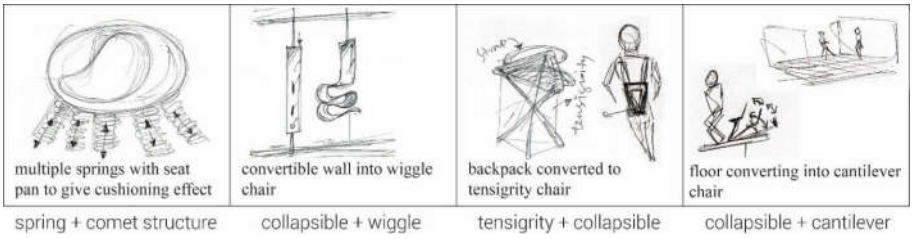

Figure 4. Example concepts with evident combined DHfFD heuristics from phase II

The presence of heuristics is observed in maximum concepts. It is important to say, maximum concepts are novel and practically possible with minor modification.

6.3 Major Findings from Phase III

The coders compared the concepts generated in earlier phases and established the correlation between the number of concepts generated and the use of DHfFD cards. It is evident from the results and responses that the tool is helpful in creative concept generation and overall, the perspective of the students towards the DHfFD tool is positive, which reflects on the histograms of responses to the questions asked at phase III. The responses are visually summarized in Figure 5.

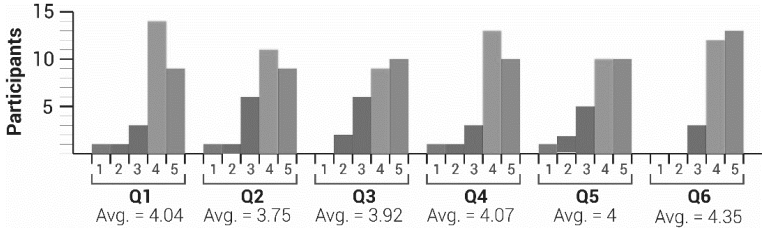

Figure 5. Responses of the participants

Along with the positive responses to the tool, a few invaluable pieces of feedback were registered at phase III during the discussion with the participants regarding the improvement of the tool. The following are the significant points that emerged from the conversation:

1. *Transformational principles*: Novice designers lack knowledge of transformational principles of the basic form and suggested the inclusion of cards with content related to transformational principles.
2. *Tool for a tool:* It is more important to refine concepts than the generation of concepts. If support is provided to make a prototype for the feasibility study, it would be helpful for beginning designers.
3. *Separation of citation of furniture:* Existing designs are influential and divert novice designers' minds while using the card and suggestions received to separate the instruction card and citation cards.

7 RECOMMENDATION

The study on introducing Design Heuristics for Furniture Design (DHfFD) to novice designers shows that the tool helps to generate diverse and novel concepts. This research integrates design tools and cognition in design; accordingly, it recommends using DHfFD in a furniture design course.

8 CONCLUSIONS

This paper discusses the impact of the recently developed tool Design Heuristics for Furniture Design (DHfFD) on novice designers while introducing it in an elective course setting. Critical observations at the control treatment phase point out novice designers' issues and necessitate domain-specific scaffolding. In conjunction with a controlled study, the tool was introduced in a course and the research indicates the tool stimulates novel and diverse concept generation. Questions and associated Likert-scale responses indicate a positive perception of the first introduction of the tool. Significant points that emerged from a conversation with the students are also the paper's key contribution. The pedagogical approach, teaching with DHfFD would help furniture design education, as there is no support available for concept generation specific to furniture design. The research mitigates the challenges of novice designers in innovative concept generation and contributes to design education. Despite the limited sample size, the findings may be applicable to similar circumstances.

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RETHINKING AND ADAPTING APPROACHES TO EDUCATION FOR SUSTAINABILITY TO ADDRESS CULTURAL AND BEHAVIOURAL CHANGE AND CHALLENGES

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ABSTRACT
Designers and engineers have continually and simultaneously initiated, responded, and adapted to economic, social, and environmental change and challenges since practice began. Although they developed beneficial products, systems, and services, they were also pivotal to the linear economy and directly and indirectly contributed to environmental and social damage. Professionals are now being encouraged to address these problems through their practice. Design and engineering education was established to support industry by producing suitably prepared graduates; consequently, pedagogy has reflected professional practice and encouraged students to develop positive and optimum solutions to challenges. However, students and society as a whole are now facing unprecedented global environmental and societal problems that are affecting their behaviour, mental health, and ability to respond to these problems. Therefore, there is an urgent need to rethink and adapt current pedagogic practice in order to mitigate these issues, to ensure that sustainability remains core to design and engineering courses and that graduates transfer and embed this knowledge in the workplace. This paper first considers how designers and engineers have adapted practice in response to various drivers since the beginning of the professions; it then describes the role of general design and engineering education and that of design and education for sustainability. The final section describes an innovative strategy – reverse psychology - and how it has been adapted to address these emerging challenges; the outcomes and impact of the approach are also illustrated through a case study and the reasons for success to date are analysed and discussed.

Keywords: Education for sustainability, reverse psychology, deep learning

1 INTRODUCTION

Continuity and adaptation have been inherent to the design and engineering design professions since their inception. For example, the invention of the steam engine and electrical systems initiated the first and second Industrial Revolutions from the middle of the 18th century; the third (computing based) industrial revolution began in the 1950s and the fourth (cyber-physical) industrial revolution is now underway. While this illustrates continual innovation by the engineering, design, and other professions these innovations have also demanded adaptability. For example, activities and outputs associated with the 1st and 2nd Industrial Revolutions included mechanisation, the development of new energy systems and materials and the division of labour (which increased efficiency). These new manufacturing processes and materials also facilitated a shift from craft-based batch production to higher volume and mass production.

Design practice also emerged at this time in response to these changes although most 'design' was executed by architects, engineers, and artists. Some British practitioners (and most notably William Morris) rejected industrialisation in favour of the spiritual reward of manufacture by hand, but other practitioners embraced and adapted to the changes, and recognised the potential to develop new products and a new visual language. Christopher Dresser was one such individual; originally trained as a botanical illustrator he is regarded as one of the first independent industrial designers and he simultaneously championed design reform and adoption of modern manufacturing in the development of wallpaper, textiles, ceramics, glass, furniture, and metalware in the late 1800s and believed that form and aesthetics

should derive from the materials and manufacturing process employed. Similarly, in 1907 the German architect and designer Peter Behrens is reported to have said that we refuse to duplicate handmade works, historical style forms and other materials for production. Both Dresser and Behrens designed for the expanding professional class consumer market, which saw unprecedented growth after World War One. Designers continued to exploit emerging technologies and materials until the 1929 stock market crash which led to a period of economic depression and unemployment. During the 1930s designers and engineers were encouraged to adapt in response to this situation as the economist Bernard London proposed 'planned obsolescence' as a strategy to restart the economy [1]. In this case they were asked to limit product life through use of non-durable materials, lack of spare parts and frequent changes in design. Notable examples include tungsten lightbulbs - which had a reasonable life span but were redesigned to fail after 1000 hours use – and GM and other car manufacturers introduced minor stylistic changes every year to encourage regular vehicle replacement by consumers who wanted to be seen as fashion leaders; these and other phenomena encouraged economic growth until World War II.

The social and economic impacts of this War were global, and the disruption of supply chains and resource shortages demanded further adaptions in approaches to design rather than designing for abundance. In the UK for example designers were required to maximise resource efficiency under the government led Utility scheme from 1943-1952, which ensured that clothing, furniture, and product designs were 'well-designed' and simultaneously durable while minimising use of materials. Unlike most of Europe and Asia, the USA was not invaded or bombed and consequently manufacturing capability remained intact throughout the War, and after the War the ability to supply goods rapidly returned to pre-war levels. Once again designers adapted to change and, in this case, they actively fuelled demand and, as epitomised by the American designer Brooks Stevens, they created 'the desire to own something a little newer and a little better, a little sooner than necessary' [2]. This approach and practice predominated in mainstream design throughout the following decades although there were some dissenters: for example Richard Buckminster Fuller (1895-1983) advocated '*ephemeralisation*' (i.e. 'doing more with less') while Victor Papanek (1923-1998) publicly described the design profession as '*harmful'* and '*a dangerous breed'* responsible for creating a *'whole species of permanent garbage to clutter up the landscape, and by choosing materials and processes that pollute the air we breathe* [3]. Consequently, his peers forced him to resign from their professional body, but he continued to promote prudence, and environmental, social, and moral responsibility. Another radical thinker, the architect Walter Stahel, also advocated resource prudence via cradle-to-cradle thinking from the 1970s. Like Buckminster Fuller and Papanek, his ideas were contrary to the mainstream until the early 1990s however when awareness of increasing demand on resources, waste and environmental degradation highlighted the need for a change in approach in line with '*sustainable development'* as defined by the World Commission on Environment and Development in the 'Bruntland Report' [4]. Some designers responded positively to the challenge and adapted their practice and thus they continued to develop the ethos initiated by Buckminter Fuller, Papanek and Stahel as Design for Sustainability.

The evolution of the Design for Sustainability (DfS) and the sustainable design process and scope is summarised in a number of publications including Ceschin and Gaziulusoy in 2016 [5] who identify and describe ten key approaches that reflect the shift in focus from product to systemic design between 1990 and 2015. They are defined as green and eco-design, design for emotional durability and behaviour change, biomimicry, cradle-to-cradle and circular economy, Base of Pyramid, product-service innovation, socio-technical systems, and transitions. This shift is both an example of continuity in the discipline and of adaptation to change and increasing knowledge about the environment, social and economic factors that underpin sustainable development. Although some design and engineering professionals do not employ these philosophies, methods and strategies, many professionals and their clients are adapting and responding to and/or leading and creating positive change.

2 THE ORIGINS OF DESIGN EDUCATION

As noted above, early professional practitioners of design were either architects, artists, or engineers; however, developments in technology, materials and manufacture associated with the industrial revolution highlighted the need for more specialist design training around Europe and in the UK. 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 and in 1762 an associated school was set up. Unfortunately, it was unsuccessful, but the government recognised the growing need for such link. In 1836 it established the Select Committee on Arts and Manufactures, as a result the first design

(Normal) schools were set up near to manufacturing centres to prepare students for employment in and support industry and to develop 'good' design. Since then both design and engineering education have flourished globally and in 2017-18 for example in the UK alone there were 165,000 students on engineering and technology courses and 175,600 students on creative arts and design courses [6].

3 EDUCATION AND DESIGN FOR SUSTAINABILITY

In order to prepare students for employment, education has both adapted in response to and initiated developments in technology, its application and technology-human interaction in all disciplines, one of which is of course Design for Sustainability. At present there are only a couple of sustainable design courses in the UK, but many others include sustainability in the curriculum either as specialist modules or as assignments within modules. Like other design subjects, DfS has evolved to reflect and lead change and consequently it has broadened to consider products and service and system design.

Design for Sustainability is currently facing unprecedented challenges. These may derive from development in education such as a 'tick box culture' encouraged by modularisation, where students fail to transfer knowledge from one part of the course to another. They can also be associated with more profound personal factors as students and other individuals encounter existential problems and fears associated with climate crisis and global warming, environmental degradation, resource depletion and supply chain security, population growth and migration for example. These concerns are manifest as recently recognised behaviours, namely eco-fatigue, eco-anxiety, and eco-apathy. Eco-fatigue has been associated with sustainability action since the late 2000s [7] and more recently with sustainable tourism [8]. It is a condition in which people become tired of discussions about sustainability, are pessimistic about the future of sustainability and distrustful of sustainability-related business claims and triggers include too much and/or confusing information and negative practices such as green washing. Eco-anxiety is defined as a chronic or severe anxiety associated with fear of climatic and environmental catastrophe [9], and it can have a very adverse impact on mental health and well-being. Climate depression is also increasing among young people and people who work in sustainability-related professions. Finally Eco-apathy is associated with learned helplessness, a condition in which individuals feel so overwhelmed by the scale of a problem that they believe that they are incapable of making changes as an individual and therefore do nothing. These conditions are being exacerbated through use of social media and the internet where algorithms repeatedly present readers with similar and/or more extreme articles so they are deprived of balanced opinion and information.

As educators it is essential to respond and adapt to these emerging challenges and to develop pedagogic strategies that simultaneously mitigate these issues and ensure that sustainability continues as a core subject within design and engineering courses and ultimately in industry. This calls for an alternative to current pedagogic practice that actively provokes curiosity, is engaging, memorable, makes an impact and is enjoyable to ensure that students fully engage with education about and for sustainability in the immediate, mid, and long-term. It is equally important to empower students so they can deal with their negative feelings and improve their mental health and well-being and the following assignment was developed to meet these various criteria and outcomes.

4 AN ALTERNATIVE PEDAGOGIC STRATEGY

4.1 The Assignment: Design your Future – your city your choice

The assignment was part of the first year 'Sustainability Week' which was introduced to give all design students a good fundamental knowledge of the subject. Students were required to work in interdisciplinary (mixed PD and EPD) groups of 3 or 4 on a 4-day assignment and to develop an unsustainable design proposal. Each group worked on a different theme, namely food, water, transport, travel, energy production, buildings, resource use, health and leisure and they must 'trash' as many UN Sustainable Development Goals (SDGs) as possible. The following figures show examples of students' proposals.

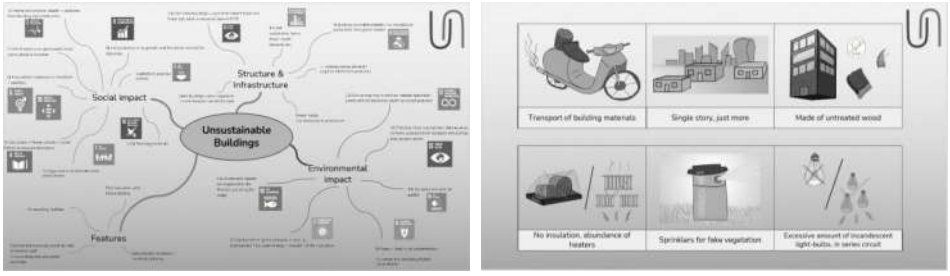

Figure 1. Unhaus - Unsustainable Buildings

Figure 2. Frozen Carnival - Unsustainable Leisure

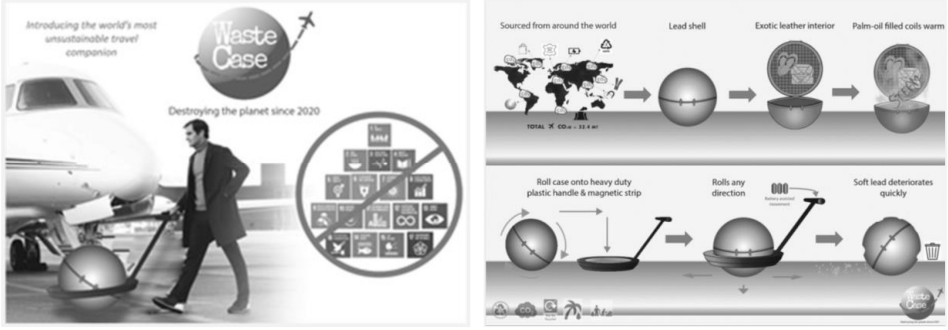

Figure 3. Waste Case - Unsustainable Travel

4.2 Results

The assignment was introduced in 2018 and has run three times and as illustrated by quantitative and qualitative review, it is proving to be increasingly successful. There has been an upward trend in results since 2018, and while the quality of project output has improved, students also appear to be transferring and implementing what they have learnt to other assignments, modules, and course years. A simple participant survey also showed that 83% of respondents enjoyed the activity more than if they had been asked to just design an 'ordinary' or mainstream product. Furthermore 56% said that the approach had *probably* and 26% said it had *definitely* deepened their understanding of sustainability and sustainable design more than a mainstream sustainable design assignment. Students were also asked to identify whether they had learnt about: (a) the UN SDGs, (b) current global challenges, (c) designers' responsibility to address the challenges, (d) designers' potential to address the challenges, (e) the effects of unsustainable design output and (f) the effects of sustainable design output. All students learnt about two or more of these points, and so learnt about all. Finally, 100% of students said they would recommend that the project should run in the future. Anecdotal feedback was also positive and included comments like: '*although I ticked all from what I learned during the project I would like to learn more'*, '*I would explore more sustainable technology'* and *'I found it a very helpful approach to find the most*

unsustainable product we could as reverse engineering it would give us the most sustainable product'. It is evident that the assignment has been successful to date; it is important to understand the reasons why this is so, and they are now discussed.

5 REVERSE PSYCHOLOGY AND DEEP LEARNING

The term 'reverse Psychology' refers to a manipulation whereby the opposite of what is being sought is asked for, the theory being that this will lead to people opting for the belief they think is being advocated against. A problem for this approach is when the person realizes they are being manipulated and takes revenge by following the original suggestion (the opposite of what is desired). Typical examples are a parent trying to persuade a child to eat a particular vegetable by telling them 'I don't think you would be able to eat it all' rather than the 'please try some' approach. This approach is used in marketing [10], where there has been an increase in the use of reverse psychology to engage the consumer who may be inured to conventional marketing principles. An extensive search using various key terms has failed to find any academic papers discussing the use of reverse psychology in teaching but research by Craik & Lockert in 1972 [11] explains why it is successful. They proposed a Levels of Processing Model which suggests that the deeper information is processed, the more elaborate and longer lasting the recall of that information will be. If information is more readily available, then it becomes easier to consider and understand. A student-centred approach to learning, sometimes called active learning, has been shown to increase the learner's feeling of being an active participant in the process and has an emphasis on deep learning and understanding. This suggests that being an active learner will encourage the student to process what they are learning at a deeper level, increasing their understanding of the topic. The novel approach of this project was to use reverse psychology to encourage deeper processing of the information. Traditionally, students are taught about the right way to do things and then put that knowledge into practice.

This paper outlines a completely different approach. Whilst the aim of most educators is to encourage students to follow the rules in order to learn, in this instance the students were told to break as many rules as possible in order that they met the learning objectives of understanding the rules; using reverse psychology to obtain the desired outcome. They were asked to come up with designs which negated as many SDGs as possible. The theory was that it would not be possible to break the rules, unless they knew what the rules were in the first place. In order to break the rules, the learners needed to think about them at a much deeper level in order to understand how to break them as illustrated in Figures 1, 2 and 3, which present example design concepts for unsustainable buildings, leisure, and travel. The students began the project by reviewing and learning about the aims and scope of individual SDGs. They then brainstormed ways of undermining and counter-acting them such as damage to climate, health, and eco-systems. This enabled them to identify criteria such as material types, durability, and toxicity and how these factors would adversely affect e.g., miners, makers, and consumers; they also considered energy generation, fuels and emissions, types of transport, efficiencies and associated impact on the environment and eco-systems and social factors such as slavery, child labour and low wages and considered whole life cycles including unregulated product disassembly and disposal. This helped them to understand the broader implications of and the complex inter-relationship between design decisions and the SDGs and they made sure that their individual design choices adversely impacted on as many SDGs as possible. For example: the *Unhaus* proposal uses the least efficient highly polluting means of transport to carry materials to site; the buildings endanger residents because the timber has not been fire-proofed, and eco-systems are destroyed through high land-use while water and energy are wasted through use of garden sprinklers and tungsten lighting. The *Frozen Carnival* replicates historical festivals but in this case the river has to be frozen artificially which requires a lot of fossil-fuel generated energy to damage the climate; food and drink are sold in single use packaging and waste is dropped through holes in the ice which damage the local eco-systems and contribute to ocean plastics. Finally *Waste Case* perfectly addresses unsustainable travel theme in that the case is made by children and poorly paid workers from soft lead which only lasts for one journey; use of lead also damages health, learning potential and the environment, while low wages prevent children from attending school. It is lined with fur from endangered animals, and it is very heavy and requires high energy inputs for transportation. The traveller also uses a private jet for local and long-haul travel, all of which directly and indirectly negate most SDGs.

While this looks positive, it is yet to be determined whether this approach will successfully translate to other disciplines, which warrants further research. Furthermore, it is essential that students understand

the true nature of the approach which is to enhance their knowledge of sustainability and that they clearly explain this in their portfolios and at interviews.

6 CONCLUSIONS

This paper briefly describes how designers and engineers have adapted practice and output in response to technical, social, economic, and environmental factors since the first industrial revolution. It also explains that the primary role of education was to prepare students for employment, and therefore that courses and curricula reflected and were adapted in line with professional practice. However recent environmental phenomena have initiated new behaviours and culture that demand an alternative approach that does not reflect the best of current professional practice and is contrary to good practice. In this case the innovative use of reverse Psychology in an educational context is a positive adaption to address challenges facing many young people and students. It is clear from the level of student engagement and the meeting of the learning objectives that this method worked well to encourage a deeper processing of the information about both the UN Sustainable Development Goals and sustainability in general. One advantage of this method is that the deeper learning means it is much more likely that this learned knowledge will remain and be applied long after the students graduate, thus having a positive impact in the quest for a more sustainable future. It was clear from the student comments that they found the assignment brief initially surprising because they were asked to break the rules, which is the opposite of traditional teaching practices. They also found the brief challenging, but this only served to make them engage beyond a superficial 'how do I pass' level and become the active learners they needed to be. Finally, when students enjoy the learning process, they are more likely to engage at a deeper level and to spend time outside the classroom thinking about the subject holistically and participate in self-directed study.

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TRUSTING AUTONOMOUS SYSTEMS – DESIGNING FOR BYSTANDERS AND SECONDARY USERS

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ABSTRACT
Knowledge and awareness of the relationship and trust between man and technology is important for users to accept artificial intelligence (AI) and autonomous systems. While research has been conducted on the interaction between operators or passengers and robotic vehicles, there is not much research on secondary users, i.e., users who are not directly interacting with the system, such as pedestrians or bystanders in the robot's environments. This paper summarizes and synthesizes the existing literature relevant to secondary users' trust toward autonomous systems. The focus is (1) to find out how the secondary user experience in human-robot interaction is affected by trust, and (2) to see how trust is designed in autonomous systems. By designing for appropriate levels of trust, the designer can empower both primary and secondary users to accept the information provided by the robot and follow its suggestions.

Keywords: Trust, autonomous system, human-robot interaction, design, secondary user experience

1 AUTONOMOUS SYSTEMS AND THE USER EXPERIENCE OF BYSTANDERS

Artificial intelligence (AI) in the form of autonomous systems, such as robots and vehicles, are introduced to our everyday life in a wide variety of domains, including transportation, military, scientific applications, entertainment, and home use. With advances in the development of autonomous systems and autonomous transport solutions, the relationship and trust between man and machine is important for humans to accept the technology [1]. This paper explores trust-related challenges in human-robot interaction (HRI) by outlining how the secondary user experience in HRI is affected by trust.

1.1 The secondary user experience of autonomous systems

To achieve full and successful implementation of autonomous systems, it is essential to understand the notions of user acceptance and intended behaviour in relation to them. However, most studies target the buyers, main users, or operators of robots. These studies do not consider 3rd persons or bystanders who do not explicitly interact with the robots. However, these persons can nevertheless interfere with and be affected by the robot's actions. Alsos and Svanæs [2] refer to these as *secondary users* [2]. Examples in the context of autonomous systems are pedestrians walking in front of a self-driving vehicle, a kayaker encountering an autonomous passenger ferry in a canal, a person getting in the way of an autonomous warehouse robot co-worker, or someone meeting a self-driving cleaning robot in a hallway. Further Alsos and Svanæs define the *secondary user experience* of a system as "the part of the overall experience of the secondary user that can be attributed to (1) the primary user's interaction with the system, or (2) the secondary user's interaction with the system with the primary users as an intermediary [2]". In this context, it is the user experience that passengers, pedestrians, or bystanders have when experiencing an autonomous system.

In fully autonomous systems, the robot is technically independent and will make decisions that require no primary user interaction. However, the primary user (the passenger or operator), will still most likely monitor and interact with the autonomous system through a user interface or a remote-control room, while having the possibility to intervene in the event of malfunction or an emergency. Secondary users, however, can only experience the autonomous system's internal state and future intention through its behaviour or feedback from the operator. As Figure 1 illustrates, the secondary user experience is affected by the overall experience of the primary users and vice versa. The primary and secondary users interact through the autonomous system, based on their interaction with the robot. Interaction between

the autonomous system and the secondary users could take place via external features indicating that the pedestrian should cross the road or not, or by the pedestrian signalling to the autonomous systems that they want to cross. Actions taken by either the robotic system or the primary or secondary user will affect the co-experience, which is the user experience created in social interaction with the presence of a system or product [3].

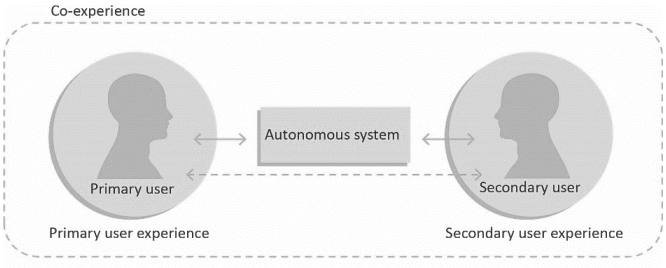

Figure 1. The solid arrows indicate direct interaction, while the dotted arrow indicates indirect interaction (adapted for autonomous systems from [1])

1.2 The importance of the secondary user experience

Before crossing the street, pedestrians tend to look for eye contact or any form of human communication with drivers. A study conducted by Lin et al [4] on the interaction between drivers and pedestrians at signalized intersections demonstrated that pedestrians feel more comfortable when they can interact with drivers before crossing a road. However, in the case of pedestrian-autonomous vehicle interaction, the interaction is between the robotic vehicle and the pedestrian. This could cause confusion since the robotic vehicle's design would probably be very similar to the current vehicle design, or, as in the case of self-driving cars, give the driver the opportunity to engage and disengage the autonomous system. This means that with the current seating arrangement, one could end up with a passenger in the conventional driver's seat. Unless the vehicle provides the pedestrian with adequate information, the pedestrian could become confused about whether to interact with the vehicle or the person.

In line with the study by Alsos and Svanæs [2], the co-experience will have an impact on the overall experience of a system. Based on the robot's features and communication skills, the primary and secondary users can make choices affecting the co-experience. For instance, if a pedestrian is unsure about whether to interact with the car or the passenger sitting in the driver's seat, the pedestrian could cross the road at the wrong time, creating dangerous scenarios. Today, robotic vehicles are programmed to stop immediately if something appears in front of their sensors. This sudden stop could affect both the passenger experience and their trust in the system, while at the same time lead to a possible accident with surrounding vehicles. Moreover, as stated by Wickens [5], humans are less forgiving of mistakes made by robots than by humans. This could again affect user trust and the willingness of the customer to buy or use the product.

2 DESIGNING FOR TRUST

In human-robot interaction (HRI), trust is considered essential in establishing and maintaining appropriate use and expectations, as it is closely associated with persuasiveness. Trust can directly affect people's willingness to accept the information communicated by the robot and to follow its suggestions [5]. Trust in HRI is closely related to research conducted on trust in automation in general. Although there are several studies on trust and automation [6-8], previous research on interaction between pedestrians and vehicles is based primarily on behaviour that involves traditional human-driven vehicles. More recent research, however, has started to explore pedestrian interaction with autonomous vehicles [9-11]. Nevertheless, few studies have focused on why it is important to design for trust for the secondary users in other fields, such as the interaction between workers and robots in a warehouse, or patients and robotic doctors/nurses in a hospital.

2.1 Three layers of trust

For automated systems, Marsh and Dibben [12] identify trust as something based on three factors – *dispositional trust*, *learned trust*, and *situational trust*. Dispositional trust represents the individual's

tendency to rely on automation, situational trust depends on the specific context the person finds themselves in, while learned trust is based on previous experience with a product or system. In other words, trust varies depending on the user's personality, background, experience, and the context-of-use. This makes trust an individual experience that will differ from person to person, making it a difficult factor to measure.

Based on Marsh and Dibben's [12] three layers of trust, Hoff and Bashir [6] created a theoretical model for automatic systems. Their study indicates three main factors for building trust between an operator and robot: *Initial trust*, *dynamic trust* and *situational trust*. Initial trust can directly affect both the dynamic trust and the performed human actions, as shown in Figure 2. Action performed by the secondary user affects action performed by the robot, which again affects the operator. How the robot chooses to respond and communicate its intentions based on the human actions, will in turn affect the dynamic trust. At the end of the interaction, the dynamic trust will transfer to existing knowledge and experience about the system.

With the correct use and understanding of the factors in Figure 2, one will be able to design for the right amount of trust. The right amount of trust could again lead to a better match between the expected and actual outcome, which in turn will contribute to a user experience that promotes feelings of security, safety and predictability. This will influence both the user experience, the secondary user experience and the shared co-experience.

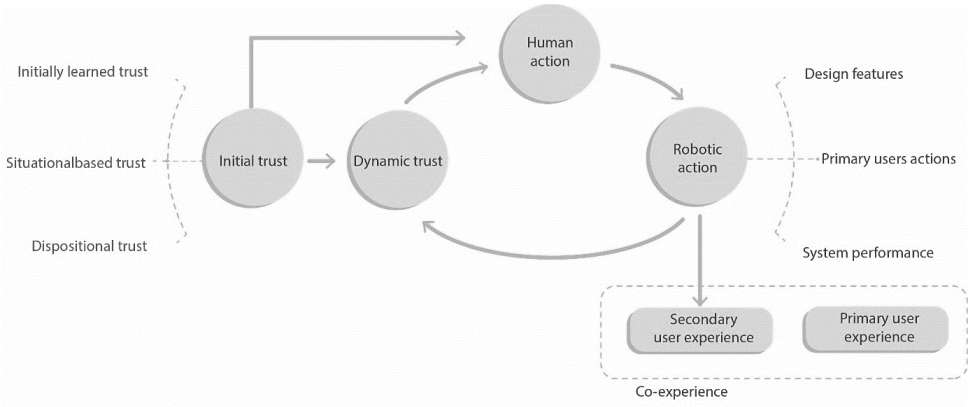

Figure 2. Factors that affect trust before and during interaction with robots. The authors' interpretation on Hoff and Bashir's' research, and how it can be translated to secondary users

2.2 Misuse and disuse

The relationship between robots with human-like qualities and trust is uncertain, but research demonstrates that humans tend to trust robots in the same way they trust other humans. This can lead to people underestimating or overestimating the risk associated with the robots' decisions and actions in the form misuse (over-trusting) or disuse (under-trusting), which can lead to negative consequences [7,13, 14]. The less an individual trusts a robot, the faster they will intervene as it progresses towards the completion of the task [15].

There have been several serious accidents due to misplaced trust in automatic systems. An example is the Costa Concordia cruise ship disaster in 2012 which killed 32 passengers and may have been a result of the captain handing over the ship's navigation system in favour of manual control due to lack of trust in the technology [16]. A more recent accident resulted in the first pedestrian death associated with self-driving technology [17]. The autonomous taxi was a test vehicle with a safety operator behind the wheel. Several factors are thought to have played a role in the accident, but excessive trust in the system could have led the driver to allow himself to watch a video on his phone instead of monitoring the car.

Automated systems are still in the testing phase, which increases the likelihood of more accidents. Although AI-based technologies must provide adequate guarantees to minimize the risk of harm, current regulations cannot completely exclude the possibility of damage resulting from the operation of these

technologies. As stated in *Liability for AI and other new digital technologies* [18], such technologies are characterized by complexity, modifications through updates or self-learning during operation, limited predictability, and vulnerability to cybersecurity threats. One thing is the factors making it more difficult to claim compensation for victims, another that it makes it significantly more important to design for the right amount of trust. By creating an understanding of the product being under development and training, one can create an expectation which correspond to the result. Designing for the right amount of trust is a crucial part of the challenges when designing for new services such as robots and should be given more thought during the design process.

3 ROBOTS AND THE ROLE OF THE DESIGNER

How do we create meaningful experiences of autonomous systems that leaves users feeling in control, and respect their values, goals, and attention? As shown in Figure 2, trust is dependant on the dispositional qualities of the user and the situation the user and robot is in, creating the need for different guidelines for different kinds of robots and systems. Robots having social interactions with humans, such as healthcare/care-taker robots, could benefit a more human-likeness approach due to the ability of establishing deeper connections with users [19]. On the other hand, robots used in industries could benefit having a machine-like design since it gives the feeling of higher levels of responsibility, possibly preventing misconceptions about the intelligence of the robot [20]. In any case, humanness can be added in the movement, appearance, sound, verbal communication, and non-verbal communication. However, human characteristics should be handled cautiously in the design process, as people anthropomorphize rather quickly [19].

A general rule is the need for a balance between the seamlessness of the interaction with the need for transparency of the AI system. In the case of non-humanoid robots, this means that secondary users are left with analysing cues such as lights, sounds, movements, and looks, in addition to analysing their environments. In other words, designing for trust is a way of designing how the robot is communicating with the world.

3.1 Trust as a part of the design process

For an automated system to work well, both primary and secondary users must be included and considered in the development process. Involving those who must deal with the future system in the design process creates better user interactions [21] and helps to optimize HRI and minimize human error [22]. Designers are trained to focus on the human in a technological system and play an important role as an intermediary between technology and psychology. However, trust is dynamic, and autonomous systems are constantly evolving, making it important to be flexible and efficient. Although designers are trained to handle future unknown problems, using different tools such as system-oriented design, design thinking and human centred design, are we using them on the right things?

While designers have limited influence in the actions of organizations for which they work, they can raise awareness of social responsibility within a company and make their voices heard. As very few products are designed and built alone, awareness of secondary users can be brought into cross disciplinary teams. One way of ensuring responsible innovation is by using The British Standards Institution's framework [23], including elements companies should consider when introducing new products, services, or processes to market. While this framework brings into the attention the importance of societal and environmental elements, and the requirement of engaging stakeholders such as end-users, it lacks the awareness of the secondary users. Both primary and secondary users must be recognized as individuals with needs, but still be part of a coherent and functional system. As people have different needs, and trust is personal, it is important to have an approach that can understand this complexity. Knowing what the different users need for information, and how to present it, creates better interaction between humans and machines and prevents disuse and misuse. Designers need to not only learn about how to design for trust, but how to design for the right amount of trust.

3.2 Communicating autonomous systems intention to secondary users through external features

Trust is reflected on how the autonomous system is communicating and interpreted by the world, making external features important in ensuring secondary user trust. The challenge lies in the ability to communicate the desired information to different kinds of users, regardless of their physical abilities, background and/or cultures. A survey from Deb et al. on interaction between pedestrians and drivers

indicated that pedestrians preferred visual signs, such as lights and screens, to indicate the vehicle's intention to stop at a crosswalk [24]. Following the study, several researchers and studies have proposed different strategies and design features to ensure the safety of pedestrians in HRI. One of those being 'Blink' from The Imperial College of London and the Royal College, allowing a two-way communication recognizing the pedestrians hand gestures to stop or keep moving [25]. However, this relies heavily on the pedestrians' learned trust and their ability to make hand gestures. On the other hand, proposals such as Simcons' prototype 'smiling car' [26], emphasizes/relies on the use of sight where the robotic vehicle will light up in a smile to indicate that the car will stop, and the pedestrian can cross the road. Since future autonomous systems will operate in public places among other technological systems, humans and animals, the systems do not only have to speak to each other but ensure a universal design able to communicate in similar manners to reduce the changes of confusion.

3.3 Trust as part of the Design Education

The traditional user interface through screens and physical buttons and knobs will go through a transformation with the introduction of autonomous systems and robots. This will require a different take on design education. As we have argued above, trust is an important aspect of the interaction between users and AI-based technologies. A designer needs to understand how to design for trust in AI-systems and robots through means such as lights, sound, movement, non-verbal and verbal communication, etc. This must be an important part of the designer's curriculum.

Even though we might not know what kind of autonomous systems and robots the future will bring, we do know that they will interact and operate among humans. To create a more humane future, we need a design education with humans in mind. This includes the understanding of the bigger picture; how the use of autonomous systems/technology has financial, ecological, and social consequences, and how psychological elements such as trust plays an important role in the user acceptance of autonomous systems.

4 CONCLUDING REMARKS

A fully autonomous system is technically independent, but still – as in the case of robotic vehicles – depends on people's trust to function properly, both primary users (i.e., operators), and secondary users (i.e., pedestrians). Appropriate design features need to be developed to ensure secondary user trust, and scientific evaluation of their effectiveness must be carried out. Trust in autonomous systems will improve if humans understand how robots are going to behave in their presence, for example by communicating actions through external features such as movement, appearance, sound, verbal and non-verbal communication. By designing for the right amount of trust, one can prevent users from getting the impression that the system works better than it does, which can have a negative effect on user experiences and in the worst-case lead to dangerous situations. With the right amount of trust, human-robot interactions will improve, thus making the system more understandable and safer, while reducing human error for both primary and secondary users.

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STUDENT EXPERIENCE OF PERCEIVED CONNECTEDNESS IN ONLINE DESIGN EDUCATION

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ABSTRACT
Online courses have been on the rise in the last few decades and recently with the pandemic across the world, many traditional design schools have transitioned to the virtual realm to continue learning seamlessly. This study has focussed on understanding the perspective of students from various design schools in India about their experience with online courses and their perceived social connectedness. This paper reports findings from a combination of quantitative and qualitative study, wherein sixty four students from five design schools across India responded anonymously to the online survey. This study assesses the level of social connectedness that students perceived with their instructors and fellow students in online classes. This paper also discusses some of the reasons for this perception, as articulated by the participants and reports a significant correlation found between felt connectedness and various factors in online learning. It was observed that while the given student populace seemed adept in online communication and exchange of information, their feedback on online classes revealed deeper insights into the aspects that affect their overall experience of design education. In addition, we submit some of the features or elements of traditional face-to-face (F2F) classrooms that students miss the most in the current online setting.

Keywords: Online design learning, connectedness, design education, virtual classrooms

1 INTRODUCTION

In the last few decades there has been a rise in online education around the world. Increased computer literacy and internet connectivity, growth in distance learning opportunities, many reasons contribute to this increase in popularity of online courses. Countries are increasingly investing in online and multimedia based courses [1]. Whereas design education is still not readily available online [2].

Social interactions are instrumental for human physical and psychological well-being. Social connectedness, which has been characterized as one of the main motivating principles behind social behaviour, is usually considered as a predictor of a successful life and it has been associated with many social and health-related benefits [3], [4]. Several researchers have recently provided empirically based guidelines for creating and maintaining social connectedness online that include strategies designed to facilitate status assessments, norm development, and role differentiation in computer-mediated communication channels that often lack the subtle social cues people use in face-to-face(F2F) interactions [5], [6]. Laffey, et al [7] 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 [8]. While fruitful social interactions happen relatively effortlessly in F2F learning settings, creating and maintaining these social connections in online learning environments requires active support and, often, instructor facilitation [9].

In design education, some research has been done to inquire into the effectiveness and success of these courses but not much has been done to fully understand the impact on learning in online platforms [10]. With Studio-based learning being at its core, design courses usually have small class sizes. They typically use project work and collaborative creative problem solving with many possible solutions [11]. Research shows that online collaboration in design can be successfully done only if student participation is high and instructor feedback is instantaneous [12]. The characteristics of studio-based teaching in design, have been identified as supporting interaction, active learning, as well as social engagement [13], thereby involving high social connectedness amongst students and instructors.

Slagter van Tryon & Bishop [14] developed the Social Perceptions in Learning Contexts Instrument (SPLCI), a research tool for measuring students' perception of the social connectedness in online courses. Not many technically validated instruments are available for instructors to collect data necessary to evaluate the success or failure of these pedagogical methods.
This study aims at evaluating student experience of perceived connectedness in online design courses to understand the impact, if any, of social connectedness on course understanding and motivations.

2 METHODS

An inductive research approach was adopted to investigate and make observations to arrive at conclusions [15]. Data was collected from graduate and post graduate level design students doing a combination of theory and practical courses in Product Design, Transportation Design and UX design from UPES School of Design, United World Institute of Design, Pearl Academy Delhi, ISDI Mumbai and Department of Design IITD. An online survey with closed and open-ended questions to study student behaviour and responses with respect to online design courses was considered to be the most suitable method to gather students' feedback for various reasons. Online surveys gave the advantage of reaching a greater number of participants in a short time, without any geographical constraints. They were used to collect both quantitative and qualitative data at the same time. It gave students the flexibility to participate as per their convenience of place and time. They also support the anonymity of respondents, allowing greater honesty and higher participation when well-designed, fast and easy to complete [16].
A 5-point Likert scale was employed, and students picked from a range of responses, Always(5), Often(4), Sometimes(3), Occasionally(2), and Never(1) [17], to help answer the 'what?' questions while the open ended questions allowed students to give in-depth information, answering the 'why?' questions about their experiences [18]. Sixty four students from 5 design schools across India responded to the survey. These students had spent a majority of their course time in traditional F2F classes and had experienced the online classes only for 2-3 months prior to the survey.
The quantitative data obtained using the online surveys was analysed by using the existing tools from the survey platform, Google forms. This data was also analysed to find any possible correlation between the variables and felt connectedness. The qualitative data obtained from the open-ended questions were coded and categorised into themes and subthemes. Similar codes were combined into subcategories and their frequency of occurrence was counted to evaluate importance. The findings, analysis and discussion are presented in the next section.

3 RESULTS AND ANALYSIS

The results and analysis done during the study have been shown in the following tables.

3.1 Online Class Hours and Platforms used

Tables 1 and 2 show the no. of hours spent and the online platforms used by them for design courses.

Table 1. Online design class hours

Online class hrs per week	<5	6-10	11-14	15-19	>20
No. of students	39	9	6	2	8

Table 2. Online platforms used for classes

Online class platform	Zoom	BB Collaborate	Google Meet	MS Teams	Others
No. of students	58	11	10	4	5

It may be noted that some students used more than one platform for online classes. Therefore, a majority of students spent not more than an hour each day in online classes and the most popular(or preferred) platform was Zoom. Students also used social media or other online platforms like WhatsApp, Miro and Mural to connect outside of online classes to collaborate and work on projects.

3.2 Virtual Behaviour and Class Participation

The students indicated how often they displayed certain behaviour online as shown in table 3.

Table 3. Virtual behaviour and experience in online classes

Virtual Behaviour and experience	Always (5)	Often (4)	Sometimes (3)	Occasionally (2)	Never (1)	Mean	Var.
Video ON	2	6	18	25	13	2.35	1.03
Verbal Interaction	8	17	15	18	5	3.05	1.44
Course Interest	13	31	11	5	3	3.70	1.10
Course Understanding	7	28	22	4	2	3.52	0.83
Connectedness with Instructor	6	12	21	14	10	2.81	1.46
Connectedness with peers	2	5	20	22	14	2.33	1.05

Here, would be an appropriate place to note that the respondents were not given a clear definition of 'social connectedness' or 'connectedness', instead were required to use their own perceptions and understanding of 'connectedness'. The terms used in table 3 are described further to better understand the questions asked in the survey. 'Video ON' corresponds to how often the students kept their video camera turned ON during classes. 'Verbal interaction in class' corresponds to how often the students interacted with the instructor or co-students during the classes. 'Course Interest' corresponds to how often the students were interested in the course they were attending, while 'Course Understanding' corresponds to how often the students understood everything that was being taught in online classes. 'Connectedness with Instructor/peers' indicates how often the students felt connected with the instructor/peers during online classes.

3.3 Correlation between Variables and Connectedness

Pearson's correlation was applied to see the relationship between variables (frequency of keeping video ON, verbal interaction in class, interest in course and course understanding) and the felt connectedness with instructor and/or co-students. Significant positive correlation was found as shown in the table 4.

Table 4. Correlation between Variables and Connectedness

Correlation with Connectedness (r.)	With Instructor	With Co-students
Video ON	-	.267
Verbal Interaction	.291	.207
Course Interest	.419	.255
Course Understanding	.249	-

A significant positive correlation is seen especially between Connectedness with the Instructor and Course Interest. This indicates that the students were more interested in the course when they felt higher levels of connectedness with the instructor. Further, when students kept their videos ON more often, they felt more connected with their co-students. Similarly, higher verbal interactions in class led to higher felt connectedness with the instructor and/or co-students. Significant correlation was also seen between the level of connectedness felt with the instructor and the understanding of the course taught.
Further, the qualitative data obtained from the responses to the open ended questions in the survey were tabulated based on the frequency of common themes that emerged from coding them. These tables help us gain some understanding of the 'why' behind the 'what', the reasons that made the students feel or not feel a sense of connectedness during the online classes.

3.4 Problems Faced during Online Classes

It was found that the most common technical problems faced by the students during online classes were power/internet connectivity or interruptions and having to stare at the screen for a long duration of time. While some faced audio issues, a few also had to face distractions at home.

3.5 Reasons for Perceived Connectedness

Table 5. Reasons for perceived Connectedness in Online Classes

Reasons (no. of mentions)	No. of mentions	Sample responses
Interactions: Discussions/teamwork (19) Chat options (13)	32	'A lot of students live in different cities and family environments which impacts thoughts and ideas, it was interesting to see

		and hear the variety of ideas that came from other students while at home.'
Visual presence: Being able to see others; Video on (8) Knowing my classmates are there (4)	12	'If their videos were on and verbal communication ensued', 'The feeling of nostalgia that we mutually shared'
Instructor input: Voice/video/feedback(5), Course content(2)	7	'Interaction, familiar voices' 'Getting timely feedback from mentor'
None/Not sure	13	'It's really hard. Required lots of effort. Nothing ever really helped'

The most common factor that helped students feel a sense of connectedness in online classes was having interactions with the instructors or students and doing collaborative work as part of class. The chat option in some of the platforms also aided in connectedness. More than a sixth of the respondents felt there was nothing that helped them feel connected in online classes.

3.6 Reasons for lack of Perceived Connectedness

Table 6. Reasons for lack of perceived Connectedness

Reasons (no. of mentions)	No. of mentions	Sample responses
Physical/Visual absence Can't see others/video OFF (7) Not there physically (15) Class environment missing (7)	29	'You can't see or share eye contact or talk to ppl... It's annoying', 'Workspace at home not fit for design related work'
Lack of Interaction No discussions (20) Session too long (4)	24	'When the session went on for a long duration and got monotonous', 'Some ideas are better communicated through in person interactions and ideation sketches are more difficult.'
Technical issues Internet connection (12), Audio issues (7)	19	'Poor connection...', 'The confusion when everyone talked at the same time'

In attempting to find the reasons for the respondents' lack of felt connectedness in online classes, it was found that almost half of them felt that physical and/or visual absence was a key reason followed by the lack of interaction of students in the classroom or college campus. Attending classes from home also added domestic distractions and made it difficult to be motivated and focused enough to work well. Students also missed out on peer-learning and building on each other's ideas.

3.7 Advantages of Online Classes

The main advantage of the online courses, according to the study, was the convenience and flexibility it afforded the students to connect from the comfort of their homes or anywhere else. Ease of access to online resources and features like breakout groups and recording options were found beneficial, especially for theoretical courses. Students often used social media or online platforms like WhatsApp, Miro and Mural to connect outside of class time to connect, collaborate and work on group projects.

3.8 Elements Missing in Online Classes

In attempting to understand aspects of F2F classes the design students missed the most during online classes, the students responded descriptively, as summarised in Table 7, with a few sample responses.

Table 7. Elements missing in online classes

Elements (no. of mentions)	No. of mentions	Sample responses
Interactions Conversations/sharing ideas(13) Debates/discussions(17) Critique/feedback/clarification(10) Accountability(1) More focus(7) Easier/faster learning(3)	51	'The instant feedback while doing a work, project or assignment to correct the mistakes and easily move on', 'A very small but crucial element missing for me was the little discussions we would have with the other students about the same topic while it was being taught 😊. It added to the understanding of the subject matter.'

Physical Presence Being with/seeing each other(14) Body language/expression(4), Movement(3)	28	'Meeting friends, having fun in class, proper discussions, looking at faces'
Ambience Classroom/studio(8) College/school(1) Learning/work environment(10)	19	'The atmosphere is different. It is after all a place not dedicated to learning, when studying from home or from other places doesn't have the same effect', 'The workspace and people which made the aura of a good working environment'
Fun Aspect Laughter/fun activities(5) Energy(3), Attachment(1)	9	'The energy of the class sessions, with a lot of back and forth interaction', 'Human interaction that is organic and the laughter that came with studying'
Everything	9	'Every single moment'

Affirming their previous responses, almost 80 percent of the respondents said they missed the animated discussions and organic interactions the most in the online setting. They explained how these discussions helped them get a better grasp of topics being taught in class or clear any doubts they have with their instructors. These interactions also helped them learn from their peers.

4 DISCUSSIONS

The results and analysis highlight the importance of being able to see each other and interact with people in physical space. While the internet is a great space to meet and connect with people, it has its own limitations due to the visual gap that can be closed only by physical presence and interaction, especially in online design education. And yet, we see many design instructors and students successfully exchanging knowledge and ideas to deliver and receive design education. While felt social connectedness of design school instructors and its effect on pedagogy has been reported earlier [19], in this study we found insights on how the students were responding to online design education and taking initiative to bridge the digital divide. Even though there is(and most likely, always will be) a clear preference for in person or F2F learning experience, we saw that students found ways to stay connected outside of online classes and discover and adapt to new platforms to collaborate for team projects by finding avenues to replicate in-person interactions and exchange of ideas. Design instructors therefore need to constantly encourage visibility and verbal interaction in online settings. They can further incorporate collaborative tools as add-ons to the online platforms they are currently using to encourage in-class participation and interaction, thereby heightening the learning experience for both the students and themselves.

5 CONCLUSIONS

This paper has reported that design students preferred traditional F2F learning environments rather than the online option due to the more holistic learning that happens due to focused learning and higher interest generated just by the experience of creative and curious minds learning and interacting together. It points out that the primary drawback of online classes was its lack of perceived social connectedness, immediate critique during ideation and organic group interactions. Whereas the primary advantage of an online learning mode was found to be the flexibility it grants in terms of location and time.

Considering the feedback from the survey participants, it can be concluded that:

1. Significant correlation was found between students' connectedness with instructor and the interest in a course, verbal interaction in class and understanding of the course. Correlation was also found between connectedness with co-students, visible faces and verbal interaction in class.
2. Perceived connectedness with the instructor and peers in virtual classrooms depends greatly on being able to see and interact with each other.
3. Current online platforms are not the easiest or most intuitive when it comes to receiving feedback or clarifying doubts.
4. Online classes reduce the possibility of collaborative work and group projects online, which is otherwise an integral part in traditional F2F classrooms.

5. Lack of proper Internet and power connectivity are practical problems still faced by many students in many parts of developing India. Also, studio/workshop facilities and classroom environment is missing in online setups.

Most of these students had experienced online classes for only 3 months. Therefore, further research needs to be carried out over a longer duration to understand and compare the deeper impact of the social connectedness on design learning. Technology focused research would help identify features that can help make the online learning experience a more rewarding one.

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ENCOURAGING REFLECTION ON GENDER BIAS IN DESIGN EDUCATION

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ABSTRACT
Gender stereotypes still dominate modern society, despite of an ongoing shift of ideas and ideals relating gender roles. Whilst design impacts our perceptions on gender roles, today's design education lacks the tools to help design students reflect upon the topic from different perspectives, and to reflect on their own likelihood to gender stereotype. This paper summarizes insights from a literature review, addressing terminology, the evolution of gender roles, the current status of gender bias in design, and current solutions, tools, and mindsets for addressing it. Based on these insights, this paper considers various approaches to introduce the topic in design education and proposes a workshop about gender bias in design as a practical yet effective way to start making up for this lack.

Keywords: Design practice, gender roles, gender system, stereotypes, bias, behaviour

1 INTRODUCTION

Today, we recognize a shift in gender roles and values in the modern society. Boundaries are being pushed as feminists are demanding equality, the voice of the queer is rising, and medical practice allows sex reassignment surgery. Simultaneously, the ideas and ideals of the masculine man and the feminine woman are still deeply integrated into our society and mindset and manifested through design. Our surroundings are filled with products, services, messages, and spaces expressing and manifesting the gender-related expectations in society. As consumers, we are subconsciously accepting images, ideals and ideas which manifest and confirm the social values and norms associated with the binary, heteronormative genders, man, and woman. This concept is described as 'gender roles' and normally represents two antipodes: the masculine male and the feminine female [1]. In other words, men are presumed to appear and behave masculine, whereas the opposing, feminine characteristics, are associated with women [2]. Consequently, behaviour associated with one gender is considered inappropriate for the other [1], thus contributing to the development of taboos and stigmas. From the early traces of gender segregation until today, gender roles have developed and shaped our perception of what it means to be a man or a woman. This has developed and translated into separated gender roles, evident through our preconceptions, expectations, and expressions, shaping and being shaped by the products, the space, and the vision we design. Knoll et al. [2] argue how such associations contribute to creating stereotypes, lacking sensitivity in reflecting variety in behaviour of and towards genders. These traditional gender roles are being maintained by materialism and capitalism, guiding design products, services and thinking. How design habitually exploits the concept of masculine men and feminine women is especially made evident in the product language of products. When put into society, such artefacts and systems communicate behaviours and expectations based on gender. Consequently, many are left out or restricted in opportunities and choices.

This paper intends to put the challenge of gender bias in design on the agenda, by exploring how designers are, and possibly can be better enabled to make conscious choices and take responsibility for the consequences of these. To do so, they need to become aware of the challenge concerning gender bias in design, while being encouraged to utilize their knowledge in practice. After further introducing the topic, this paper review existing tools and mindsets for educating designers in the role of gender bias in design and proposes a workshop format to this end.

2 TERMINOLOGY

2.1 Biological context

There is a distinction between the term's 'sex' and 'gender' in literature. 'Sex' refers to the biological factors separating male and female, whereas 'gender' is more often used when speaking of sociological and psychological factors [3]. However, the latter is exposed to confusion with 'sex', as it is a constantly evolving term, defined by name, sexuality, external and internal genitalia, chromosomes, and genes [4]. The biological term 'sex' categorizes people by their physical attributes and mechanisms [3]. Grounding in the reproductive functions, where male and female are considered the two main categories, this is often referred to as the 'binary gender system'. However, modern research argues for a new way of conceptualizing sexes, by describing gender as a spectrum, with male and female as extremes [4]. The spectrum model includes non-binary sexes and genderqueers, such as intersex and transgender, and induces sex and gender studies.

2.2 Social context

Speaking of 'gender' in a social context, more ambiguous factors are accounted for. Originating from the biological understanding, gender refers to social roles, meaning characteristics or attributes associated with and expected from a particular sex [3]. This system, where the biological separations of the sexes have been brought onto social processes, creates a structure of social relations [5] on a symbolic, structural, and individual level [6]. Bem [1] explains how the gender structure is a set of polarized characteristics, being either masculine or feminine, strongly associated with being male or female, respectively [2]. Furthermore, Knoll et al. [2] argue how such associations contribute to creating stereotypes, lacking sensitivity in reflecting variety in the behaviour of and towards genders. Butler [7] argues for a more fluid gender theory, with the existence of many possible categories of gendered and sexual practices, beside the binary definitions. In other words, gender identity depends on, amongst others, age, ethnicity, sexual orientation/identity, social status and/or (dis)ability [8]. Nevertheless, literature reveals that the perception of two main, opposing genders, being imposed with distinct gender roles, are deeply integrated into most Western societies.

3 EVOLUTION OF GENDER ROLES

Whether speaking of the biological 'sex' or the social 'gender', society consciously and subconsciously imposes different sex and gender roles onto people. Stereotypical gender roles are collections of norms and attributes based on the heteronormative, binary genders. These beliefs are stated to distinguish women from men [9] and are often influencing our thoughts, feelings, and behaviour. In a study of gender roles in a historical context, Hansen et al. [10] suggest the Neolithic Revolution is a major factor in the formation of modern gender roles. This revolution marks the transition from a hunter-gatherer society to an agricultural society. Further, their research presents how the societal contribution was more equally distributed amongst the sexes in the hunter-gatherer society [10]. As the agricultural society demanded more workforce, women were more often pregnant than their hunter-gatherer ancestors, leaving them with less time to take part in activities other than child-rearing [11]. Simultaneously, men provided for the family and society, resulting in the growth of patriarchal values [10], initiating the development of the 'separate spheres ideology' (SSI) in the 19th century. Since then, machines have surpassed the human workforce and the rise of feminism has progressively desegregated the sexes in society. With increased research and knowledge on sex and gender over the past 30 years, acceptance of variety and diversity has increased [2]. Nonetheless, present gender roles and norms of Western societies are bearing the mark of being shaped by the former segregation patterns [10].

As established values in society, the mindset of gender roles is criticized by many scientists and advocates in different fields. Bem [1] explained how expectations, behaviour, beliefs, thoughts, and preconceptions are affected by the concept of masculine men and feminine women. Additionally, Bem argues that behaviour that is not 'assigned' to the biological sex is considered problematic or taboo. Moreover, some state it promotes the idea of masculinity and male being the standard, while femininity and female are subordinates, whose purpose is to fulfil male heterosexual desires [6]. Consequently, being a man with feminine traits is regarded as more controversial than a woman with masculine traits [12].

4 GENDER BIAS IN DESIGN

The environment is constantly reminding us and influencing our perceptions on gender roles, reinforced by established systems and structures. Further, these told and taught ideas and ideals of gender and gender roles are passed onto our children [1]. Martin et al. [13] describe how the perception of gender roles develops in a series of four stages while growing up. The taught behaviour towards others, ourselves and products is reinforced by the environment we design and continues into adolescence and adult life [14]. The first stage concerns what children up to the age of four learn about the direct association between artefacts and the sexes, such as "cars belong to boys" and "dolls belong to girls" [13]. This behaviour is a clear consequence of how the separation principle is expressed through product language and design [6]. In the second stage, children at the age of four to six start understanding the associations relevant to their own sex [13]. Products targeted at girls promotes the expectation of girls to be beautiful, quiet, and caring, whereas toys targeted at boys create the assumption of boys being tough, smart, and logical. This correlates with gender-related products in general, where products for helpfulness and performance are associated with female and male characteristics respectively [6].

Around the age of eight, children move to the third stage, where associations relevant to the opposite sex are taught [13]. The gender stereotypes children are being exposed to, teach them how to behave, treat, and what to expect from others, based on assumptions about gender [14].

Despite the changes in gender roles over the past 30 years, traces of the gender system are to be found in design [15], where women and men are being perceived and depicted in stereotypical gender roles to promote products and services [2]. Eisend et al. [16] point out how this reinforcement of stereotypical values in society through designed products and services can lead to negative consequences. A prominent example of how design and gender roles are intertwined is the sex-segregated toilet which communicates a universal need for privacy between the sexes, rooted in the SSI where women were considered ‘vulnerable’ and should be spared from the public space, dominated by the ‘vile’ men. Moreover, the gendered segregation, based on the binary genders leaves people with another gender identity uncertain of where to go. However, the tendency to reproduce stereotypical values have led to a growth in criticism of the lack in sensitivity to depict variety and diversity in genders [2], resulting in for example Stalled!, a public restroom concept aiming to "register the complex, fluid and intersectional nature of race, class and gender in a way that meets the goals of social equity, diversity and inclusion." The criticism is also evident in product design, where for instance the exclusive fashion brand Gucci, launched a dress for men in their Fall Winter 2020 collection. Their intention was to disrupt "the toxic stereotypes that mould masculine gender identity".

5 EXISTING SOLUTIONS AND MINDSETS

Both scientific literature and design practice offer a number of methodologies and approaches focusing on inclusion and equality. Universal design, inclusive design, and design for all are just a few examples. Additionally, the development of strategies and methodologies specifically paying attention to gender inequality and inclusion is increasing. Table 1 lists five methodologies that address the relation between gender and design. It also includes four toolkits which aim to challenge the heteronormative mindset, although these are not explicitly addressing design. It should be noted that few of these account for gender fluidity as they mainly focus on equality between the binary genders.

A gap analysis suggests that these design approaches and toolkits have in common that they lack references to tools or guidelines on how to become aware of gender bias when designing, and how to address the complexity of the gender bias challenge. Designers need to become informed of how their practice is influenced by traditional values and economic forces, such that awareness of possible biases is raised and the consequences of these can be managed. When awareness is raised, existing tools and methodologies can be utilized in a controlled manner.

A lack of dedicated design tools does not mean that the topic of gender inclusion is not addressed in society. In areas other than industrial design, several examples of gender inclusivity to inspire designers can be found. Examples include gender inclusive classrooms, *gender-inclusive recruitment, gender-inclusive language* and *gender-inclusive architecture* [3]. While these examples reveal progression in society, the appropriate question to ask may be whether design is keeping up with this pace, and how designers can become more in control of the implications of their work.

Table 1. Overview of existing design approaches and solutions with attention to gender

Methodology	Goal	Gender model	Gap
Gender-blind design	Disregarding gender as a factor in human interactions (https://eige.europa.eu/thesaurus/terms/1157)	binary	Does not recognize biological differences between genders
Gender mainstreaming	Accounting for women's and men's interests and concerns ([8].	binary	Does not explicitly account for gender fluidity. No clear design guidelines to create awareness
Gender neutral design	Avoiding gender stereotyping and association (https://forty8creates.com/gender-neutral-design/)	binary	Do not account for extreme feminine and masculine characteristics
International Gender Design Network (iGDN)	International initiative dedicated to put Gender and Design on the agenda (http://genderdesign.org/about-igdn/mission-and-objectives/)	not defined	No tangible solutions to create awareness in the design process
Gender in design	Integrating gender in design by providing toolkits with comprehensive methods (http://genderindesign.com/.)	fluid	Not efficiently creating awareness of gender bias in the design process
Inclusive design: Mixing	Methodology used to create all-inclusive public restroom concept, (https://www.stalled.online/home)	fluid	No design guidelines to utilize the findings in future projects
Toolkits			
Method kit for equal places/ gender equality	Based on gender mainstreaming. Cards to discuss and improve equality within organizations (https://methodkit.com/shop/methodkit-for-equality/)	binary	Focus on equality between (binary) genders and is not explicitly targeting designers
Gender equity toolkit	Used when designing for gender equality in workplace (https://www.leylaacaroglu.com/portfolio/2016/12/16/gender-equity-toolkit)	binary	Only considers leadership and companies
Gender in design toolkit	Address the difference between sex, gender, and intersectionality. A collection of critical questions, case studies and design methods.	fluid	No tangible solution/tool to use for designers
Gender and Security Toolkit	For people working with/for others who are deprived of liberty by integrating gender perspectives [18]	fluid	Does not concern everyday products and services

6 TOWARDS AN INTERVENTION FOR EDUCATING DESIGNERS

With the above in mind, the authors initiated a project aiming to develop an intervention educating designers on the role of gender bias in design and to create awareness about potential bias concerning the binary gender system and stereotypes. One way to do this would be to confront design students with the problems of (designing for) a binary gender model through critical design, for example utilize artistic methods, such as installations or campaigns, presenting the challenge in a dystopian or utopian way. Another way would be to encourage reflection by presenting a nuanced overview of the challenge. The latter was considered a more including concept, allowing design students to reflect upon the interplay between design and gender roles, and to find and develop their own values as designers. Initial research revealed that students generally expressed an understanding of the concept of gender bias and acknowledged that they themselves may be biased with or without realizing this but lacked the means to reflect over this, and to translate these reflections and resulting insights into their design practice.

Various educational concepts were evaluated. Developing an entire course was quickly dismissed due to the challenge of evaluating students in a course which has as main purpose to raise awareness and encourage reflection. Developing a new tool or adjusting existing ones or developing a game or a service were all considered to be too limited with respect to the information richness to be included for meaningful reflection and to avoid resorting to simple stereotyping. It was also considered to develop a set of guidelines, but because gender bias in design is a complex and comprehensive topic, it would be challenging to find the balance between too normative or biased, and too abstract or vague. Within the context of the project, it was decided to create something realistic which could be realized in the nearest future. As result, development of a workshop concept with the purpose of raising awareness of gender bias in design was concluded to be the most feasible to conceptualize. Workshops function as arenas for discussion and reflection upon complex topics, such as the relation between design and gender values and roles. Building on a combination of conveying information and practical tasks, students are able to understand the challenge in a historical and practical context.

6.1 Final workshop concept

After several iterations, which are not discussed here because of space restriction, the final workshop concept consists of five parts alternating between theoretical and practical ways of learning and concluding with presentations and reflections from the tasks.

Part 1: Introduction [1 hour] consisting of two main elements:

- A warm-up, in-medias-res exercise [15 min] where students are first to design/sketch two bags, one targeted at women and one targeted at men, then to describe the functionality, attributes, and aesthetics of their designs, and finally to reflect over how gender aspects affected their designs. This warm-up provides an immersive approach and starts creative, reflective, and critical thinking.
- An introduction of the gender bias in design challenge [45 min], presented by an expert in the field, focusing on
- Gender stereotypes and roles related to femininity and masculinity
- Historical context of gender roles and gender (binary and gender fluidity), including SSI and different factors affecting gender roles, from a political, feminist, cultural and capitalistic perspective (as briefly addressed in section 3 of this paper)
- How we learn about gender roles in childhood (extreme examples of gender bias)
- Contemporary context of gender roles and gender, and its expression through design (examples of products and services).

Part 2: Analysing products [1,5 hours]. This second, practical task builds on the previous theory. Here, the students explore and analyse different products (images of feminine, masculine, and neutral products and services are provided) to find how the intentions of the designs might be gender-biased, and through what types of visual cues. The purpose of the task is to connect theory and practice, experience gender bias in context, trigger reflection and discussion, using the theory from part 1.

Part 3: Designer's responsibility [30 min]. The last theory part concerns the responsibility of designers in this challenge. The purpose is to learn how bias surrounds us - the extent of it and what it does, as well as the consequences of not being aware of this. The presentation focuses on awareness of affordances and what design expresses, learning examples of where gender design has an impact on users, stories, and experiences with gender-biased design and how/why they fail/succeed, and finally on how and why designers should be more critical and challenge gender bias.

Part 4: Redesign [3 hours]. This part consists of two tasks. First, students are asked to pick two of the designs from part 2 and change their product language from masculine to feminine and vice versa. Thereafter they reflect on what has changed in terms of binary stereotypes, and how this is conveyed in the overall impressions of the designs convey. Second, they are challenged to redesign one of the designs such that it is no longer gender-biased and argue from different viewpoints why this is the case.

Part 5: Presentation [1,5 hours] is devoted to short 7-minute presentations reflecting on the practical exercises, focusing on takeaways and findings from the workshop.

6.2 Testing and evaluation

Because of the pandemic and limited access to students, the final concept could not be extensively tested and had to be compressed in time and number of participants. In the final testing round, these included master and PhD students in Industrial Design and Psychology. Rather than a full record of the testing, a number of observations from the test are shared here. What seemed to work well is how the workshop was an eye-opener, even for participants who already stated to be aware of the issue but had not explicitly reflected over it. They became very aware of their lack of ability to conceptualize what a man and a woman are, other than through stereotypes. Throughout the workshop, the participants showed ability to reflect upon the challenge from different perspectives through fruitful discussions and assess how their professional design practice may (or not) be influenced by it. They expressed how they were more aware of the negative consequences of gender stereotyping on women but realized throughout the workshop how this applied to men as well. Other stated takeaways for future design practice included reflections on how gender bias occurs in design, a feeling of better control of the effects of gender bias when designing, reasons for why (not) design should target a specific gender, more reflected views on gender roles in design, and a lot of questions and curiosity. It was noted that participants seemed to hold similar values; ideally, participants would have been more diverse in values and opinions on this topic, potentially leading to discussions providing greater insights of and reflections upon various perspectives.

7 REFLECTIONS

Gender bias in design is a wicked problem, and in the process of trying to address such a problem, new and more complex questions arise. Instead of ignoring them, we should recognize them to handle them accordingly. The proposed workshop can be a useful instrument for achieving this, but it is still mostly a reflective one. To address this wicked problem, further knowledge is required; hence, further research is proposed addressing questions such as: Where in the design process does gender bias start to occur? How to distinguish between gender and sex in design, as in, when to focus on biological and societal contexts? To what extent are functionality and aesthetics intertwined? What are the positive and negative effects of gender bias on the well-being of different segments of users? Better insights on these questions and their answers will be food for further development of educational approaches to address gender in design, beyond the proposed workshop format. For now, this format has received interest from both students, researchers, teachers, and professional designers in the industry, and will hopefully contribute to reflection among those exposed to it. With a growing culture for online collaboration tools, there are many further possibilities in experimenting with the current format. Since the workshop main focus is discussion and reflections, rather than physical output, arranging it through platforms such as Teams and Zoom, with group discussions in designated so-called 'rooms', could give a similar effect. The experience of arranging such workshops and using Miro proved how easy, yet effective it is.

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APPLYING CRITICAL DESIGN TO COMMUNICATE CULTURAL INSIGHTS EMPHATICALLY: A CASE STUDY

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ABSTRACT
This research paper explores Critical Design's use to communicate cultural insights generated through a human-centred design (HCD) research process executed by Industrial Design students. The hypothesis behind this research is that Critical Design could bring an enhanced emphatic reflection on these insights. We deployed this approach to a collaborative project between a major international company that designs and sells ready-to-assemble furniture, kitchen appliances, and home accessories based in Sweden and Tecnologico de Monterrey´s School of Architecture, Art, and Design in Mexico City. This design exercise's objective was to understand better the desires, goals, frustrations, and cultural differences of end-users in the field of the connected home in Mexico. The research framework consisted of two stages: i) an explorative stage that involved HCD research activities such as daily studies and co-creation workshops with families, and ii) a creative/reflective stage where the students utilized critical and speculative design tactics to translate cultural insights found through the first stage. This study used a qualitative analysis approach to investigate which method carried more meaningfulness by comparing the students' whitepaper at the end of the first stage and the hypothetical objects' results at the end of the second stage. We found that what we called "Hypothetical Products" can assist an HCD report by taking the insights from the research process, and by using a Critical Design approach, it can bring a more significant dimension on empathy to the findings and data that an abstract written detailed results report.

1 INTRODUCTION

Human-Centred Design (HCD) research is a creative approach with the principle to "know your user" [1]. This research approach relies on understanding the product's context and users' experiences by moving into the field to observe users and how they interact with any product. HCD research utilizes tactics such as daily studies, cultural probes, and deep-dive interviews to obtain insights about the people it is studying through an emphatic lens [2]; these results are communicated through a document containing a set of design criteria or design principles, design strategies or approaches, competitive analyses, or experience roadmaps [3]. These reports and whitepapers are the sources of evidence of the recorded results; however, some limitations exist on bringing a more emphatic approach and better influencing the report's intended audience. We explore alternative ways of sharing these cultural insights by utilizing design tactics related to Critical and Speculative Design to enhanced emphatic reflection on these insights. To do this comparatively, we were inspired by other design researchers to find meaning from empirical data by holding semi-structured deep-dive interviews with the three company´ designers that participated with the students during this exercise.

2 COMMUNICATING HUMAN-CENTERED DESIGN RESEARCH

It is well understood the challenges designers find when communicating HCD research results. Designers face sharing ideas with colleagues with different thinking ways, like engineers or marketing, can struggle to bridge the gap between collaborative teams [4]. One way to communicate design

research is through detailed reports. However, reports linger in danger to become verbose, diminishing people's chance to find time to read them [5]. Alternatively, Segelström argues that visual representation is useful among designers who wish to formulate insights from the user material collected and communicate insights to their clients and keep the data "alive" [6]. However, generating these visual representations can have limitations to understand people in an empathic way. A popular visualization tool like a Customer Journey Map can help understand an organization's customer experience. However, there are instances when it is not done correctly; in that case, it can just function as a graphical representation of a customer's touchpoints with an organization, leaving behind all the emotional aspects of the experience, resulting in a useless tool to promote innovation within a service system [7]. Another visualization tool described by Segelström is the Personas Method, which works as a representation of ideal or prototypical end-user based on behaviours and motivations. This method allows designers to relate to and empathize with users and encourage them to view product problems from the user's perspective [8]. As Personas is a subjective representation, it is challenging to verify that the method is accurate as it is complicated to validate, making it useful only for inspiration where there is no claim for validity [9]. As one of the main goals for HCD research is to bring as much information as possible to bring a better understanding of a particular segment of users; the designer must use a plethora of methods and techniques that could complement each other and bring a complete picture, especially when a detailed report, journey maps or personas can be limiting from the empathic point of view.
In the next section, we will open a case for Critical Design as a tactic to improve the empathic dimension for HCD research.

3 THE HYPOTHETICAL PRODUCT

Traditional design practice is highly rhetorical, where the designed object is persuasive when it creates a new vision in social life by communicating usability, usefulness, and desirability. Nevertheless, design can also seek an intellectual outcome [10]. Such design practice can be Critical Design. According to Malpass, Critical Design is used as a medium to engage user audiences and provoke debate. With other converging design manifestations such as Design Fiction or Speculative Design, Critical Design relies on hypothetical or fictional objects to explore possible technological futures. Through debate and interaction with these hypothetical products, an audience can consider matters more immediately than abstract theories [11]. A clear example of these hypothetical products is what Kirby famously refers to as *diegetic prototypes*, a prop-like artifact that, within narratives, contextualizes emergent technologies within the social sphere [12]. Hypothetical products can be used as physical anecdotes designed to prompt speculation in the viewer about the world these objects belong to [13]. A particular characteristic of these hypothetical products (and man-made products in general) is the symbolic qualities in the context of their use, where not only the physical and physiological functions are considered, but the psychological, social, and cultural context. A product can carry a message using a sort of vocabulary of forms that can transfer informative messages that can report possible uses and cultural heritage, individual experiences, and style. By engaging product design, one can be cast in the role of communicator, using the psychological and social uses of objects through the symbolic qualities of products, as man-made forms can embody, like an indistinguishable symbolic unity, both signs and referents relative to a community of users [13]. In this case, this academic exercise appealed to hypothetical functional objects, or as we will call in this paper, hypothetical products, to create this urgency to reckon concerns on the Mexican culture that a user research report might not communicate in the same engaging ways as a product could. This paper explores how a hypothetical object might give a bigger perspective than an abstract insight.

4 APPLYING CRITICAL DESIGN TO COMMUNICATE CULTURAL INSIGHTS EMPATHICALLY: A CASE STUDY

A Swedish international company that designs and sells ready-to-assemble furniture, kitchen appliances, and home accessories wanted a deeper understanding of their future Mexican customers. The company paired with Tecnologico de Monterrey´s School of Architecture, Art, and Design in Mexico City. For this challenge, undergraduate industrial design students applied User-Centred, Critical, and Speculative Design to gather information about how Mexican families related to smart home devices. The project had two main stages. The first one focused on HCD Research. After doing secondary research and constructing a general scope of the research question, every team recruited a Mexican family and lent

them a collection of smart products manufactured by the company for a week. During this period, the students gathered insights through HCD activities like a daily study and a co-creating workshop. In the second stage, focused on Critical Design, each team developed a hypothetical collection of smart devices that expressed the Mexican user's emotional needs, aspirations, and frustrations found by their research (Figure 1.1). This project's results were presented in October 2020, during a major design festival in Mexico City. It is worth mention that this semester-long project was temporarily interrupted by the Covid-19 pandemic in its second phase. As the students did not have access to the university facilities, the main deliverables were digital renders and other visualizations. Having described the project and the method, the next part of this paper presents four cases and the analysis.

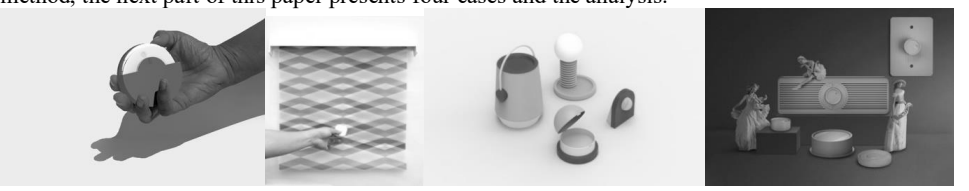

Figure 1. Hypothetical Products developed by the students

4.1 Team1: Easy

Through HCD research, the first team found that older Mexican adults (aged 50 to 60) can feel "technophobic" while using smart home devices. After carefully observing how older users felt intimidated by technology, the team found that they perceived "mistrust" and "overwhelm" while exposed to smart devices, causing a dependency on the family's younger members. The students concluded that Mexican users might not be as familiar with smart devices as their European counterparts, making the current design language not universal. As a critical design approach, the team investigated what this type of user would be familiar with in terms of technological devices. They discovered these users would trust more tangible interactions: buttons, sliders, and switches; they also found inspiration on electronics from the '70s and '80s, where buttons would do loud clicks. After this, they researched ways an older user could feel more familiar with the technology. Therefore, the team created a collection of interactive possibilities aiming to challenge the conception that technological objects should be clean, minimal, and predominantly using white finishes.

4.2 Team 2: Negotiation of the Space

The second team of students dived into how Mexican families lived in smaller places with constant space negotiations. During the first stage, the team found that this family had two sisters sharing the same room and the same bed. The older sister, a university student, had a completely different schedule as her younger sister, a high school student. For them, it was challenging to do various activities while sharing the same limited space. In the second stage of the project, this team observed that it was very common to use textiles to separate spaces as a substitute for doors. This team proposed changing the existing smart blind's textile patterns used during the daily study as they found that the Mexican user would be more comfortable when there are more colours and visual elements in their surroundings. Inspired by folk art, this team rethought the smart blind for a Mexican context.

4.3 Team 3: Lumetría

The third team dived into the emotional needs the Mexican society has towards celebrating traditions. After interviewing and observing their corresponding family, they saw their meaningful relationship with the social gatherings. As they found out, Mexican families prefer to gather socially in their own homes rather than public spaces. This team focused on how smart lighting could create different environments for different moods and celebrations. A Christmas atmosphere is entirely different from a "Day of the Dead" celebration. This team designed a collection of smart luminaries that could create different atmospheres according to the celebrations. The students turned to the posthumous work of Mexican architect Luis Barragán and used light and colour as an inspiration. The team proposed a collection of three lighting devices: one was fixed in the walls, and two tabletop lamps created colour and light combinations that could generate different home atmospheres.

4.4 Team 4: Remembrance Collection

Finally, during their first stage, the fourth team found opportunities in how older people relate to smart devices. After analysing how their studied family used the smart home devices, they found the grandmother perceived these devices as delicate and fragile - even though they were not. She wanted to feel confident and included while using these devices. Inspired by these insights, the team proposed an alternative design of the company's smart home devices by changing the physical appearance to arouse the user's predominant characteristics that they could remember from their youth. This finding concerned the team, as one of the students explains: "Everyone should be able to use a smart device no matter their age. So we created a collection that, through its appearance, could invite our grandparents to use these home smart devices." By looking into how the design looked before the digital era and using visual cues that could remind us of art-deco details popularized in Mexican households in the '60s, this team of students challenged the paradigm that technology should look like something futuristic, technocratic, or new. At the end of the project, a white paper and project documentation was delivered to the companies' designer, and a final presentation with different stakeholders was organized to share their results.

5 METHODOLOGY

To understand the effectiveness of how Critical Design can assist a User Research Report, we had to find a methodology that could allow us to access the perception of usefulness. As our sample was relatively small, as only three company's designers were eligible to understand the real significance that describes our hypothesis, we decided to have an inductive [14] research approach inspired by the work of Michelewsky, who demonstrated that one could concentrate on eliciting meaning from empirical data [15]. We choose to have these qualitative research methods to provide learning on particular expectations, experiences, and a person's attitude, problems, needs, ideas, or environment. We carried out an in-depth interview with each designer during February 2021. Each interview had a duration of 45 minutes, was transcribed, and was analysed by identifying the aspects when a project made them feel to understand better the Mexican user and their context in an emphatic way. The quotes had been edited to respect the privacy of the company.

5.1 Learning about Mexican Culture and the Mexican Family

These projects aided the designers to understand the Mexican culture, especially on aesthetic values and recognition of how diverse cultures can be as one of the company's designers puts it: *"One part that was standing out was that when it came around the form and the colour was very different from Scandinavia."* The semantic characteristic of these hypothetical products gave the viewer a more significant dimension on the aesthetic aspects of product design, adding more cultural context than only having a descriptive explanation commonly found on detailed reports. Also, the designers expressed that all projects *"accomplished showing some type of insight in relation with the Mexican culture"* and felt like *"all projects highlighted something and created some type of awareness."* The hypothetical products helped the designers to understand the Mexican family on a more empathic dimension. As each product had a specific user with specific needs in a specific context, it helped the designers understand their everyday needs more concretely. Regarding the Negotiation of the Space project, one designer said: "*Concrete in the sense that they made it about family life, how that family lives; very tangible by coming up with such a concrete example like: Ok! it is one room, two sisters, they have different needs, and we need to shut the curtain off."* Another example of hypothetical products helping the designers to be more emphatic was the project Easy. As they focused on the elderly users, it helped the designers to have a deeper understanding of their frustrations while using newer technology: *"That is where I felt getting into the frustration and pain points of the elderly people, like the fear of doing wrong and so."*

5.2 Influence for Designing Future Products

When asked if these hypothetical products would reach any kind of influence for future projects, the designers mentioned that it helps bring mindfulness of the diversity of the users and the people their company is trying to reach. This could bring "*much awareness*" into a development process. The designers found these exercises useful not only for a specific project but as a constant learning process where *"it helps to read as diverse insights as possible and try to make them stay in the mind of our designers as they execute their work."*

Also, the designers described that the project "Remembrance" caused a change of mind. As product designers tend to look forward when it comes to product design, the characteristic of the project to "look back" into what is familiar for an elder user caused some steer, as a designer explained: *"I am quite locked in to thinking that design is only looking forward, is about new things, new expressions... However, how about it also connects back to the past?" To me, that [Remembrance] was an angle which I thought was interesting".*

6 CONCLUSIONS

The result of this study not only supports the work of Segelström on the usefulness of visual representation to communicate insights, but as these Hypothetical Objects bring an emotional layer of understanding that mere visual representation like a customer journey lack of, as Rosenbaum argues [7]. Turning on our interviews, we asked each designer to complete the sentence "*These hypothetical products could_____ a user research report."* They used the words "enrich," "enable," "enlighten," "complement," and "support", contrasting with what Ross depicts on detailed reports [5]. This study found that the designers felt the user research reports were valuable as they were factual, but the Hypothetical Objects can give a better context. They also expressed that the exercises helped them see distinct aspects away from their surroundings and experiences. For this project, the designers found that they can perceive the colour or flavour on another culture's experience. Also, the designers expressed that the hypothetical projects became "manifestations" of the sum of all the learnings. By looking at them it enabled inspiration, taking a step both for product concepts but also for drawing some conclusions and insights from Mexican culture and how they manifest: *"One part that was standing out was that when it came around the form and the colour was very different from Scandinavian."*

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USING LINKOGRAPHY TO VISUALISE THE INFLUENCE OF EDUCATIONAL BACKGROUNDS ON COLLABORATION AND CREATIVITY IN IDEA GENERATION

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ABSTRACT
Differences in disciplines are one kind of diversity, a well-supported factor to influence the degree of outcomes' creativity in design. It is needed to analyse design discussion in detail and evaluate outcomes to support idea generation by multi-disciplinary teams. Linkography has been developed to analyse and visualise design activities done by either individual or group. Linkography lets researchers connect design moves, described as a small unit of verbalisation lasting a few seconds in design activities. A total of 16 undergraduate and graduate students participated in the experiments. The participants were divided into groups of four participants. The participants conducted two group work sessions; one in the non-diverse group, which consists of four students either from art or engineering, and the other in the diverse group, consisting of two students from art and two from engineering. Within a session of the experiment, the participants generate and select ideas. This paper reports the first step of the session, which is a 10 minute idea generation. The experiment was analysed by three aspects: questionnaire assessing participants' self-reflection, design outcomes assessing the degree of creativity of outcome, and Linkography assessing group discussion dynamics. This paper aims to reveal multi-disciplinary group discussion dynamics in comparison to single-disciplinary teams during idea generation. Findings will be useful for academic researchers as well as educators and practitioners in design.

Keywords: Multi-disciplinary team, Linkography, idea generation

1 INTRODUCTION

In highly competitive markets, companies must develop innovative products or services. In this era, design education can play a critical role in making students acquire required competitiveness such as creativity [1]. In such a PBL course and product development in companies, it is necessary to have teams consisting of people from diversified backgrounds to develop innovative products [2]. However, an increasing degree of diversity in a team does not directly link to a higher quality of project outcomes. This fact increases the importance of understanding factors influencing both design projects and PBL, which are conducted by multi-disciplinary teams. The members' diversity allows diversified viewpoints, which determines the number of resources available to apply to the solution of the problem [3]. 'Diversity' in a team is divided into two categories: bio-demographic diversity and task-related diversity [4]. Both diversities are reported to have positive impacts on outcomes. Bio-demographic diversity represents characteristics that can be immediately observed and categorised, e.g., age, gender, and national culture. Increasing age diversity positively affects a company's productivity if the company works in creative industries rather than routine tasks [5]. A group with gender diversity generates more ideas and has more viewpoints on design topics than a group without gender diversity [6]. On the other hand, task-related diversity represents individual attributes that cannot be observed, e.g., education and expertise. Cognitive styles diversity and self-efficacy have positive impacts on design outcomes [7]. Disciplinary diversity in a team is a crucial factor for innovation and new knowledge [8]. Increasing disciplinary diversity can positively affect innovation's financial value, whereas merely increasing the degree of diversity in a team does not always increase the innovative value [2]. Although diversities' positive influence is reported, it is unclear what factors encourage the positive effect of diversity and what factors withdraw the drawback of diversity. Therefore, it is necessary to investigate discussion dynamics by visualising interaction between people having different disciplinary backgrounds.

Linkography was initially developed as a method to visualise individual design activities by connecting design moves with a link node [9]. Goldschmidt (1995) defined a design move as *'a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move'* [10]. Figure 1 illustrate Linkography terminology. Evaluators find links between design moves based on "common sense" [11]. Link nodes visualise the links. 'Critical moves (CMs)' is one of the perspectives to interpret Linkography. CMs are design moves with a high number of link nodes. Links to proceedings moves are called fore-links, and links to preceding moves are called back-links. A high number of back-links means that the design move was derived from or integrated with many previous moves, which is relevant to convergence, while a high number of fore-links means that the move inspired many future design moves, which is relevant to divergent thinking [12]. The application area has been expanded to team design activities, including design discussions [13, 14].

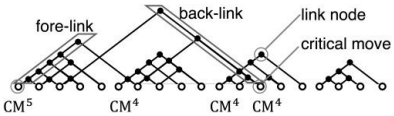


Figure 1. A Linkography illustrating terminology

This study's research question is how the degree of disciplinary diversity within a team impacts creativity of design outcomes and group discussion. This paper reports an investigation of an experiment that compares multi-disciplinary groups of art and engineering students in comparison to single-disciplinary teams of either art or engineering students during idea generation. The group discussion dynamics were investigated by the creation of Linkography.

2 METHOD

A total of 16 undergraduate and graduate students participated in the experiments. Half of the participants were enrolled in art universities, and the other half in engineering universities. The participants were divided into groups of four participants. The participants conducted two group work sessions; one in the non-diverse group (homogeneous): four students either from art or engineering, and the other in the diverse group (heterogeneous): two students from art and two from engineering. Within a session of the experiment, the participants generated and selected ideas. This paper reports the first step of the session, which is a 10 minute idea generation. Half of the participants conducted the session with a homogeneous group first, and then they conducted the other session with a heterogeneous group. The other half of the participants conducted the sessions in counterbalanced order. The first session's task was to "propose a service or product related to the reading experience for college students." The second session's task was to "propose a service or product related to the gift-giving experience for college students". The experiment was analysed by three aspects: questionnaire assessing participants' self-reflection, design outcomes assessing the degree of creativity of outcome, and Linkography assessing group dynamics. The questionnaire addressed to what extent each participant considered each aspect of creativity (novelty, usefulness, and feasibility) during idea generation.

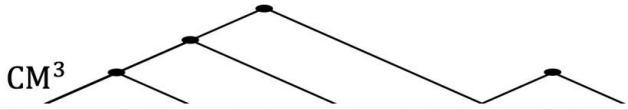
The degree of creativity was assessed by the quality and fluency of ideas. The fluency was evaluated by counting the number of Post-it Notes the participants wrote down. Two trained evaluators evaluated the quality of ideas in terms of three criteria which are novelty, usefulness, and feasibility. Each of the ideas was shown to the evaluators with seven-point Likert scale questions addressing the three criteria where a higher score meant a stronger agreement. Originality was assessed with a question that "this idea is not only new, but also clever, imaginative, and unexpected". Usefulness was evaluated with a question that "this idea can be applied to the problem and will solve it efficiently". Feasibility was asked with a question that "this idea is feasible and can be easily implemented". Creativity evaluation of ideas was conducted by two trained evaluators, who were asked to evaluate the creativity of 30 ideas prepared in advance for practice multiple times until the Cronbach's alpha coefficient [15] became 0.7 or higher for each of the three scales. Next, the raters were asked to rate the creativity of the ideas remaining from the idea sorting process and then asked to discuss the ideas among themselves so that the difference in the rated scores among the raters would be within 1 [16]. The creativity of the ideas created was determined by averaging the creativity of the ideas modified by the discussion between the two raters.

The questionnaire was used to assess what participants thought during idea generation. The questionnaire had questions asking to what extent the participants pay attention to each of the three

criteria of creativity. The questions were asked with seven-points Lickert scale questions such as "when you were thinking about an idea, did you pay attention to the originality of the idea?".
Linkography was used to visualise the dynamics of group discussion. Linkography identifies links among design moves. In this study, each conversation turn-taking was used as a design move [13, 17]. In other words, each utterance was regarded as a design move. In this study, we chose to include backchanneling feedback such as "yeah" and "yes" because backchanneling feedback plays a significant role in moving conversation in the Japanese language [18]. In linking design moves, a guideline used by Hatcher [14] was used with minor modifications, which includes rules of words to be connected. After creating Linkography of the conversations, we applied codes as shown in table 1 to each design move relevant to the codes. For example, backchanneling feedbacks were not coded with the codes. The codes were developed based on the work of Hatcher [14]. Figure 2 shows an example of the result of Linkography and coding. In figure 2, backchanneling feedback was omitted for the sake of increasing the visibility of the figure. CMt denotes a design move with t link nodes. The numbers of CM4, CM5, and CM6 were counted. We also counted the number of codes having each code.
The numbers of CM and codes and the result of questionnaire and creativity of outcomes were statistically analysed by nonparametric methods. We compare within students meaning the difference between the same students in homogeneous groups and heterogeneous groups and between students meaning the difference between students studying arts and studying engineering in either homogeneous or heterogeneous group.

Table 1. Categories of codes used for the analysis

Category	Sub-category	Description
Idea	New	A novel idea
	Incremental	Back-link to a new idea, and the idea is considered as an improved idea of the new idea
	Tangential	Back-link to a new idea, and the idea is considered as an expanded or combined idea
Knowledge		Knowledge of existing products, the experience of a speaker, general knowledge



speakers	Engineer 3	Engineer 3	Art 1	Engineer 3	Engineer 3
codes	New	Incremental	Tangential	Incremental	Knowledge
speech	It's good to choose and buy products, but it's also good to make original or self-made gifts.	For example, a key chain with a picture of your friend's face on it.	Like a workshop for making gifts.	Maybe an A0 size poster made by a friend.	I had given it to him in the past when I was in high school.

Figure 2. An example of Linkography and coding result

3 RESULT

3.1 The assessment of outcomes and questionnaire

Figure 3 shows the result of questionnaire analysis, and Figure 4 shows that the result of average fluency of each participant in idea generation and quality analysis of creativity. In figure 3 and figure 4, for example, "art students in homogeneous or in home" stands for the result of students studying in art university worked only with art students. Figure 3 shows that there was a significant difference in the attention of engineering students between the experiment's conditions. The result suggests that engineering students perceived that they paid more attention to ideas' originality during idea generation. Figure 4 (left) shows that there were significant differences between art students and engineering students in homogeneous groups and the difference between art students and engineering students in

heterogeneous groups. The results indicate that art students generated more ideas than engineering students regardless of the experiment's conditions of the degree of diversity.

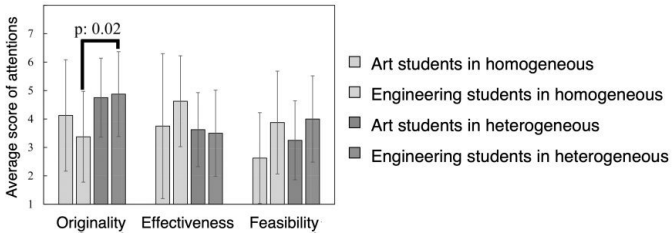


Figure 3. Result of questionnaire analysis

Figure 4 (right) shows the results of the assessment of the quality of ideas in terms of three criteria. There was a significant difference in art students between the experiment's conditions. The result indicates that art students generated ideas of less originality in the heterogeneous condition than in the homogeneous condition. There was no significant difference in other criteria.

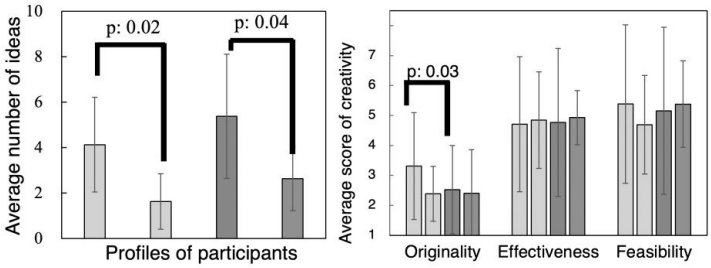


Figure 4. Result of creativity analysis. Legends are the same as Figure 3

3.2 Linkography

Figure 5 shows two typical Linkography generated in the experiment. The left figure visualises that ideas were reacted by backchannel feedbacks from other participants. The right figure visualises that idea was followed by interpretation and backchannel feedbacks first. Then, another idea was proposed in connection with the previous ideas.

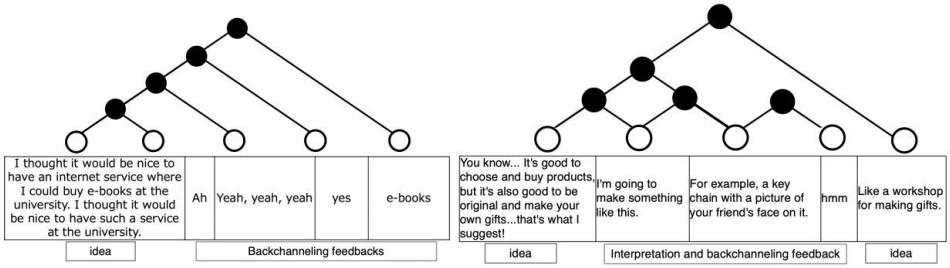


Figure 5. Examples of Linkography results. Left: Backchanneling feedbacks followed a proposition of idea. Right: An idea inspired another idea

Table 2 shows that the average number of total design moves in a session and the number of CM. The result shows that there were no differences in fore-link and back-links in CM4. The ratio of fore-link in the heterogeneous group was slightly smaller than homogeneous groups. In contrast, there seem to be more back-links in the heterogeneous group than in homogeneous groups. However, as the number of groups was not large enough to conduct statistical analysis, the result cannot be generalised.

The number of codes categorised by the defined codes is shown in Table 2. Table 3 shows more utterances coded as "new" in sessions only by art students than in sessions only by engineering students.

Table 3 also shows that engineering students tended to speak more about knowledge, existing solutions of background information than art students. The average ratio of utterances coded as tangential was similar among art students, engineering students, and heterogeneous groups.

Table 2. The result of critical moves (CM) (Mean (SD): ratio to the total moves)

		Average number	Average rate (%)		
		total moves	back-link	fore-link	sum link
CM4	Art	221.5(108.19)	2.5(3.54): 0.84	23.5(20.5): 9.48	39.0(31.1): 16.1
	Engineer	196.5(74.25)	1.00(1.41): 0.69	21.5(16.26): 10.1	33.5(20.5): 16.24
	Diverse	184.25(50.87)	1.75(1.50): 1.05	16.0(4.55): 8.68	26.75(6.55): 14.65
CM5	Art	221.5(108.19)	1.00(1.41): 0.34	16.0(15.6): 6.25	27.5(23.3): 11.18
	Engineer	196.5(74.25)	0.00(0.00): 0.00	14.5(10.6): 6.85	24.5(17.7): 11.6
	Diverse	184.25(50.87)	0.00(0.00): 0.00	9.00(3.56): 4.84	15.5(5.32): 8.31
CM6	Art	221.5(108.19)	0.50(0.71): 0.17	11.5(10.6): 4.57	17.5(17.7): 6.76
	Engineer	196.5(74.25)	0.00(0.00): 0.00	11.5(6.36): 5.64	17.5(9.19): 8.64
	Diverse	184.25(50.87)	0.00(0.00): 0.00	4.75(2.22): 2.64	9.50(4.80): 5.01

Table 3. The result of coding (Mean (SD): ratio to the total moves)

	The number of moves per person	New	Incremental	Tangential	Knowledge
Art	221.5(108.19)	11.5 (2.12): 6.16	4.50 (6.36): 1.51	4.50(3.54): 1.86	13.5(12.0): 5.42
Engineer	196.5(74.25)	2.50 (2.12): 1.59	2.00(2.83): 1.39	2.50(0.71): 1.30	32.5(30.4): 14.5
Diverse	184.25(50.87)	11.5(6.45): 7.21	1.75(1.71): 1.10	2.00(1.15): 1.09	20.3(14.1): 10.6

4 DISCUSSION

The analysis results in creativity and questionnaire show that the diversity increased the attention of engineering students toward originality of ideas. However, the creativity of engineering students in heterogeneous group did not differ from them in homogeneous groups. On the other hand, art students generated ideas of less originality in heterogeneous conditions than in homogeneous conditions. The result is consistent with the lower degree of innovative outcomes of diversified groups on average [2]. These results imply that in short-term conditions, diversity had negative impacts on outcomes. We might find different results when the duration of experiments is longer. Investigation of the causes of the differences is a direction of future studies on design education of multi-disciplinary team.

The Linkography result successfully visualised the dynamics of discussion of different educational backgrounds. The difference in discussion styles between art students and engineering students might be why lower creative outcomes of diversified groups on average [2]. The difference implies that teams of diversified groups suffer from process conflicts which occurred due to different thought in how team processed projects [19]. The barriers might be able to be overcome by offering a discussion process that is acceptable for all educational backgrounds, such as design thinking [20].

The result shows that there were fewer critical links in the heterogeneous group than in homogenous groups. It implies that brainstorming might not be a suitable method for encouraging collaboration among different educational backgrounds. It also implies that the short-term period's experiment may

not be a good experiment setup to investigate cross-disciplinary collaborations' difficulties. Observation of team design projects might be a useful research strategy to investigate the difficulties.

5 CONCLUSIONS

This study experimented with comparing outcome creativity, participants' perception, and group discussion dynamics of students of two different educational backgrounds. The result shows that diversity in a team might hinder group discussion due to differences in discussion styles. It also implies that brainstorming might not be a good method to encourage collaboration between people having different educational backgrounds. The findings of this study are a first step in visualising the difficulties of cross-disciplinary collaboration.

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HOW SHOULD DESIGNERS FORMULATE USERS' INSIGHT? - COMPARISON BETWEEN NOVICES AND PROFESSIONALS

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ABSTRACT
This research investigated the difference between novice and professional designers in terms of skills of gaining insights into design process. This study experimentally examined the designers' behaviours in gaining insight by comparing how novice and professional designers empathise differently toward users. In the experiment, designers were asked to create a concept map and gain insights from a prepared user-interview transcript. The participants were interviewed about how they gained insights of users from the transcript. The concept map and insight statements were analysed. As a result, we clarified a difference between novice and professional designers which were generalisation of the transcript and inclusion of suppositions into insight statements. This study is a first step to analyse and support the insight generation of novice designers.

Keywords: Empathy, gaining insight in design

1 INTRODUCTION

To be successful in today's market, companies aim at developing innovative ideas of new products or services, which respond to the underlying user-needs [1]. To develop innovative solutions, it is crucial to find a clear and right problem to be solved by designs, which can be achieved by discovering insights from the target users [2,3]. Insight in design is defined as a *"clear, deep, meaningful perception into a particular design contexts"* [4]. Gaining insight is one of the most important challenges in design process [2]. It is critical to get deep empathy with the users to gain meaningful insights [1]. Empathy has been researched in the area of psychology, which influences research of empathy in design. Batson (2009) described that empathy is supposed to answer two questions: "how one can know what another person is thinking and feeling" and "what leads one person to respond with sensitivity and care to the suffering of another" [5]. Thereby, empathy in design is expected to play roles in perceiving user's feelings and emotions to gain insight into users' needs. Kouprie (2009) model empathy in design as a process that comprises four phases, discovery, immersion, connection, and detachment [6]. Through the process of empathy, designers need not only to step into users' world but also to observe the users' world to contrast the users' experiences with designers' own experience and knowledge. Hess (2016) divide empathy in design into four distinct empathy types by two dimensions: affective experience versus cognitive process and self-oriented versus other-oriented empathy (Table 1) [7]. The four distinct empathy types show that empathy requires cognitive and affective processes with users. In affective mode, designers pay attention to users' emotional states either by experiencing the same internal state or by feeling for users. In the cognitive process, designers understand users' situation by imagining how designers would do in the potions of users or imagining how others think in the context.

Table 1. Taxonomy of empathy in design by two dimensions [7]

	Affective Experiences	Cognitive Processes
Self-oriented	**Emotional Congruence** Experience the same internal state as another	**Projection** Imagining how one would think and feel in the position of another
Other-oriented	**Empathic Concern** Feeling connected or happy for another	**Perspective-taking** Imagining how another thinks or feels

Smeenk (2019) proposes *the empathic formation compass* by combining the empathy map [7], the landscape of human-centred design[8], and *the mixed perspectives frameworks* [9,10] on the same map to express the relations among the maps from different researches in one image [9]. The proposed map can be used as a method to track the use of empathy in design process. The theoretical frameworks of empathy in design offer foundations of understanding empathy in design, while the literature has not revealed how designers gain insights through empathy.
This research aims at revealing the following two questions: "what is the difference between novice and professional designers in gaining insights from users' context?" and "what are the factors which make the differences?"

2 METHOD

Online experiments were conducted to compare novice and professional designers in how participants empathise with users and gain insights. The experiment participants were graduate students (n=11) in engineering who were learning design thinking for more than six months and professional designers (n=5) who had more than three years of working experience in design consultancy farms. In the experiment, participants were told that their task was "design a new product or service for a pleasant morning". The participants worked individually in the experiment, which was recorded by the online video meeting application. The experiment consisted of four steps (Figure 1).

Figure 1. The process of the experiment

After a short briefing of the experiment procedure, participants were asked to read a prepared user-interview transcript which was a pre-prepared transcript of an interview conducted by an author with an interviewee. The participants were asked to think as if the same team member did the interview. The interview was related to the theme, especially focused on the wake-up time. The transcript contained sixteen questions and the responses (Q&Rs), the user's daily life in the morning, and the user's profile information, such as age and gender (Figure 2).

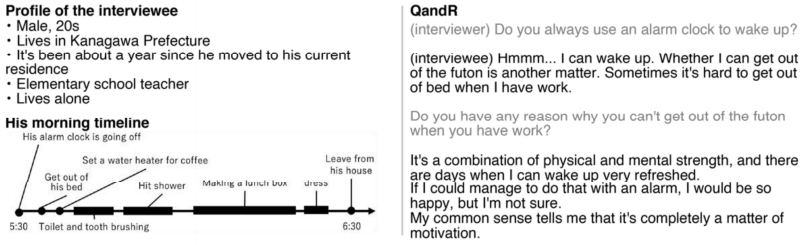

Figure 2. An excerpt of the given interview transcript

Then, the participants were asked to organise and analyse the transcript to find out the problem of the interviewee. The participants created a concept map to visualise what they were thinking and how they expanded their thoughts. Concept map is a technique that helps to generate, organise, and visualise the ideas, which was used in a software of supporting to gain insights in design [2]. In the third step, the participants were to write down at least one insight in eight minutes, based on their analysis of the transcript. A template of insight was given to the participants, which was *"'OO' needs 'XX', because '...'"*, because good insights should have comprised, the user, their needs, and the reason why they needed it [2]. *'OO'* was the subject of the phrase, *'XX'* was what *'OO'* needs, and the reason was written in *'...'*. The participants were asked to select the best four insights and to rank the selected insights. Then, the participants were asked to explain how they came up with the insight statement which had been defined

at the previous step. This part aimed to clarify the participants' perspective and the logic toward the insight statement. In the interview, we asked seven questions to clarify how the participants gained the insight. The questions were (1) which parts of the transcript did they focus on, (2) which parts of the concept map were connected to the transcript, (3) which parts of the concept map were connected to insight statements, (4) why did they focus on that part of the transcript, (5) did they imagine what the user might have thought or felt or did they project themselves in the situation of the user which referred to the definitions of "perspective-taking" and "projection" [5], (6) were there any information missing in the interview transcript which they wanted to know, and (7) were there anything they felt like a problem but could not verbalise as a user statements in the given format. After the experiment, a questionnaire was given to the participants.

As a preliminary analysis, we analysed the experiments with three criteria. First, we looked at which part of the interview transcript the participants had used to generate insight. The given interview transcript had sixteen Q&Rs which were numbered from #1 to #16, and the figure of user's daily life, which were numbered as #17. We counted how often each segment was used based on the elaborated concept map. The numbers were normalised by dividing the count by the total number of insights generated by the same participants' profile, i.e., novices or professionals because the number of participants and the number of insight statements were not equal between professionals and novices. The insight statements were evaluated by dividing segments of the insight format, which was *""OO' needs 'XX', because '…'"*. The *'OO'* part, 'subject part', were coded into three categories: the user, a person who has a 'character' of the user, such as "teacher" and "a man who often oversleeps", and object or stuff, such as new products and morning routine. The number of each of the three categories written in the insight statements were counted and then normalised the count by dividing it by the sum of the number of insight statements generated by each participant's profile. We called *'XX'* part as, 'object part,' and *'…'* part as 'reason part'. We coded both parts by the criteria of whether the participants' supposition(s) was included. If exactly the same words or phrases as both of the parts were stated in the user-interview script, the part was coded as 'directly from the interview'. Otherwise, we coded it as 'supposition included'. As each part was coded into two categories, an insight statement fitted into one of four groups as Table 2. After coding all the insight statements into four groups, we examined the difference between novice and professional designers with the number of insight statements coded as each group divided by the sum of the number of insight statements. The values were calculated separately for novice and professional designers.

Table 2. Taxonomy of the insight statements in this experiment

		'…' reason part	
		Directly mentioned in the interview transcript	Including participant's supposition
'XX' object part	Directly mentioned	DxD	DxS
	Supposition included	SxD	SxS

3 RESULT

Figure 3 is an example of the final outcomes of the experiment. Area of the concept map and insight statement were generated during the analysis and stating insight statement phase. The arrows and notes were added based on the interview. This study reports the result of the count of the interview transcript used for the insight statements and analysis of the insight statements.

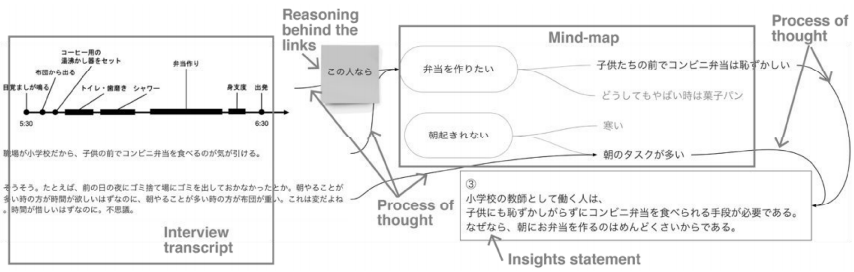

Figure 3. An example of concept map and process of gaining insight

The generated insight by novice participants was, for example, “People who wake up early need to have an open mind, because rushing to get ready can cause a lot of stress.”. The example of insight by professional designers was “the user needs support to finish daily tasks efficiently (To gain a control over life) because it would save the user more time”.

3.1 Result of use of the interview transcript

Figure 4 shows the comparison of the ratio of novice and professional designers for each Q&Rs in the interview transcript (#1~#16) and the figure of user's daily life as # 17. The results were statistically analysed by proportion test. There were no significant differences in the comparison, where the smallest p values ($0.17 > 0.05$) were founded in $i = 12, 14$. This result suggests no difference in which parts of the interview transcript were used between by novices and by professionals.

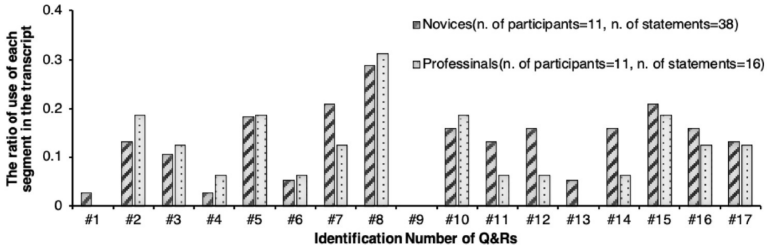

Figure 4. Q&Rs connected to user-needs per number of user-needs

3.2 Result of Subject part of needs

The novice participants generated 38 insight statements, while professional designers wrote down 16 sentences. The subject of each insight statement was coded into three categories. The number of insight statements coded as each category was divided by the sum of the number of insight statements. Figure 5 shows that the result of the ratio of the subject of insight statements. For each category, significant differences were found by proportion test ($p < 0.01$). Novice designers were more likely to write generalised characters which are the same 'character' with the interviewees of the transcript as a subject of insight statements. By contrast, the professional designers wrote more "the user" or "not the user nor character" than the novices. "Teacher" was the only character that professional designers wrote in the insight statements, and that was the most frequently stated character (12%) of all participants as well.

Table 3. Examples of each category and proportion of the characters used in the subject part

Character categories	Examples of each category: *'OO'*	The number novice/professional (percentage in all codes)
teacher	Teacher	5/4 (12%)
cannot wake up / oversleep	A person who often oversleeps	7/0 (17%)
cannot get out from the bed	A person who cannot get out of bed	5/0 (12%)
many tasks to do	A person who has many tasks in the morning	4/0 (10%)
drink coffee	A person who drinks coffee in the morning	2/0 (5%)
low self-control	A person with poor self-control	1/0 (2%)
wake up early in the morning	A person who must wake up early	2/0 (5%)
work efficiency	A person who values efficiency	1/0 (2%)
have something to do	A person who has things to do in the morning	1/0 (2%)
consider	A person who thinks what to do in his head	1/0 (2%)
lives alone	A man who lives alone	5/0 (12%)
go to work in the morning	A person who goes to work in the morning	2/0 (5%)
have morning routine	A person who has a morning routine	1/0 (2%)

Forty-one user-needs were categorised as 'character,' and thirteen different types of characters were mentioned (Table 3). In table 3, the numbers of each categories were counted within insights statement of the same participants' profile. The ratio of each character to all insight statement categorised as 'character'. The characters were based either on participants' profile or on the transcript of the interview. The result implies that in writing down sentences, the novice participants tended to generalise while professionals stick to the interviewee.

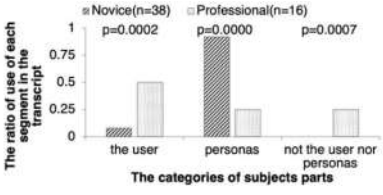

Figure 5. Comparison of subject part

3.3 Results of the user-needs construction

The object part and reason part of each insight statement were categorised into four groups. Figure 6 (left) shows the proportion of each category to the total numbers of insight statements. Between novice and professional designers, there was the tendency that professional designers were more likely to construct the insight statements in SxS way, which contained the supposition in both object part and reason part than novice designers did. Moreover, among the insight statements that contained at least one supposition, the result of proportion became shown in Figure 6(right).

Novice designers wrote down 23 insight statements, while professionals wrote down nine statements. There were significant differences in the value that professionals were tended to write down SxS insight than novice designers did by proportion test. Figure 6(right) also shows that professional designers wrote more SxS insight than DxS and SxD. This result implies that professional designers wrote SxS insight when writing insight including suppositions.

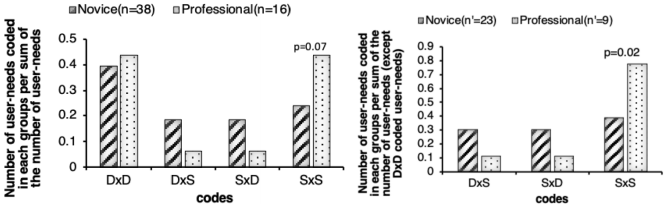

Figure 6. (left)The proportion of the coded user-needs / (right) Proportion of the coded user-needs (without DxD grouped needs)

4 DISCUSSION

We compared the insights creation process and insight statements between novices and professionals. The results show that there is no difference in what interview transcripts were used between novice and professionals. It means that the differences between novice and professionals lie in the analysis of the transcript. First, there were significant differences in the subject part of user needs for all three categories. This result implies that novice designers tend to generalise the user by his or her character. Jones (2008) described that using 'personas' can improve the creativity in design process when it is used to understand the user's nature. However, badly constructed personas, such as 'promotional personas,' may cause assumptions and preconceptions [11]. Hence, generalising users by their character might not be good because it limits the capability of empathy. The insight statements of professional designers were more likely to be coded as SxS group. In other words, professional designers put more suppositions in their insights than novice designers did. This tendency is consistent with interview results with designers, which is that novice designers can solve well-defined problems rather than discover and define design challenges by themselves [12]. The result implies that novice designers cannot reframe design challenges because they try to find problems literally in what they hear or observe, rather than what they

suppose based on the result of user research. The result made us speculate that novice designers did not empathise with the interviewees by using the taxonomy of empathy, such as perspective-taking. The novice designers might see the interviewees as a sort of system having problems that can be observed from outsides. Since the interview script was given to the participants as a document, it might have been difficult for the participants to immerse themselves into the interviewee's world, which is an important step of empathy in design [6]. The results also suggest that novice designers did not gain insight by a synthesis framework of "I know this" and "I saw this", which is used to identify insight from gathered user research data [4]. It might also be useful for novice designers to follow such a template which forces them to write down those aspects explicitly. The findings suggest novice designers should not generalise users by picking up one of his or her characters when verbalising the insight but should empathise with the individuals rather than picking up what is observed and interviewed. This study imitated a part of empathy and insight generation process within long design process. The longitudinal study of empathy in design is needed to expand this study's findings. The limitation of this study is the limited number of participants. It is also of interest for design education research to investigate how professional designers acquire the skills throughout their carriers.

5 CONCLUSIONS

This research aimed at revealing the differences between novice and professional designers at the stage of insight discovery in design process. As designers usually are required to find out the proper insight from complex user situations, empathy is a key technique to facilitate this challenge. As a result, this research found that there were mainly two differences. Novice designers tended to generalise the user by one of his or her character, which had a negative impact on empathy. Professional designers put more supposition in their insights than novice designers did. The results suggest that novice designers should not generalise the user by their character and try to empathise deeply with an individual user. This paper is a first step to analyse and support the insight generation of novice designers.

ACKNOWLEDGEMENT

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PRESERVATION AND PROMOTION OF INTANGIBLE CULTURAL HERITAGE - A PARTICIPATORY DESIGN APPROACH

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ABSTRACT
Current research literature on intangible cultural heritage (ICH), conservation, and development increasingly acknowledges that ICH has meaning for multiple stakeholders and is served best by integrating them into conservation processes. This article explores participatory design and its methods and tools for ICH purposes because they seem to provide promising approaches for keeping ICH vital in the traditional cultural locations and settings, as well as in the diasporas.
Following the introduction, the second part of the article explores the role of design when preserving and promoting intangible cultural heritage (ICH) in theory by reviewing the literature on ICH management, participatory design, and participatory preservation projects. The third part applies findings from part 2 in a participatory design project on ICH preservation in the diaspora community of Uyghurs in Norway. The conclusion in part 4 discusses learning experiences on combining design research and practice in a master's course. The goal of the project was to design a concept, that displays, disseminates, and connects Uyghur culture internally amongst the people in the diaspora as well as mediate Uyghur ICH to people in the Norwegian society. Findings of both the theoretical study and the project indicate that the sustainability of ICH preservation depends on that living heritage is kept alive. For this to happen, ICH must be allowed to transform according to the time and place of the culture bearers. This kind of transformation is especially significant for diaspora cultures.

Keywords: Participatory design, intangible cultural heritage, diaspora, preservation, cookbook

1 INTRODUCTION

The Uyghur culture is at risk of disappearing. Both the tangible and intangible cultural heritage of Uyghurs, who are today living in Xinjiang Autonomous Region is controlled and restricted by Chinese authorities. As a result, Uyghurs, whose culture is quite distinct from the majority Han Chinese culture, are at risk of losing their identity, cultural expressions, and religion. Uyghur inhabitants are under heavy surveillance, restricted from leaving China and having contact across the borders. Uyghur refugees have settled in many countries all over the world, and most of them are eager to do what they can to preserve their cultural heritage and protect their human rights while living in the diaspora.

1.1 Methodological approach and background of the study

The study presented in part 2 and 4 comprises a literature review and a practical project which are both part of a Master course at the Department of Design at the Norwegian University of Technology in Trondheim, Norway. The objectives of the course are to write a scientific article on a self-chosen topic to gain theoretical insights, to apply these insights in a project, which further explores the topic, and to present a design concept/solution. The literature review article provided the student, who is the first author, with a deeper understanding of the role of the designer in cultural heritage projects, while the project aimed to find a solution to preserve and promote the intangible cultural heritage of approximately 2500 Uyghurs living in Norway. The following part of this article is discussing participatory approaches concerning intangible cultural heritage preservation and promotion and explores how engaging the relevant communities can contribute to cultural revitalization, strengthening of identity, and social sustainable development.

2 INTANGIBLE CULTURAL HERITAGE PRESERVATION

Intangible cultural heritage (ICH) is defined as the immaterial expression of cultural heritage. It includes oral traditions, language, values, ways of living, social practices, performing arts like dance and music, knowledge, skills of handcraft and place-making, and so on. [1]

UNESCO's definition of cultural rights includes: "… the rights of individuals and communities to enjoy and make use of cultural heritage and cultural expressions, as well as the right to play an equal role in the identification, safeguarding, and transmission of their cultural heritage" (UNESCO, n.d.)

The declaration thereby points out that the need for ICH safeguarding is connected to human rights and serves as a reference point for the elaboration of policies in favour of cultural diversity [2]. A major issue concerning the practice of safeguarding heritage is however that policymakers determine what is worth safeguarding and what can be neglected, or even looked upon as a threat to society. This is problematic in terms of decision-making and the UNESCO cultural heritage programme has been criticized for it by various authors, who argue that state institutions can exploit policies in their favour [3], [4], [5] using heritage interventions as political instruments. Though required to consult the heritage bearers, the lack of communication with the relevant groups often goes unnoticed.

Another challenge pointed out by Mountcastle [5], is the contradiction between the living character of ICH that transforms through dynamic processes and continuous decision-making and the act of identifying and listing the ICH as something consistent. ICH develops and changes over time, responding to events, conditions, and development of societies. For that reason, traditions and practices in diaspora communities are never the same as in the homelands, but are nevertheless "authentic", as the diaspora community has developed their own ICH, where heritage is interpreted and re-invented to respond to the new time and setting [6]. Due to the living characteristics of ICH, participatory approaches must address the heritage bearers directly, both when dealing with ICH in its original place or diaspora [3], [7]. Although criteria of participation are sometimes applied loosely several newer ICH projects, which were analysed by the first author of this article, are aiming at culture bearers' participation.

2.1 The role of Participatory Design in preserving ICH

Participatory approaches in heritage management are often used to address the stakeholders' relationships to the heritage that is dealt with. This can reveal the intangible traditions connected to a place, objects, or monuments defined as tangible cultural heritage. It opens discussion and can help to record knowledge. Participatory design (PD) in particular, uses participatory approaches to reach some sort of tangible or intangible outcome, whether it is a new service, experience, system, or product [8]. PD also comes in varying degrees of participation, and the level of empowerment experienced by participants relates to the level of participation. Davidson et. al. illustrates this with the "Ladder of community participation" (Figure 1), which shows that user participation in PD can range from "manipulation" of users as the workforce to "collaboration", or most preferably "empowerment", which leaves the user with the most control of decision-making and execution of the project [9]. These authors also suggest that a participatory approach, in particular, is useful to realize projects (like surroundings, architecture, services, events, and exhibitions).

In the light of Davidson's Ladder [9] of community participation, real grass-root heritage projects are the most empowering, while simple actions as informing and consulting heritage bearers before actions deprive them of their autonomous ICH development and is, therefore, a violation of human rights.

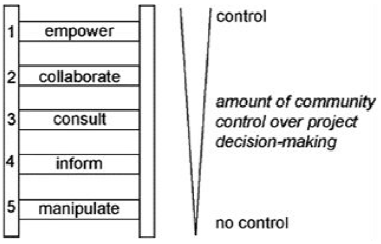


Figure 1. Davidson's Ladder for Community Participation

2.2 The analysis of case studies from literature

To relate Davidson's ladder to real-life participatory design projects, the first author of this article analysed five case studies from the literature concerning their participatory content as displayed in Figure 2. One case was from Egypt [10], two from Finland [11] [12], one from Norway [13], and one from China [14].

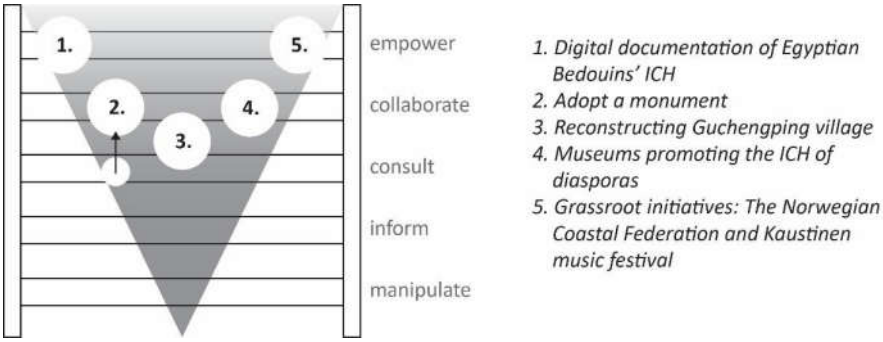
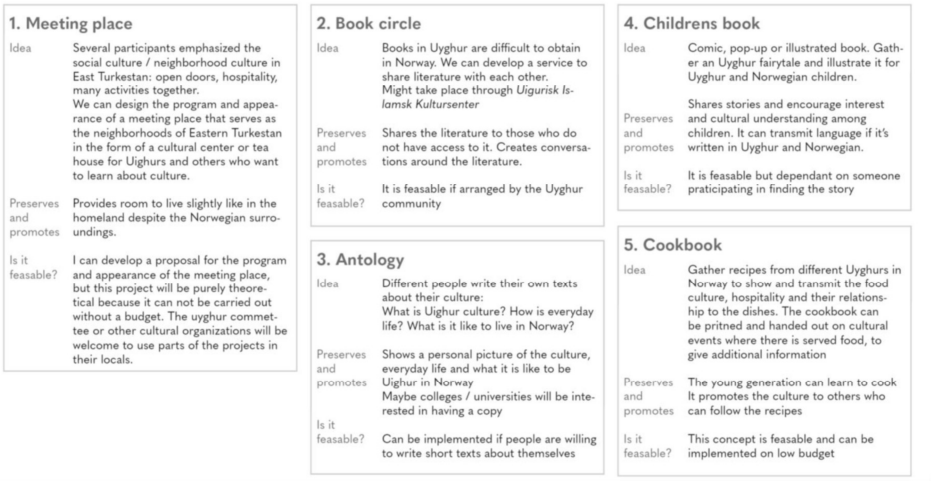


Figure 2. Participatory projects located in Davidson's Ladder (Figure designed by Author 1)

The role of a participatory designer in participatory projects is both facilitating the participants to engage in the research and creation process, and to use the designers' skill of envisioning and visualizing concepts and ideas. Conclusively, the theory investigation resulted in summarizing three principles for participatory ICH projects:
1) to benefit the community by addressing their real needs and wants,
2) to promote motivation, ownership and authenticity by facilitating self-expression and decision-making by participants and
3) to create a shared identity between designers and participants [10 The role of a participatory designer in participatory projects is both facilitating the participants to engage in the research and creation process and to use the designers' skill of envisioning and visualizing concepts and ideas. Conclusively, the theory investigation resulted in summarizing three principles for participatory ICH projects:
1) to benefit the community by addressing their real needs and wants,
2) to promote motivation, ownership, and authenticity by facilitating self-expression and decision-making by participants and
3) to create a shared identity between designers and participants [10].
Findings from theory contributed to the decision to conduct the project and concept development as a participatory design approach, trying to include the users as much as possible in the process of creating. Participatory tools applied in the project were interviews to lead the project direction, a focus group to include users in decision making and further developments of the concept, and an iterative feedback-refinement process to ensure that the end product is finished in terms with the users. The project methodology and process plan were built upon principles of user-centred design as well as participatory approaches.

3 RESULTS

The following section presents results in form of solutions for preserving and promoting Uyghur intangible cultural heritage within a participatory design concept. Based on the findings from desktop studies, stakeholder information and -interviews, and ideation concepts were discussed with a focus on the most relevant cultural aspects for the Uyghur stakeholder group: The concepts were: culinary culture, social life, literature, language, and music/dance. Figure 3 shows the 5 concepts that were considered for further development.



1. Meeting place

Idea	Several participants emphasized the social culture / neighborhood culture in East Turkestan: open doors, hospitality, many activities together. We can design the program and appearance of a meeting place that serves as the neighborhoods of Eastern Turkestan in the form of a cultural center or tea house for Uighurs and others who want to learn about culture.
Preserves and promotes	Provides room to live slightly like in the homeland despite the Norwegian surroundings.
Is it feasable?	I can develop a proposal for the program and appearance of the meeting place, but this project will be purely theoretical because it can not be carried out without a budget. The uyghur commettee or other cultural organizations will be welcome to use parts of the projects in their locals.

2. Book circle

Idea	Books in Uyghur are difficult to obtain in Norway. We can develop a service to share literature with each other. Might take place through *Uigurisk Islamsk Kultursenter*
Preserves and promotes	Shares the literature to those who do not have access to it. Creates conversations around the literature.
Is it feasable?	It is feasable if arranged by the Uyghur community

3. Antology

Idea	Different people write their own texts about their culture: What is Uighur culture? How is everyday life? What is it like to live in Norway?
Preserves and promotes	Shows a personal picture of the culture, everyday life and what it is like to be Uighur in Norway Maybe colleges / universities will be interested in having a copy
Is it feasable?	Can be implemented if people are willing to write short texts about themselves

4. Childrens book

Idea	Comic, pop-up or illustrated book. Gather an Uyghur fairytale and illustrate it for Uyghur and Norwegian children.
Preserves and promotes	Shares stories and encourage interest and cultural understanding among children. It can transmit language if it's written in Uyghur and Norwegian.
Is it feasable?	It is feasable but dependant on someone praticipating in finding the story

5. Cookbook

Idea	Gather recipes from different Uyghurs in Norway to show and transmit the food culture, hospitality and their relationship to the dishes. The cookbook can be pritned and handed out on cultural events where there is served food, to give additional information
Preserves and promotes	The young generation can learn to cook It promotes the culture to others who can follow the recipes
Is it feasable?	This concept is feasable and can be implemented on low budget

Figure 3. Concepts from Ideation phase

The concepts were evaluated regarding their cultural importance, but also relating to their realizability and preservation over time. The cookbook (5) was a good and easy option because food is something that concerns us all and Uyghurs are very proud of their cuisine. Also, a cookbook does not exclude any users from participation and eating is an important part of everyday life. A meeting place (1) also seemed like a good option, as it could embrace many aspects of the culture and especially the social life. It could have elements for each interest to appeal to many different people. However, facilitating the physical design of such a place can be challenging. The children's book (4) addresses the parents' wish to transmit knowledge about language, culture, and history to the younger ones. It could also see Norwegian kids as a target group to heighten understanding about cultural diversity. However, the target group for this concept is somewhat more limited and might contradict children's motives as not everyone is yet maturely motivated to learn about the language and cultural background of their parents.
The anthology (3) is more of a documentation form and might be less useful for everyday life safekeeping of the intangible heritage. There is also a high threshold to contribute with such personal written text and would not appeal to everyone. The book circle (2) is also for those who are especially interested and excludes those who are not as excited about reading.
To be able to appeal to more target users, both Uyghur and others, and to address cultural "living" heritage in a design solution and not only documentation, the concepts of cookbook and meeting place were chosen and presented to the focus group. All participants thought that food is an important part of the Uyghur culture and that food is a good channel to represent it. The participants thought that the cookbook was a good idea, but they were concerned about the fact that Uyghur cooking requires a lot of skills, and the cooking process is not easily described with text only. The participants were however positive about sharing their recipes in an online version. They also liked the meeting place concept and said they would probably go there themselves, although they were not so sure about what should be in such a place. After discussing the two concepts the cookbook was chosen both because it is more likely to be implemented and to find participants, and because food concerns everyone, and as one participant pointed out: "*Our life and culture really cannot go on without food*."

3.1 Discussion of selected solution

The selected solution that has been designed consists of a service that includes both a physical and digital format, to address all issues discovered in interviews and the focus group. The storyboard in Figure 4 explains the two main components of the service, a printed recipe booklet and a webpage, how they work together, and how it relates to the current practice of cultural events, "food-exhibitions" and Uyghur holidays like Nowruz and Eid. The printed recipe booklet is an addition to the database generated through the webpage. It cannot hold the videos, but it has an important function by having a presence in real-world cultural events that are currently arranged by different Uyghur societies in Norway. Since Uyghur food is often complicated, the booklet should direct the user to the webpage with the current

recipe if it has a video. In addition to the recipes, it should also give background information about the food, like where it originates, who submitted the recipe, what is the author's relationship to the recipe, etc. Since the recipe owners are the ones submitting this information, they can define and express themselves the culture connected to the food.
The service needs an administrator, which could be the culture branch of the Norwegian Uyghur Committee who also arranges events. The administrator should handle the webpage and recipes submitted and prepare and print the booklet for events.

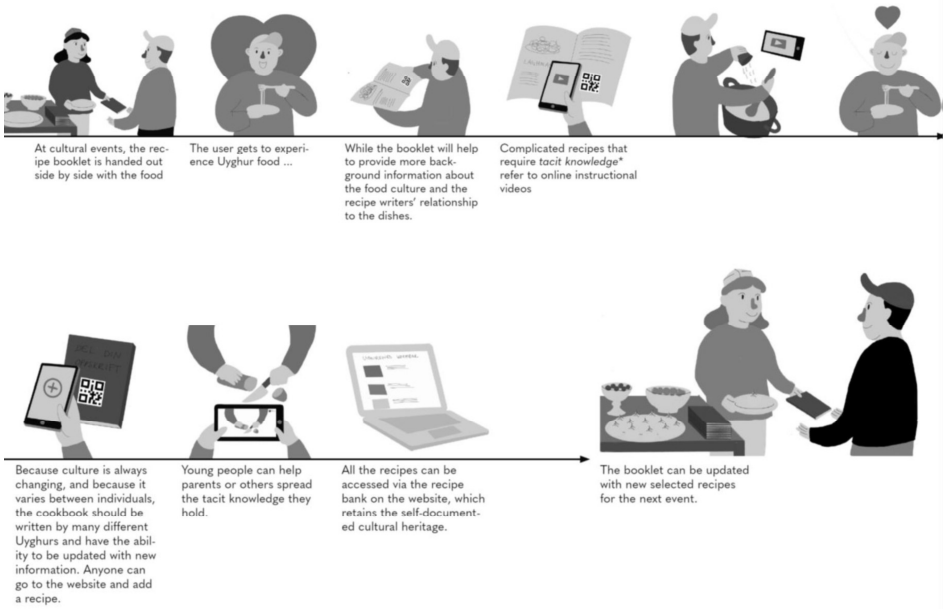


Figure 4. Cookbook Story Board

Due to the COVID-19 outbreak, Norway was in a lock-down from March 2020 till the project deadline and it was very difficult to get a response from the focus group on the final concept, so the feedback step before finishing and delivering the project was not done. The first author got feedback from a Uyghur friend, who was very positive about the concept and wanted to start submitting the recipes of her parents right away if it was realized. The proposed solution is therefore a prototype of iteration 1. It needs to be user-tested and get feedback from Uyghur users. If further development will be done, important points to validate through the participants would be whether it represents their culture in their terms, whether they would use this system, if it is understandable and user-friendly.

4 CONCLUSIONS

By combining design theory and -practice in the project, the first author experienced the importance of participatory approaches in design problems concerning society and culture. The main challenge was to connect with the user group and to establish trust and mutual understanding in a limited time frame, especially because the users are outside of the author's social and cultural periphery. However, the project exemplified the theory that user engagement is crucial in cultural matters and that the role of the designer is among others to try to understand and facilitate the needs and values of people affected by the project. Intangible cultural heritage can be revitalized by new design solutions. The value of participatory approaches to the wider design and heritage community is increased stakeholder collaboration on a local and regional level and ICH activities that keep living heritage dynamic through direct user involvement.

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A NEW SERIOUS GAME FOR CHILDREN TO EXPLAIN INNOVATION AND ENHANCE CREATIVITY

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ABSTRACT
Serious games, educational games that aim the development of a competence in a ludic way, for children are soaring on the market. Nonetheless, very few tackles the subjects of innovation and creativity. The purpose of this article is to present a new serious game to address this point. In fact, a project was carried out two years ago, resulting in a serious game called "Lino has an idea!", which had interesting approaches. The team had registered feedback on their game from teachers and students from third and fifth grade. The feedback together with our ideas lead us to improve the game.
The purpose of our serious game is to create an immersive universe where children can learn how an idea can be developed and become a project. The different steps of the innovation process will be based on the different stages of innovation. The serious part of this game includes a time to brainstorm around the methods of creativity used in the innovation field. One of our goals is also to design the game more immersive for children, so they can really be invested in it and enjoy playing.
We conducted a case study with two classes of children aged 8-9 and 10-11 years old. In this article, we present the concept of our serious game and the results and conclusion of that case study.

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

1 INTRODUCTION

Creativity and innovation are real assets and skills sought after in the world of industry and work. While some are innate, innovation techniques are skills to be acquired, and the sooner the better. However, educational games for children are currently underdeveloped [1]. In this article, we will present our process of creating and designing our game, as well as a review of its testing in classrooms.
Section 2 of the article will be devoted to a benchmarking study of educational games. Section 3 will develop the objectives of the game, the gameplay imagined, and the physical realization of the game. The classroom experience and the debrief of this experimentation will be seen in sections 4 and 5 with the possibilities of evolution. Finally, in the concluding section, we will discuss the perspectives and recommendations following the creation of the game.

2 BACKGROUND

Lots of games for children are developing creativity [2]. But there are closer to an individual awakening of creativity than to a real educative game giving the bases of the innovation concept in team. Although serious games are booming in higher education and companies, there are used very little in primary school, middle school, and high school (Figure 1) while these are ages when brains are developing quickly and are very receptive to these kinds of activities. And, according to our research [1], if serious games are underdeveloped in primary school, serious games dealing with innovation and teamwork are absent.

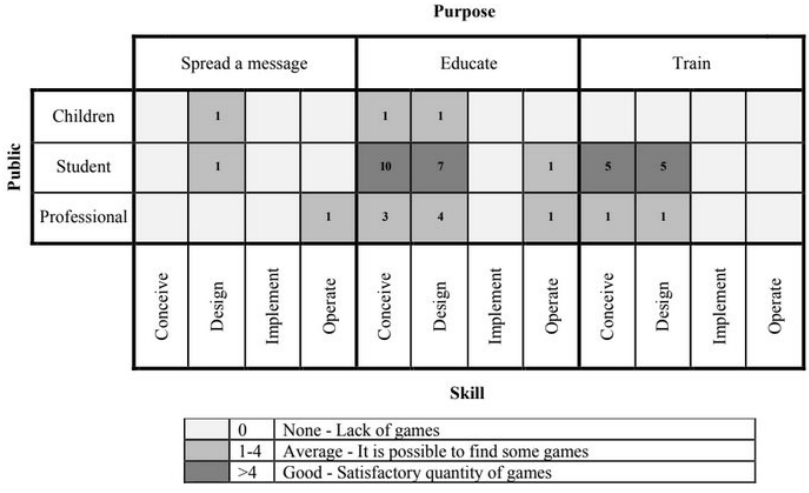

Figure 1. Taxonomy of different serious game (from [1])

In order to benefit teaching and learning, one of the most interesting ways is to enhance the interactive dynamic of games [3-5]. As most traditional forms of teaching cannot attract and please children, adapted principles, structures, and mechanics, need to be designed. According to *Educause* [6] "game-based learning platforms can create an engaging dynamic that inspires students to develop competencies and skills as they focus on the activities of the game."

3 RULES AND GAMEPLAY

For the design of our game, we followed the DICE generic model in 4 steps: Define, Imagine, Create and Evaluate [7]. Based on the results of the previous game "Lino has an idea!" [8], this part presents the updated objectives, rules, motivation tools used and universe.

3.1 The objectives

The game's aims are educational and playful games designed for primary school classes. The serious game is dedicated to give them the first keys of the creative process of innovation: the product's constraints, the steps, some creativity methods, etc. The other objective is to give them teamwork tools and autonomy.

3.2 The rules

Before the start of the game, children form randomly groups of four to seven. Then each child chooses a role in the team, to facilitate team efficiency (Table 1).

Table 1. Roles in the game

Role	Animal	Description
Guardian of the word	Penguin	Manage the speed distribution with the talking stick
Master of the time	Rabbit	Manage the time and the rhythm
Goalkeeper	Squirrel	Keep the objectives in mind and refocus the discussion
Secretary	Owl	Take care of the written trace
Designer	Deer	Take care of the drawn trace
Presenter	Bear	Present the final product in front of the class
Reporter	Giraffe	Explain the team progress to the supervisor

The game is constituted of seven steps which represent the seven steps of the innovation process (Table 2).

Table 2. Game rules

Steps	Explanation	Time
Definition of the need	The group throw the dice and agree on a product idea	10 min
Choice of innovation	Each member proposes his vision, and the group finally chooses a product	10 min
Method of creativity	The group is given a creativity method and put it in practice	20 min
Recreation	The children go to the schoolyard to be more efficient for the endgame. They can use the schoolyard to exchange between groups.	15 min
Convergence of ideas	The group draws up a list of advantages and disadvantages and makes the final modifications	10 min
Presentation	The group prepares a quick presentation and presents the object to the class	15 min
Feedback	The children vote for each category and the teacher presents the nominees. Then the children close their eyes, and the leader asks them some questions about how efficient their group was and how did it work	10min

3.3 The motivational tools and the universe

The game is dedicated to children. So playful and motivational tools are quite essential [9]. That is why we used the Lino narrative frame. Lino is a young fox who dreams of a product and spends the following day shaping his product idea with his friends, teachers, and parents. His school day rhythms the game. For the aesthetic and attractive aspect, we used a graphical charter adapted, with cute animals (Figure 2).

Figure 2. Game universe

We also added some entertaining accessories: three dices to represent Lino's dream (technological field, type of object and a main characteristic) and a wheel of tricks to choose a creativity method. Finally, in order to motivate all groups, we added a nomination at the end permitting participants to vote for the other products in four categories: Useful, Funny, Original and Aesthetic.

3.4 Game board

To create a board for our game that would be both playful and interactive for the children, and also, that shows the different steps of Lino's day in school, the first configuration was « classic » with cases. Nevertheless, the drawback of this configuration is that we do not see a real linear evolution of the

innovation, but more of a cycle as if after one round, the players had to start another round. The objective is to show the path of thought and action to develop an innovation, so the image of a cycle is not appropriate. There must be a clear distinction between the beginning, i.e., the idea, and the end, i.e., the final presentation of the innovation. Thus, the board was conceived with a spiral shape, like a snail, with the beginning at the extremity and the end in the centre (Figure 3).
Playing with the spiral allows to create a board with steps at different levels, creating a real path through innovation. Moreover, the board is separated into two pieces: one piece to hold the cards, the dice, and other accessories, and one piece with the spiral divided in steps. This enables an interaction with the board from the beginning because children have to put together their spiral board like a puzzle.

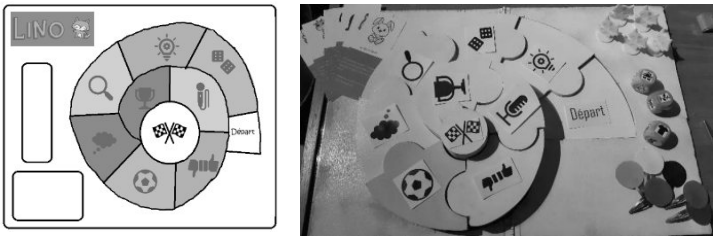

Figure 3. Game board prototype

For the need of the experiment, a first prototype of the board with different techniques was built either by cutting wood and with 3D-printing. On a larger scale, to sell the game, we would have to use materials and techniques that are both solid and cheap. The Lino pieces were 3D-printed, and images were glued on the wood dice.

4 CASE STUDY

A case study, taking in account usability [10] and game engagement [11], was managed twice in January 2021, in a primary school in Le Pecq, a city in France near Paris. The public targeted are children from 8 to 10 years old, so the game was tested in two classes, one of 28 pupils in third grade (~ 8 years old) and one of 20 pupils in fifth grade (~ 10 years old) (Table 3). In the first case, children were grouped randomly by 5 and in the second, they were grouped by 7.

Table 3. Gender repartition in the classes

	GIRLS	BOYS
Third grade	12	17
Fifth grade	8	12

Figure 4. Photos taken during the case study

The class was organized in work islands to foster teamwork (Figure 4). The process presented Figure 5 was used. The designers' team (5 members) supervised the game and the children by explaining the rules and answering their questions. Both classes were free to create whatever they wanted, regardless of feasibility. In the third-grade class, one supervisor was assigned to one group.

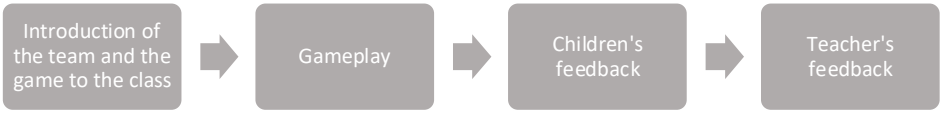

Figure 5. Steps of the case study

At the end of the game, children took a satisfaction survey of four questions, based on a 3 steps Likert scale made of four emoticon faces, from 😟 to 😀, which they coloured depending on the state they were feeling (Table 4).

Table 4. Questions and mean of the answers to the survey

QUESTIONS	3RD GRADE /3	5TH GRADE /3
Did you find the game fun?	2,69	2,85
Did you understand all the game rules?	2,15	2,58
Did you understand the “trick” given by lino’s teacher?	2,31	2,25
Do you like the design of the game?	2,70	2,74
TOTAL	2,41	2,60

Then, the class was asked orally three qualitative questions so children could react to what has been said: 1. After this game, how would you define innovation? // 2. What did you like the most in the game? // 3. What did you unlike the most? // 4. What would you add in the game? After the game, children had a clearer vision of innovation. Very few children reported something they did not like; they were enthusiastic, as shown in the table above, and liked the team play.
The designers’ team also registered the feedback of the teachers to determine the affordability and the relevancy of the game. Teachers reported the capacity of the game to foster children creativity and enhance teamwork skills. However, they questioned the physical game board, instead of a digital one.

5 DISCUSSIONS AND PERSPECTIVES

This experience was globally satisfactory for both classes (third and fifth graders) and their teachers.
First, we observed the children. Both classes were highly motivated and deeply involved in the game. The fifth graders were globally calmer than the third graders. The fifth graders listened more to each other and were more able to respect the roles they were assigned to. During the game, we noticed that the storytelling about Lino's day had more impact on the third graders than on the fifth graders. This storytelling phase allowed the third graders to calm down and refocus on the activity. For the fifth graders, the storytelling did not change their way of playing. Ideally, the storytelling format should be adapted to the age of the pupils, so that Lino's story can be shared effectively for all age groups. We have also noticed that children in the third and fifth grades progressed very quickly in developing their innovation, making the intermediate stages of creation obsolete. A way should be found to "slow down" the pace of the children, by allowing them to take advantage of all the tricks of the game in order to create their own innovation.
In a second step, we collected the students' opinions and their ideas of improvement. The fifth-grade students would have liked to experience storytelling in video format: this would have provided real added value by capturing their attention. The third graders would have liked to move more in the classroom, for example by allowing each member of the group to stand up in order to move his/her team's pawn on the game board (during our experiment, only one child from each team was designated to perform this task). Children in both classes would also have appreciated having a real "talking stick". The third graders particularly liked the dice step, they also loved drawing. The fifth graders preferred the oral presentation step in front of the class. They were also very responsive to the design of the game board and the role cards.
From the teachers' point of view, the game was very enriching for both classes and allowed the children to get used to teamwork. Nevertheless, a teacher cannot currently set up this game alone: the presence of several adults is necessary to guide the children. The teachers also pointed out to us that the design

of the dice was not optimal for the children. Indeed, the drawings on the sides of the dice lock the children into very specific ideas. Replacing the drawings with words (for example, replacing the drawing of the rocket with the word "space") would allow children to expand the range of possible ideas.
Teachers are delighted with the experience and would be able to buy a copy of the serious game for their school.

6 CONCLUSIONS

As we have seen in the article, children need to develop their creative and innovative skills as soon as possible. After defining the rules and the gameplay, we designed the game board as well as the different cards and sheets useful for feedback. We then tested it in a school: the children had fun and wanted to start playing again.
This educational game allows children to work in groups, which is not always possible in class according to their teachers, and also to discover new methods of creativity. During the game, the children must find ideas, improve them, and decide together on their final innovation.
For the next steps of the project, a study has to be conducted to improve the game board and accessories accordingly to the children and teacher feedback.

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CONSTRUCTIVE ALIGNMENT OF A FLIPPED DESIGN AUTOMATION LECTURE

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ABSTRACT
Design automation in mechanical engineering requires students not only to obtain competences in the application of computer aided design software and the creation of knowledge-based product models. Future knowledge engineers need e.g., communicational skills in order to acquire the relevant knowledge for later implementation in design automation systems, or skills for planning, modelling, and exploring a design solution space. In a flipped classroom setup, where the responsibility for the learning process and thus several degrees of freedom regarding topics and their weighting are transferred to the students, a later summative assessment needs to fulfil two basic requirements: First to reflect the individual learning progress of a student, second to discover if the higher learning goals of the course are met. Constructive alignment is a technique to relate teaching activities, learning outcomes and assessment to each other and to the competences that a learner should acquire. The present paper reports about the assessment for a flipped classroom design automation lecture. Starting from the educational objectives and the learning activities, two different assessment mechanisms are characterized: A semester project where two or three students works as a team of knowledge engineers to create a knowledge-based engineering system, e.g., a product configurator, and an oral exam where each student has the opportunity to report about his or her individual learning process and dispute this with the teaching staff.

Keywords: Knowledge-based engineering, flipped classroom, constructive alignment

1 INTRODUCTION

Computer-aided design (CAD) systems are among the fundamental software applications with which mechanical engineering students come into contact. The definition of shape and product properties in these systems is fundamental to virtual prototyping and knowledge-based design [1, 2]. A capstone course for design automation in this field requires students not only to obtain competences in the application of CAD software and knowledge-based product modelling but also methodological and self-competences. Future knowledge engineers need e.g., communicational skills in order to acquire the relevant knowledge for later implementation in design automation systems, or skills for planning, modelling, and exploring a design solution space [3, 4].

Teaching design automation in a flipped classroom transfers the responsibility for the learning process and thus several degrees of freedom regarding topics and their weighting to the students. Additionally, working on self-chosen semester projects in a team opens up the opportunity for the students to carry own knowledge, experiences, and challenges from past design projects into the course, making the range of possible projects and the corresponding knowledge enhancement broad [5]. Considering this, a later summative assessment needs to fulfil two basic requirements: First to reflect the individual learning progress of a student, second to discover if the higher learning goals of the course are met.

Constructive alignment is a technique to relate teaching activities, learning outcomes and assessment to each other and to the competences that a learner should acquire [6, 7]. Two fundamental conceptions therefore are that first learning is the result of students gaining meaning from activities and second teaching needs operationalization according to learning outcomes and supporting students in achieving them [8].

The present paper discusses constructive alignment of a design automation lecture and focusses then on its assessment mechanisms. It is structured as follows: The following section 2 presents a brief theoretical background focusing on the flipped / inverted classroom concept, constructive alignment, and the context of knowledge-based engineering. Afterwards, section 3 deduces constructive alignment

for the design automation lecture using a methodology for creating knowledge-based systems. Section 4 then focusses on the assessment methods, before sections 5 and 6 present discussion and conclusion.

2 THEORETICAL BACKGROUND

2.1 Flipped classroom

Although the shift of lecture time and out-of-class passive learning activities is widely known from distance education, flipping, or inverting the classroom is a different pedagogical approach [9]. The idea is to intentionally push passive learning activities like listening to lectures outside of class while active learning, like laboratories, discussions and more complex problem solving is experienced in-class [10]. The consequence is that the consumption of learning material is independent from place and time and contact time between teacher and students is efficiently used [11]. Additionally, in combination with problem-based learning, group collaboration and a high responsibility for their own learning process the concept is able to encourage students to better explore the course content compared to a traditional lecture. The flipped classroom concept dates back to the late 1990s but is becoming increasingly popular with the intensive use of the Internet, as asynchronous teaching materials can be easily delivered online and through learning management systems. Nevertheless, the use of flipped classroom is not widespread in engineering disciplines and there is comparatively little research regarding its impact on engineering education in general [12, 13].

2.2 Constructive Alignment

Teaching means to transmit knowledge to students. Here, constructive alignment sets the focus on operationalizing quality of teaching and learning with three key questions [6]:

1. What is the intended learning outcome that a student should have obtained after passing the course?
2. What are the teaching and learning activities that are necessary to carry out in order to get to the learning outcome? Is it e.g., application of a theory, generating new ideas on basis of requirements, solving problems, or diagnosing?
3. What are authentic assessment methods in order to reflect the learning activities and check if the learning outcome is really met? Especially in design engineering a method shift from classical exams towards project assessments, customer journeys or communicating with clients is emphasized.

The benefits of constructive alignment for the teacher are a higher likelihood that students will learn in the wanted way, the development of trust and shared goals between teacher and student, and growing student confidence in their own learning [14]. A prerequisite is total transparency: Before the learning begins, teachers clearly express what students should learn and how to express their learning by themselves. Another side effect is greater standardization and fairness of grading [15].

2.3 Knowledge-based Engineering

Knowledge-based engineering (KBE) aims at creating product models that can be easily adapted to new requirements and used to automate design tasks [16, 17]. KBE thus is useful for design tasks with a high number of routine tasks like configuration design activities but also for decision support for human designers and co-creation between e.g., human designers and computer-based agents [18, 19]. Today's CAD systems offer different possibilities to establish knowledge-based models, like the use of parametric constraints and equations, design rules or the integration of external knowledge sources and reasoning [20]. Knowledge engineering, i.e., acquiring relevant knowledge from human and non-human resources and formalizing it according to the later purpose, and building knowledge-based product models require theoretical knowledge, but rather experience and skills in working in teams, project management and communication as well [21, 22]. In order to be relevant, a corresponding teaching set-up must consider such educational objectives and give the students the opportunity to gather routine by doing and experiencing projects [23].

3 CONSTRUCTIVE ALLIGNMENT OF A DESIGN AUTOMATION LECTURE

The application of constructive alignment raises the question: Align to what? As described earlier, a design automation lecture should enable students to work as knowledge engineers and let them create knowledge-based product models. In order to get to learning objectives, a look into methodologies for

creating such models is a first hint. As an example, MOKA, the Methodology and tools oriented to knowledge-based engineering application [21] can serve.
Here, Stokes presents a process model, which is applicable independently from domains. The phases are:

1. Identify: Investigate business needs, determine type of the KBE system, and examine knowledge resources.
2. Justify: Derive acceptance criteria from requirements, generate project and business plan.
3. Capture: Collect knowledge from non-human and human resources, structure, check for purpose and file.
4. Formalize: Develop product and process model, certify formal knowledge model, store repository, and prepare for implementation.
5. Package: Translate formal knowledge model into working KBE system.
6. Activate: Involve stakeholders, implement software, and train users.

This enumeration allows formulating learning objectives for future knowledge engineers. To those belong:

1. Knowledge engineers need to investigate requirements for KBE systems and estimate implementation efforts.
2. They have to orient at methods for creation of KBE systems in order to derive project plans.
3. A knowledge engineer needs profession in acquiring knowledge from different information sources, including human experts.
4. Knowledge engineers need profound routine in formalizing knowledge into KBE system features and reasoning.
5. They also have to argue which way of implementation is superior and in which way it fits to the requirements.
6. A knowledge engineer needs good skills in communication and visualization in order to involve customers and later users of the KBE system.

At Leibniz University of Hannover, the lecture *Knowledge-Based CAD 1 – Configuration and Design Automation* addresses five major topics to operationalize the learning objectives, which is *parametric CAD models and part families*, *advanced assembly control via skeleton techniques*, *spreadsheet-driven design*, *knowledge engineering and methodologies* as well as *product configurators and expert systems*. For each of them, learning material according to the flipped classroom was created like commented lecture slides, screen casts or video tutorials. Attendance time is 10 sessions of 150 minutes each. Usually, the instructor engages the students at the beginning with a small warm-up task targeting the prepared course material. Then, groups of three to five students complete modelling tasks related to the topic at hand as learning activities. Meanwhile, the teacher moderates and guides the learning process of the groups. Each session is concluded with a wrap-up and participants then upload their results to a learning management system for all participants to access. An exception to this template is the Knowledge Engineering and Methods topic, which requires students to work in groups to prepare a poster session on a specific method to be presented and discussed in a Gallery Walk. After this session, the students form to learning tandems or triplets and negotiate an accompanying semester project with the teachers. Therefore, the students need to formulate a synopsis of max. two thousand symbols and a preliminary project plan as Gantt chart. This already contributes to the first learning objective of investigating the task and planning implementation. The teachers then approve this, and the students can start execution. Here, the task is to implement e.g., a product configurator but for later grading, the documentation of the project is decisive.

4 ASSESSMENT MECHANISMS

The project documentation is one of two pillars of the assessment in the lecture *Knowledge-Based CAD 1 – Configuration and Design Automation.* The documentation has to answer the following questions:

- Relevance of the project: Did the team generally find a solution for the targeted problem?
- Validity of project results: Are the models generated based on comprehensible facts, calculation bases, etc.? Were useful methods and tools used for the models generated?

- Reliability and robustness of project results: Have alternative solutions been discussed? Would the use of other methods lead to the same goal? Have the limitations of the model been tested and named?
- Traceability of the documentation: Does the documentation describe not only the results but also the way to get there? Has the choice of methods and tools been adequately derived and justified? Can models be replicated by others with the help of the documentation?
- Form of documentation: Is the documentation structured in a meaningful way, do directories and appendices exist? Are spelling and punctuation, correct? Are the graphics appropriate to their information content?

Before starting project work, the students get to know about the above questions in order to meet the requirement of transparency about assessment criteria and their weighting. Additionally, the teachers offer to scan through a preliminary version of the documentation. This creates a typical situation from the sixth phase of the MOKA cycle: Customers and users test the implemented system as well as its documentation, ask questions and give remarks for improvement. This pillar mainly targets on the first five learning objectives stated above.

As the documentation is the result of group work, a second pillar was necessary to reflect the individual learning process of each student. The teachers chose an oral examination for this. It follows the principle that the student first has the opportunity to reflect his or her learning on one of the major lecture topics by him/herself. After preparation, the student gets seven minutes of time, two meters of whiteboard and four pens as resources for the presentation. Afterwards, the teaching staff asks questions on this and interviews the student about different fields of knowledge. For grading, both width and depth of the knowledge fields are relevant but also the form of presentation (e.g., capability of visualization) in the first part of the examination. Consequently, this assessment aims more on the last learning objective.

5 EXPERIENCES

Within the last four semesters, nearly 70 bachelor and master students in mechanical engineering passed the course, which resulted in 28 semester projects. An average documentation consists of 40 pages and 30 pages of appendix where the students paste code form their KBE system, additional diagrams e.g., for the configuration process or the formal knowledge model known from the MOKA cycle. Until now, all tandems or triplets took the opportunity to let the teachers review a preliminary version of the documentation. The teachers made the following observations, which did not significantly differ between the student groups over time:

- Argumentation skills: The majority of documentations has initially quite a superficial argumentation of the chosen way of implementation. An example: If students chose VBA to create a product configurator this is usually due to the lack of a context sensitive user interface in other implementations. After mentioning, this point is usually addressed with an additional section and three to four statements why this way is superior to others.
- Project management skills: What was astonishing is the fact that nearly a third of the documentations showed that the students take not sufficient time for planning. Requirements that are fuzzy and not clearly examined at the beginning of the project often lead to the necessity to rebuild parts of the knowledge model, e.g., when design rules cannot be translated into a formal model. Nonetheless, a complete redesign of a KBE system did not occur until now.
- Documentation of the knowledge model: Here, the students are commonly safe in handling. The knowledge model is usually documented as parameter plan, configuration process flow chart, spreadsheet implementation and design rules.
- Visualization skills: The use of diagrams and figures is in average good. Comparing the preliminary version to the final version, the record of the solution space is initially not supported by pictures that show different configurations that the KBE system is able to generate. Here after mentioning, some students still dread to show this.

Regarding the oral examination, the students chose commonly either spreadsheet driven design or expert systems as starting points for their presentation. However, these presentations differ from each other and comply with our requirement of individuality. Visualization has a quite broad spectrum in the examination: Most students use prepared index card as templates for e.g., diagrams that are put on the white board. Some students use sticky notes instead and try to involve the teachers in the presentation.

Regarding student feedback, the uncommon assessment formats at our university challenge the students. Nonetheless, due to the transparency in grading and in the learning objectives, our students do not feel this as threat. Especially for the bachelor students the project documentation is felt as a good practice since in their studies written reports are a shortcoming. Some of our students thus feel better prepared for their thesis after completing the course.

6 CONCLUSIONS

The orientation along the specified learning objectives, which is forced by constructive alignment, was a good foundation for the creation of the lecture *Knowledge-Based CAD 1 – Configuration and Design Automation.* For the teachers, the focus on the objectives led to a good choice of learning activities for both preparation and presence time of the flipped classroom lecture. For the students, especially the assessment in form of natural mechanics in the later profession as knowledge engineer are a clear benefit. Meanwhile, the teachers offer outstanding students tandems and triplets to derive scientific papers from the documentation and the data of the semester project.

Constructive alignment is comfortable as it enables a top-down planning of a lecture. The definition of learning and teaching activities leads automatically to a process view and thus to the identification of inputs, outputs, and resources. As it is shown in conjunction with a flipped classroom, this also works with certain degrees of freedom. However, the consideration of all possible prerequisites of our students and the reflection of different learner types is exhausting and not always possible beforehand. Consequently, continuous feedback between students and teachers about learning obstacles, curricular constraints or working in the presence is still a value. And this cannot be planned, letting this happen certainly can.

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CAN COMPARATIVE JUDGEMENT IMPROVE PRODUCT DEVELOPMENT AND PRODUCT-SERVICE SYSTEM DESIGN FOR STUDENTS

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ABSTRACT
One issue within current product development literature entails, both with students and with professionals, the reliable scaling, and the objective assessment of products. This article will attempt to describe a way how master's students at the University of Antwerp, within a product development case, can both assess each other, assess the process of product development, and assess the final product using comparative judgement (CJ). This, while achieving learning goals described at master level. Our evaluation was anchored by use of Comproved, a validated instrument designed to comparatively evaluate products of students, during the design process (formative) and when uploading the final deliverables (summative) for the course. The current study evaluates how first year Master students (n=72) apply CJ using an online tool, Comproved (Comproved.com) during a semester-long group project on Product-Service System (PSS) design. Based on post hoc questionnaire details and interviews, we will list the advantages and the disadvantages of CJ, as stated by students. Finally, we will list the potentials of CJ during product development cycles and their impact on product quality, reliability of judgement and metacognitive strategies for learning.

Keywords: Design education, design process, product-service systems, reliability, assessment, comparative judgement, metacognition, and learning

1 INTRODUCTION

Product-Service Systems (PSS) are systems in which products and services are designed in unison, reinforcing each other, putting emphasis on the whole and how they work together rather than being designed separately. But putting emphasis on its integral nature, PSS design requires a structured process with a broader scope in mind. Tools and methods to support PSS design exist in different formats. However, there is a big difference in having the right tools, having the competences to act on them and being able to question the overall approach independently [1, 2].

In a learning context, students are taught the 'PSS Design Toolkit' [3] which provides an opportunity to create innovative interactions between consumers, the products and services they use, and the providers offering them. In cognitive terms, learners require to make links and translate between different levels and aspects of product development, to account for all interacting product aspects. This, while at the same time never losing sight of the 'big picture'. This requires advanced analytical thinking (understanding every small part of a product or service), and synthetic competencies (how the parts lead to an innovative design), and metacognitive awareness (why a combination of subparts leads to a better service, while another combination doesn't), e.g., Puryear (2015).

In contrast to traditional product design, the main challenge for student designers is coping with this increased complexity, i.e., a multitude of interacting variables. Additionally, they are required to manage a variety of underlying design processes, where early representation and communication are key for the design phase and enable a more successful strategic rollout of the PSS concept. With our toolkit, we posit that reiterative exploration is critical to support the designer's creative process, but are those processes alone helping students see 'the bigger picture'?

2 COMPARATIVE JUDGEMENT

A growing body of literature is finding support for the notion that comparative judgment can help learners and assessors in different learning and working situations [5, 6]. Comparative judgement (CJ) asks an assessor to compare two products and ranks one product over the other. These products can be both small scale – such as a short presentation, a paper, or a drawing; and large-scale such as a masters' thesis or a full fledge solution to a real-life solution to a problem. Doing multiple comparisons using multiple judges (students, teachers or external assessors), a measurement scale can be created using the Bradley-Terry-Luce model [7, 8] showing the relative quality of each product [9]. Furthermore, each product receives an ability score and detailed feedback.

A major strength of CJ, in terms of assessing difficult-to-specify constructs such as a product design process, is that the result is based on the collective expertise of the rater. Or, its validity is anchored in what is valued by the community of practice within a given discipline [10].

Studies indicate CJ can be beneficial in some cases during a learning process [11, 12]. Where rubrics, even those which specify performance levels and/or standards for each criteria, are often far too abstract for students to really grasp what 'quality' is for a given competence [13], CJ shows exemplars to students which is more relevant when it comes to understanding what quality is [14–16]. By analysing exemplars, students experience how high-quality products differ from average products [17]. Furthermore, by comparing products, learners are taught to think why product a is better than product b and learn to articulate why a product is better. This thinking process is often referred to as metacognition, whereby the learner attempts to understand all intricate aspects why a product is better than another one. When learners compare each other's products or services, both during and at the end of an educational process, learners are also comparing each other's analytical and synthetical thinking process, which can improve their metacognitive awareness of the product development process.

Compared to using rubrics, the comparative assessment is done in terms of holistic processes (Figure 1), whereby the whole is more than its aspects, or when it comes to designing with increased complexity, e.g., product-service systems (PSS), resulting in a more reliable grading for complex assignments [6, 18].

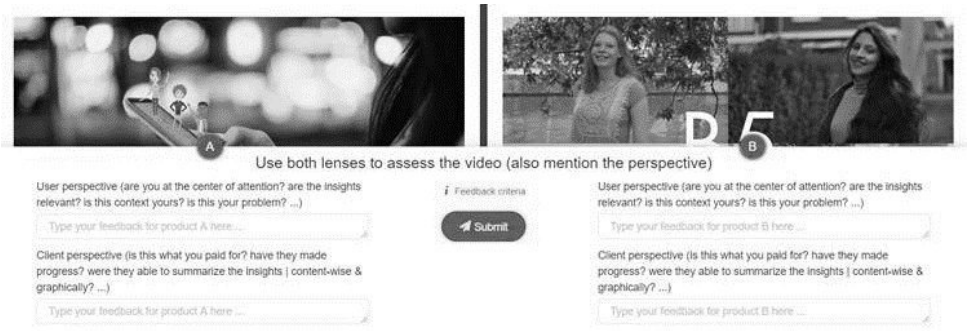

Figure 1. An example of a comparative judgment task where students choose either A or B as a better product and provide feedback based on certain criteria

Not all studies found all-round positive effects. Bartholomew et al. (2019) for example found that feedback given by students in a CJ setting was rather superficial and mainly aimed at the aesthetics of a certain design, and rarely in-depth. Other studies have indicated that not just any product can be compared. Comparisons with too much information, or which are too different, e.g., [19], do not lead to reliable results.

2.1 Research Question

Rubrics usually divide the product into small aspects, a presentation is subdivided into criteria on layout, on persuasive message, and so on, where each criterium receives a separate score. CJ, on the other hand, focusses on the entire product and compares the entire product as such into a holistic process [6, 18]. In the following paragraphs, we will detail the relevance of this holistic assessment in the context of product development education.

While previous research has found both a myriad of positive and negative educational effects using CJ, our study aims at understanding how students perceive CJ during such a PSS design process. Do students feel CJ is a valuable tool? Do students feel it has improved their metacognitive thinking? And finally, what are perceived strengths and weaknesses by students when using CJ during a learning process and for the final assessment.

3 RESEARCH METHOD

3.1 Educational setting

Seventy-two master students in product development were placed into groups of four. Most students did not have experience with the PSS design toolkit in the design course and do not have experience with designing PSS. The program curriculum and this particular course was until very recently taught in Flemish, which limits our student population to those from Belgium, the Netherlands, and still a limited number of European students (Erasmus mobility). Gender is approx. equally divided.

This population participates in the design course entitled 'IPO Project: Integrated Systems'. To achieve the objectives for this twelve-week design course, student teams are expected to generate user insights, explore new opportunities, and then define and design a relevant Product-Service System (PSS) concept for a given context, such as 'milestones in life', 'physical and digital traces', 'tackling obesity', 'smart city sharing', 'Quadruple Helix' and specifically this years' topic 'Future Urban Health'.

During the course we used a CJ tool, Comproved, to allow students to give feedback and rank each other's weekly presentation, mid-term, and final presentations. This presentation was a short, personalized visualization of their project (ranging from two to ten minutes), which allowed for a comparison between the different student teams, their design process and progress. In the middle and at the end of the design course, a jury was held evaluating the projects. The evaluative role of CJ in here was both formative (weekly and mid-term presentations) and summative (for the final presentation).

3.2 Participants and Instruments

We used a mixed method methodology to broadly understand how CJ has impacted the students' learning process. We asked participating students to provide a reflection of half a page (max.) on the general educational experience. About all of the students (n=72) sent in the information. An additional survey was sent, asking broad and specific questions on educational quality (n=18) [20], to have a more detailed insight into the educational experiences using CJ. To avoid bias, we did not ask specifically about Comproved in either the reflective questions or the survey.

4 RESULTS AND DISCUSSION

4.1 Qualitative analysis

Two raters independently categorized results of the open questions into 3 broad categories: strengths, mixed/neutral experiences, and weaknesses of CJ. Afterward, ratings that did not have a consensus were discussed and recategorized. We found 12 remarks that related to the strengths, 9 remarks that were categorized as neutral/mixed and 4 remarks that were perceived as weaknesses. In this paper we will focus on the positive (strengths) and negative (weaknesses) educational effects as indicated by the students using CJ.

4.1.1 Strengths of comparative judgement

Students understand that serious evaluation of these products is important. The CJ software was nice to work with and to receive feedback. Especially the videos via the software worked very well, students often got good feedback from them. They experienced it as interesting to give feedback like this and stated: *"If we had given a live presentation in an auditorium for the mid-term, we would not have received as much feedback as now*". Overall, the students are interested to follow the processes of the other groups, making it fun and informative to see what others are working on and how they approach things. CJ indirectly supports the process and delivers overall better presentation quality of the students' products: *"I found it very instructive to make a video to show our progress as a group, because we learned to present better (a) but this was also the ideal moment to critically review our work (b) while making the video". "Making the short interim progress videos helped to motivate us (a) and to prepare us for creating the final video(s) (b), and the other videos were also inspiring for our own work (c)".*

"The videos seemed to me to be more work than a regular morning presentation of the project, but like this we learned to work better with première pro, resulting in a new skill for the portfolio". The CJ software provides a dashboard with all the other products so you can explore them on a later occasion. Therefore, CJ proved useful for groups who want to see the progress of other groups (a), and to get their own progress and presentation skills assessed (b). Furthermore, the CJ software offers the ability to open up the rankings so that both place (quality rating) and feedback on other work is available and that this is perceived as a great learning opportunity (Figure 2).

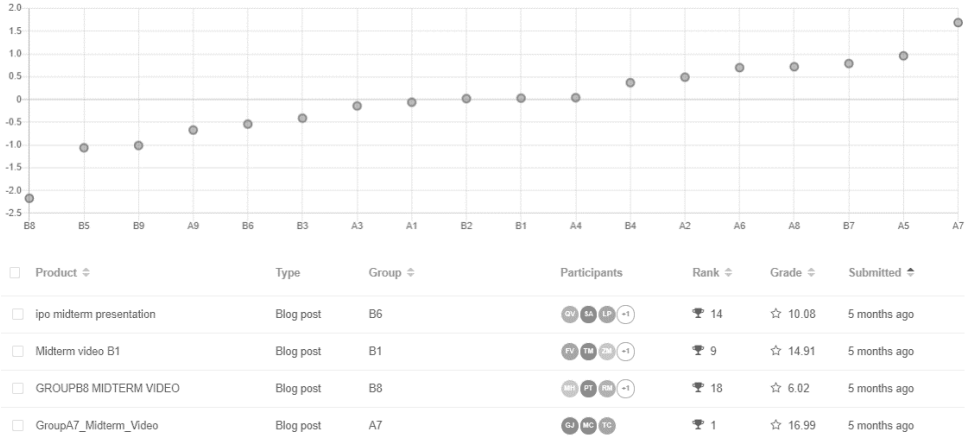

Figure 2. The comparative judgment software allows students to view and compare their rank (grade when selected by the teachers) and feedback with other work

4.1.2 Weaknesses of comparative judgement

For interim products, student preferences go to the small-scale short presentation, a paper, or a drawing. When it comes to the large-scale products – describing full fledge solutions to a real-life problem (PSS design) – students prefer to compare and assess fewer products, people would watch it more carefully, focus better and give better feedback. From a certain length, it felt like only a part of the video (product) was viewed each time, resulting in negative reactions from people who did not understand, or gave comments that were totally irrelevant, not useful, or at least much less than the students (receiving the feedback) expected. Consequently, we have to be more precise on communicating the assessment criteria and goal of the assessment itself: *"Rating is so black and white, sometimes the idea of product a was better than product b, but the product (video) was worse. It felt like comparing apples with pears"*. Students also perceived a certain difficulty with the overview of comments, there is no hierarchy or difference when stating the feedback on the product being from professors or students. This resulted in not knowing what was good and what certainly was not good (enough) in terms of prioritization and being able to proceed. This forced us to talk the feedback over in the consecutive group consult, making space for a discussion between student and teacher, in order to summarize CJ feedback and emphasizing priorities opposed to confusing or irrelevant comments. Finally, we have to take into account, that CJ products should always be uploaded earlier (putting more pressure on the deadline), and making a video takes much more time than e.g., preparing a presentation.

5 CONCLUSIONS

This article describes how master's students of Product Development can assess each other, the progress during the design, and the final 'product' using CJ. The results show that the students perceived CJ to be helpful during and at the end of the design process. Furthermore, we describe a crossover between CJ and PSS design learning objectives:

- CJ motivates students to envision early stage conceptualizations and representations of the design (process), as such new prospects are opened up, envisioning possibilities and next steps.
- A continuous comparison of interim 'products' supports student designers to explicit their doing, making, and inventing, enabling communication with others and provide a better understanding of

the design process, which otherwise would remain largely tacit knowledge (even for the designer).

- CJ allows streamlining of the design process, makes it consistently comprehensible and provides a benchmark between peers. Specifically for PSS design, designers should be apt to deal with communicating its complexity and achieve simplification with the right representation.
- Unless provided, a set of alternative solutions - to compare with - is usually not a given. CJ allows comparisons between designs in terms of better and worse, but also in judgement of best.

This article has tested the CJ tool in the context of a complex (i.e., real-life) PSS design assignment. Besides the measurement concerning students' face validity with the instrument, the presented results of the CJ software show stability and reliability in two ways:

1. *Power in numbers*: 6 times 24 users (weekly basis) (n=144) and in the middle of that 1 time 72 users for the formative use of CJ, and in the end, again data from 72 users for the summative use of CJ provides significant reassurance that the results we have presented are meaningful.
2. *Reliable scaling*: To compare the same products by multiple raters results in a more objective assessment of the products compared to more subjective grading using rubrics (criteria and interval scoring) of design products by their professors. This, because comparing is a more natural way of assessing [21] in which people tend to be better than in making absolute judgements [22].

We have also corroborated the CJ results together with a rubrics evaluation in order to create a more detailed and nuanced picture of the results. As such, CJ results help frame a more cohesive story for the support in peer-assessor evaluation and student engagement in that process.

When initiating this course, the design process, its progress, and intermediate presentations would normally take place on campus. However – due to COVID-19 – the educational program passed rather quickly into in 'code red', forcing us to completely rethink our remote approach. At that time, Comproved was being integrated in the digital learning platform of the University, ready to be pioneered. Rather by forced coincidence, this CJ software showed great strength as an online substitute to the formative and summative evaluation. It proved to be a direct addition and support to the design process and its progression, something that we will definitely hold on to in post-COVID teaching times.

6 FUTURE RESEARCH

While CJ has proven to adding to the understanding of evaluation as part of students' active education in this one course, we would still like to see how CJ supports the creative work and critical reflection of students graduating and becoming design professionals. Furthermore, there is a difference between student usage of CJ and its effects on the assessor evaluation of a design course in an educational setting. Therefore, our avenues for future research will gear toward usage of CJ to assist in a more objective and reliable evaluation, and see this research extended by design academics evaluating their more complex design courses at other educational institutions (using Comproved or similar CJ software).

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DIVERSITY IN DESIGN: ADDRESSING THE BLACK AWARDING GAP

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ABSTRACT
Recent international events have focused attention on the issues of systemic racism and colonialism within institutions, and a spotlight has been shone on UK universities' attempts to evolve in creating secure and inclusive futures in the face of societal change. While access to University education for Black students has improved significantly in the UK over the past decade, there remains a major discrepancy in success rates at degree level. Students with an African or Caribbean heritage are considerably less likely to obtain good honours (first or 2:1) in their degree classification than any other ethnic group and are also less likely to maintain their course through to completion. While differences in entry qualifications may play a part, the larger part of this awarding and retention gap must be due to other factors.
Drawing on an overview of the initiatives currently being proposed by the UK's top creative universities to tackle the awarding gap, this paper uses interviews with past and present Black students from art and design courses at Arts University Bournemouth (AUB) and Bournemouth University (BU) to explore a range of issues - including economic and cultural barriers, institutional bias, educational content, communication issues, and direct and indirect racism. Some of the proposed initiatives for tackling the problem are also discussed, and while the responses highlight the underlying complexity which is causing the slow progress in closing the awarding gap for Black students in higher education, the desire to be better understood and supported as individuals by lecturers and peers, with greater opportunity for open and frank dialogue, was paramount.

Keywords: Black, BAME, attainment, diversity, awarding gap

1 INTRODUCTION

During 2020 international events focused attention on the issues of systemic racism and colonialism in the UK and across the world. The deaths of Breonna Taylor and George Floyd at the hands of US police officers, followed by global protests and the eruption of the Black Lives Matter movement sent shockwaves through every sector of society, including education. Universities play a pivotal role in responding to societal change and creating a secure and inclusive future for the design industry. While most UK universities have recognized the issues surrounding Black, Asian and Minority Ethnic (BAME) student retention and attainment for many years and have facilitated a range of initiatives to combat these problems, 2020 has seen more widespread scrutiny and greater urgency in HE's efforts to address its treatment of Black students and staff [1].
Over the past decade access to University education for Black ethnic groups has improved significantly in the UK. According to the admissions service UCAS, in England the proportion of Black 18-year-olds entering higher education rose from 28% in 2010 to 45% in 2019. This represents the biggest increase of any ethnic group, and the entry rate is now well above the national average rate of 35%. In 2019 English undergraduate courses welcomed almost 51,000 Black students [2].
However, there remains a very significant discrepancy in success rates at degree level for students with a Black heritage. Figures from the UK independent regulator Office for Students (OfS) indicate that Black students are around 10% less likely than any other ethnic group to be awarded a first or upper second classification, as former Education Secretary Damien Hinds acknowledged in 2020:

> *What we were absolutely aware of was this gap in attainment at firsts and 2:1s. The Office for Students is focused on this, trying to identify what the blockage is.* [3]

Part of this discrepancy can be statistically explained by differences in age and entry qualifications: Black Caribbean students in particular are, on average, older when entering Higher Education (HE), and are more likely to have progressed via college or vocational qualifications [4]. However, the OfS estimates that there still remains an 'unexplained' gap of 17 percentage points between Black and White graduates, based on 2016/17 figures [5]. In addition, the OfS also reports that Black students are more likely than any other ethnic group to withdraw early from Higher Education, with a non-continuation rate of 15.0%. This compares to a figure of 8.7% for White students [6]. Although Connor et al. [4] argues that that this discrepancy reduces considerably once a number of key factors are taken into account – such as age, subject, entry qualifications and gender – the issue still remains and has steadily worsened since 2010.

2 THE SCOPE OF THIS PAPER

From their personal experience teaching at Bournemouth University (BU) and Arts University Bournemouth (AUB), and from previous research looking at BAME issues in design education, the authors had been aware that progress on reducing the awarding gap had been limited, despite awareness of this issue for many years. In order to try and gain further insight into this, the authors conducted a review of the latest measures and initiatives put in place by a number of universities that were specifically targeted at reducing the Black awarding gap. This was followed by discussions with several Black alumni of BU and AUB to ask them about some of the issues they faced while at university, and to try and gain their views on the validity of the planned approaches.

While most universities refer to this issue as the 'attainment gap', the authors have chosen to use the phrase 'awarding gap'. This is in line with UCL's BAME Awarding Gap Project, which rejects the term attainment as 'it implies that the responsibility of inequality in attainment lies with the student's themselves' [7].

3 DETERMINING THE TOPICS FOR DISCUSSION

In deciding which universities to look at with regard to initiatives, the authors were keen to focus on institutions with a strong design profile. For that reason, the top twenty universities in the 2020 Guardian university league table for design and crafts were targeted. Any measures targeted at the Black or BAME awarding gap appearing in university Access and Participation Plans and publicly available Diversity and Inclusion documentation was recorded. In addition, wherever an institution declared a link to any resources such as the UCL Toolkit, the UUK/NUS #Closing the Gap Report, or the PReSS Project, measures contained within these initiatives was also noted. A total of 70 distinct measures were listed, and these were grouped into 16 broad areas. A bar chart was created to show how many universities included at least one of the measures contained within each one of these areas (Figure 1).

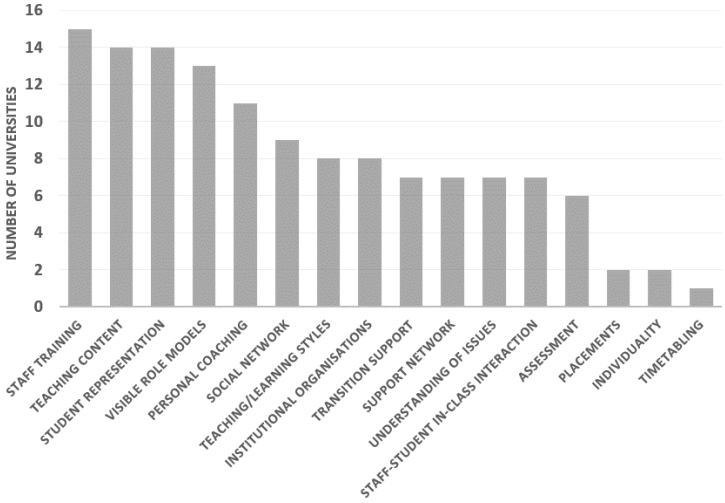

Figure 1. Frequency of areas mentioned

3.1 Other issues

While it is commonly agreed that the reasons behind reduced Black success rates are many and varied, the research conducted by Connor et al. for the UK Government [3] pinpointed the most frequently reported issues that BAME students felt had affected their academic performance as:

- financial difficulties
- problems with balancing part-time work and study
- problems with facilities and getting support from staff

The research also reported that Black African students were the most likely ethnic group to experience problems that they felt had affected their academic results, and suggested that the following issues are likely to also have an effect on BAME student outcomes:

- difficulties in adjusting to life within a group with different social backgrounds
- issues with establishing relationships and getting support from tutors (Black students specifically)
- lack of confidence
- difficulties in transition between school and HE

While it can be argued that the focus of this research places the onus on the students themselves, rather than on any deficiencies in the content or culture of the teaching establishments, it is interesting to note that many of the issues described above were not strongly addressed by the university initiatives. The authors therefore felt that it would be useful to discuss these issues with the participants.

It was also noted that all of the universities consistently use the terms BAME or BME within their initiatives, despite the fact that in at least two cases the local Student Unions professed misgivings about the use of the terms. The Secretary of State for Health and Social Care Matt Hancock drew criticism from many quarters in 2020 by answering a question on the lack of Black representation in the UK Government by referencing the two 'Black and ethnic minority' members of the UK cabinet – both of whom are of South Asian heritage – and the 'lazy homogenisation of all non-white groups' [8] has become increasingly under fire, particularly amongst some Black groups. It was therefore decided that questions on terminology would be included.

4 THE RESPONSES

The authors contacted 11 Black alumni in total, of whom six agreed to participate in the research; this comprised of five product design graduates from BU and one fine art graduate from AUB. The years of study covered 2009 to 2020 and ages ranged from 24 to 30. Five of the participants were female – four with a Black African background, one with a Black Caribbean background – and the one male participant had a Black African background.

Prior to the discussions, a questionnaire was distributed to collect some background information. This determined that almost all of the participants had a term-time job while studying at university, including during the final year, and this could be for up to 24 hours per week. While most of the participants had not experienced direct racial abuse while at university, half felt that they had experienced indirect racism and that they had felt disadvantaged because of their ethnicity, including one who felt that their university studies had been severely impacted by indirect racism.

4.1 The discussions

Once the results of the questionnaire had been collected, two interviews and one focus group discussion were held via Zoom due to Coronavirus restrictions. Both authors attended all of the discussions, and while it must be admitted that the involvement of teaching staff known to the participants may have limited direct criticism, the contributors agreed that they would be honest and frank in their views, and no reticence was detected by the authors.

The resulting discussions have been collated and grouped by subject area to summarise findings.

4.1.1 Terminology and ethnic grouping

All of the participants saw the terms BAME and BME as largely positive, although there was misunderstanding from at least one person as to what the acronym stands for. The general view was that it was being used to bring positive focus to groups of people who had been overlooked. However, two participants did express some reservations, with one feeling that it could lead to deceptive data, and the other feeling that it was restricting focus on distinct backgrounds:

'People use that category to solve everything…they don't really differentiate. Black peoples' culture is different to Asian culture. I do want there to be more material based on differences'

Two participants also highlighted problems with combining all Black students under one banner, drawing attention to the differences between African and Caribbean cultures, and within Africa itself. Both acknowledged withdrawing from the university Black Afro-Caribbean Societies because of too much focus on a culture they did not share, and a third participant also questioned the validity of generalised, Black-focused societies:

'Just because we're Black doesn't mean we have to talk about certain things. They will be like, oh, let's talk about this food or this subject, just because we're Black. And it's like, why do we have to have a Black people's society. There's no White Society – because that would just be racist, right? So, I was like, I don't have to join in this society just because I'm Black.'

4.1.2 Career paths and role models

Professional design role models did not play any part in our participants' initial desire to follow a creative path, and they were driven instead by an innate desire to be creative. One participant spoke of the lack of visibility of design as a career choice while growing up:

'In Nigeria, the creative is an architect. I told my parents…that I wanted to be a designer, to which my dad said, "What the hell is that?" – as I knew he would say.'

The lack of creative role models – both while growing up and in university teaching materials – did not appear to generate much concern. Some participants said that they had not really been aware of it, while others had registered the lack of Black content but found it understandable 'because maybe there is not that much out there.' Only one participant said that they found the teaching content slightly lacking in cultural variation: 'I had to kind of work a little bit to find artists.'

One participant had attempted to become a role model to two younger Black design students while at university and had been successful in convincing one not to drop out of their course. None of our participants had been exposed to visits from Black alumni while at university, and it was acknowledged that this would have been helpful.

4.1.3 Student representation and the conversation about race

Black representation at every committee level in university was considered as a positive step, with one participant questioning the validity of a representative speaking about a subject that they have not experienced. One participant became a senior student union representative as a direct result of their negative experiences as a student: 'I just wanted to turn my sour experience into something good.'

Likewise, all of our participants were enthusiastic about encouraging open conversation about racial issues - though it must be acknowledged that they would have been unlikely to have agreed to take part in this research otherwise – and it was noted that this type of frank conversation is stifled in a higher education environment, with both staff and students loath to open up:

'There is that feeling of holding back because of not seeing people that look like you, so therefore you may feel like they may not understand.'

4.1.4 Support networks and relationships with lecturers

Most of the participants had accessed some form of support while at university, for a variety of reasons ranging from financial to psychological. Most spoke of the difficulties of being away from the traditional family support network, the struggle to find an alternative form of support and the stigma of seeking professional help. The idea of specialist Black advisers was briefly discussed, with reference to the BAME mental health services currently being offered at Bristol University [9] and this was felt to be positive in the context of offering choice. All of our participants professed to having a strong Christian faith, and this was often cited as being a strong source of support.

The general feeling was that university support, when sought, had been positive and useful, and that differences in skin colour had caused no issues. However, one participant spoke at length of how seeking

advice from one lecturer had soured their relationship with the teaching staff and their peers for the remainder of their course, when the lecturer mentioned the issue openly in class:

> *'It could have come from a good place; however, that wasn't the environment for it, when it was asked in front of other students that I wasn't even friends with but were in the same year, them having to know something that I was deeply struggling with. It sort of robbed a relationship that could have been.'*

As a result, the participant – who had previously been a 'social butterfly' – suffered withdrawal, difficulties in forming friendships and confidence issues 'which was something that was never really a feeling of mine until I was put into a space of being a minority.' This also led to a growing estrangement from the teaching staff:

> *A lot of lecturers didn't even try with me… I'll see them move to a white student – they'll be laughing and stuff like that… I felt for one second there was something up with me. And now looking back… I regret not saying anything.'*

Several participants discussed 'microaggressions' perpetrated by staff. Two examples related to ignorance about the complexities of Black hairstyling, and another stemmed from an assumption that a Malawi student was from Kenya. While these memories were often relayed in a humorous way during the focus groups, they clearly made a lasting negative impression:

> *'That lack of understanding – although to them it may be humour – it was quite offensive, and it was an ongoing thing.'*

> *'You don't have to go that extra mile if you don't fully know where this person is from, or you don't really fully know the cultural context. We are all students, we all need to keep on learning, even as a tutor. I would appreciate that even more.'*

The proposal of a 'toolkit' to help staff communicate better with students was felt to be a positive idea.

4.1.5 Group work and assessments

The participants had all experienced a fair degree of group work while at university and there was a mixed response as to whether there was any disadvantage felt being the only Black member. One participant in particular spoke of their first experience of group work being a defining moment:

> *'I really struggled and that's when I start realising, "ok, there is a clear difference here", whereas before I never saw a difference with colour.'*

This experience led to the participant realising that they felt naturally more comfortable in a group with other Black students, despite making a special effort to try and fit in with white peers, 'and I could never really figure out why that was.'

The issue of anonymised marking was also raised, but it was felt that this would be detrimental in a creative environment, and that teaching staff should take into account how hard students have worked and 'have a little bit of bias.'

5 COMPLEX ISSUES = VERY SLOW PROGRESS

The authors' review of university initiatives to reduce the Black awarding gap led to more questions than answers, especially in the context of creative degrees. Anonymised marking, for example, is problematic due to the continuously assessed studio-based nature of creative course work, and there was little support for this from our interviewees. Student engagement with projects focused on addressing barriers to student success is generally good but students are rarely included in policy making and programme development at a high enough level to represent a broad enough voice of those underrepresented in HE. In addition, awarding gap-focused projects are generally underfunded and represent a very small part of services provided by universities. To bring successful change, efforts to close the gap need to be an integral element across all aspects of university life and need to be bought-into by senior management [10]. Outputs are hard to quantify as data collection is not streamlined and often related to central university reporting. However, it is alarming that the issues discussed at great

length in the early 2000s by Connor et al. for the UK Government [4] show no sign of improvement nationally. Where progress is being made – such as at Kingston University – it is through relatively simple measures such as student and alumni mentorship and giving academics time to engage with students on a more individual basis [10]. Measures such as these are in direct opposition to the increase in the student-to-staff ratio experienced nationally by UK universities over the last decade [11]. Large student numbers make individual relationship development and student-centred teaching increasingly difficult for staff. Unconscious bias could also easily present as a problem in these large cohort environments as a Black student tutored on a more individual basis than their white peers' challenges parity across the course.

The small student sample interviewed for this paper highlighted how individual each student scenario is and that categorising students under the umbrella terms of BAME or Black, while a positive start, fails to reflect the nuanced approach that is needed. Each story shared was very different, affected by family, culture, community, and different levels of financial hardship. Those with international backgrounds particularly struggled to find their place amongst their peers, consequently leading to isolation, mental health issues and drop in performance. What all the participants had in common was the desire to be better understood and supported by their lecturers and peers, and to discuss the issue openly:

> *'Just having the conversation in itself is actually really, really great because I feel like a lot of Black students have really suffered in silence.'*

To create truly secure and inclusive futures the black attainment gap needs to urgently become a thing of the past.

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USING PRODUCT DESIGN METHODOLOGY IN TEACHING ON PUBLIC HEALTH AND LIFE

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ABSTRACT
This master study is a pilot research project on mental health and communication. In 2020 the interdisciplinary project 'Public health and life skills' was introduced as part of Norway's new national curriculum for primary and lower secondary education. The interdisciplinary project lacks diversity in its teaching methods. This pilot research project examines how design methodology can contribute to the development of a teaching method. The goal is to teach students to express their inner life, that is, the human mind. Through a method inspired by grounded theory, the project explores the assumption that a visual language for the inner life can prevent mental health problems. Arts and crafts is proposed as a subject where this visual language can be learned, as the curriculum renewal emphasises the value of creative work. The purpose of the method is not to be therapeutic in a professional sense, but rather to have preventive and health-promoting effects by teaching students to speak out and recognise how they feel. This approach should be further investigated in practice amongst teachers and then among students in a classroom situation. The pilot research project indicates that design methodology can have essential value in the development of a teaching programme in public health and life skills.

Keywords: Public health, professional renewal, mental health, creativity

1 INTRODUCTION: EDUCATIONAL TOOLS FOR PUBLIC HEALTH

In the autumn of 2020, the new curriculum for primary and lower secondary education in Norway was introduced. The purpose is to give students future-oriented in-depth learning [1]. One of the overarching themes in the curriculum is public health and life skills and is intended to have a preventive effect and to promote good mental and physical health [2]. A study from 2019 shows that such competence is in demand among both students and teachers. Students especially demand knowledge about how to cope with stress and adversity in life, while teachers seek knowledge about how these skills should be taught [3]. No specific guidelines or tools for teaching public health and life skills currently exist, other than the subjects in which it should be included. Among other things, social studies should make students aware of their own identity and 'offer perspectives on what a good life can be' [4].

2 BACKGROUNDS: POOR MENTAL HEALTH IS EXPENSIVE

Preventive work in mental health is valuable, as mental disorders are the most expensive disease group in Norway. Common disorders such as depression and anxiety cost more than severe disorders such as bipolar disorder and schizophrenia. This is because they lead to the loss of working days and because treatment has a relatively small effect in the long term. Prevention rather than treatment is the best solution, both economically and socially [5]. Research shows that the effect of teaching about mental health in school is only short term. On the other hand, there is evidence that such teaching can reduce the likelihood of recurring severe illness. In addition, it can create a lower threshold for seeking help early [7]. Based on the pilot research project, the following research question was formulated: *How can design methods contribute to developing a teaching method for the interdisciplinary project 'Public health and life skills' in primary and lower secondary education in Norway, with the goal of teaching children and young people to express their inner life?* The issue was highlighted during the data collection. By inner life is meant the human mind and the unconscious and conscious. The project's goal was thus to come up with a preventive and health-promoting method that can be used for teaching the topic of public health and life skills in primary and lower secondary education. The solution had to focus on unity and community in a classroom situation. The aim of the pilot research project was to investigate what preventive work entails because the background information showed that this is very important in

mental health. The method should therefore not have a therapeutic approach. The method was to be created by investigating whether creative expressions could stimulate conversations about the inner life. This is because the curriculum renewal emphasises the value of creative work [2].

3 METHODS: A QUALITATIVE APPROACH

The pilot project used a qualitative research method, inspired by grounded theory. This is a relevant method in this study because few or no design theories currently exist on preventive methods in mental health in Norwegian schools [8]. Data collection on topics related to public health and life skills will form the basis for a theory. An account will be given of curriculum renewal to provide a framework in which the development of the theory is established. A comparison of contradictory views on public health and life skills will then be presented, based on two booklets: *Livsmestring på timeplanen. Rett medisin for elevene?* [Life skills on the timetable: The right medicine for students?] written by philosopher and psychologist Ole Jacob Madsen and *Folkehelse og livsmestring i skolen* [Public health and life skills in school] written by Karen Ringereide and Siri Landstad Thorkildsen, respectively special adviser and communications manager at the Regional Resource Centre on Violence, Traumatic Stress and Suicide Prevention Region South (RVTS South). This reveals the positive and negative aspects of public health and life skills, as well as the value of prevention. An in-depth interview with Terese Grøm, secretary general of LEVE (Norwegian Organisation for Suicide Survivors) will provide insight into what preventive work must entail. Selected examples will be given of teaching programmes on mental health and life skills that work, followed by an account of the value of pictorial communication. After an analysis, a possible approach is presented, including essential concepts.

4 DATA COLLECTION

4.1 The curriculum renewal

The purpose of learning in the curriculum renewal is, among other things: *The pupils and apprentices must develop knowledge, skills and attitudes in order to be able to master their lives and to be able to participate in working life and society.* The values in the objectives clause of the Education Act form the basis for the school's practice. *Human dignity* focuses on the value and equality of the individual. *Identity and cultural diversity* emphasise students' identity and belonging, as well as language. *Critical thinking and ethical awareness* should give students good judgment, and emphasise, among other things, artistic work as a good method. *Creativity, engagement and inquisitiveness* emphasise that the school should emphasise different ways of exploring and creating, including through 'sensing, and thinking, aesthetic forms of expression and practical activities. The value of artistic and cultural expression for the individual's personal development is also highlighted. Respect for nature and environmental awareness aim to make students climate conscious and environmentally conscious, while democracy and participation should teach them democracy in practice. The latter focuses on the value of being heard. An important principle in the curriculum renewal is social learning and development. This means the value of dialogue, and that students should be able to communicate their thoughts and feelings with each other. The new curriculum introduces three interdisciplinary themes based on current societal challenges: public health and life skills, democracy and citizenship, and sustainable development. The theme of public health and life skills is introduced to provide students with knowledge about physical and mental health. Life skills is defined as 'the ability to understand and to influence factors that are important for mastering one's own life'. The teaching should equip the students to cope with success and adversity and among other things, to handle thoughts, feelings and relationships [2]. Life skills are included in most subjects through topics such as sexuality, personal finance, drugs and literature [2]. No specific tools are proposed for how this should be implemented in practice. In the Norwegian subject curriculum, literature is proposed [9], and in the mathematics curriculum, personal economics is proposed [10]. No specific themes are proposed in the subject curricula for arts and crafts and music, but creative expression is highlighted as an important element [11].

4.2 Contradictions

There are few moderate voices in the debate on public health and life skills. Ole Jacob Madsen on the one hand, and Karen Ringereide and Siri Landstad Thorkildsen on the other. Ringereide and Landstad Thorkildsen believe that public health and life skills can create a more relevant school and prepare students for life after school. According to them, life skills align with the OECD's statement on the

school of the future. They focus on the fact that happiness and joy can lead to life skills. At the same time, they promote the tradition of the Norwegian school as a preventive arena, with examples of traffic safety and dental health. They emphasise the principle that prevention measures should apply to everyone, not just to those in risk groups or with diagnoses [12]. Madsen, on the other hand, fears that life skills can create further social differences from which only the resourceful will benefit. Deprived students are described as students who experience serious problems with difficult family circumstances, substance abuse, bullying, abuse and the like. Madsen claims that these benefit more from treatment for mental health care issues [6]. He believes prevention is the wrong move, based on the research of Katherine Frohlich and Louise Potvin, researchers in preventive and social medicine at the University of Montreal. They point to general prevention as problematic because deprived people in society benefit less from such measures than those with more resources, and thus inequalities are created. Preventive work should rather be aimed at weaker groups in society [6]. Ringereide and Landstad Thorkildsen base their views on prevention on the work of Arne Holte, professor of health psychology [12]. Holte is inspired by the British epidemiologist Geoffrey Rose (1926–1993), who argued that general prevention is the right measure if the risk of disease is widespread [6]. Madsen believes that life skills can lead to students over diagnosing themselves because they know more about mental health. He refers to medical doctor Bruce Charlton, who warns that prevention can make a population sick [6]. Ringereide and Landstad Thorkildsen further argue for preventive measures with the American study *Adverse Childhood Experiences*, one of the largest studies on how a life can be affected by negative experiences in early childhood. The study points to risk factors that can have ripple effects in life despite a good innate potential. Ringereide and Landstad Thorkildsen believe that the school and the teacher can have a good preventive effect on these. They further criticise the educator Gert Biesta's view of what the school's tasks are, namely qualification, socialisation and subjectification. This involves knowledge to be able to participate in society, such as through work, the ability to function in society, and the ability to be oneself in interaction with others. To achieve this, students' most important needs must be met, according to the Australian psychologist Howard Bath, whose research deals with children exposed to trauma, but Ringereide and Landstad Thorkildsen believe it is transferable to the Norwegian school system. The needs are 'good relationships and help to regulate emotions, impulses and behaviour'. These are based on what are referred to as the three pillars: security, relationship and emotion regulation. Madsen is critical of such an individual focus and its ability to take responsibility for mastering his own life. 'Psychologization' of society is highlighted as the reason for the introduction of life skills. He refers to the transition of the Western world from collective societies to today's individual societies, with reference to the book *The New Individualism: The Emotional Costs of Globalization,* written by sociologists Anthony Elliott and Charles Lemert. Life has become an individual project, where individuals must create their own context. Furthermore, Madsen refers to the economist Robert Crawford, who in 1980 introduced the term 'healthism'. This was an image of a tendency to place health, illness and solutions in individual-based categories. Madsen also believes that self-regulation – the ability to control oneself – is unfortunate. Around 45 per cent of young girls consider school to be the biggest cause of stress and pressure. He therefore believes that the school is 'acquitted' by introducing life skills. At the same time, it is emphasised that young people are exposed to what is referred to as future discipline earlier than before. He suggests that the pressure must be reduced, and that the environment must be patient with young people trying to find their place in life [6].

4.3 Examples of teaching programmes on mental health and life skills

There are some examples of teaching programmes related to public health and life skills. RVTS South has created LINK – *Livsmestring i norske klasserom* [Life skills in Norwegian classrooms], a nationwide teaching programme in preventive mental health care. The programme involves students learning from each other through joint reflection and exchange of experiences on topics such as emotions, self-image and violence. The teacher is only supposed to facilitate discussions among the students [13]. As part of the so-called *Trondheim project* (2017–2018), selected secondary school students had mental health and life skills on the timetable throughout the school year, and were taught by a psychiatric nurse. The project showed that the students especially enjoyed learning about thoughts and feelings [14]. However, the occurrence of mental illness among students increased afterwards, possibly due to students' increased awareness of their own mental health. The reason may be greater attention to signs of this in oneself [15]. Klomsten and Uthus believe that public health and life skills must not deal with mental health [14]. Malin Kathrine Vik designed a resource booklet for the curriculum renewal in connection

with her master's thesis in aesthetic subjects within drama and theatre communication in 2020. The booklet provides an introduction to how drama can be used to teach life skills. The booklet has been well received, and several teachers and professors in pedagogical studies have bought it [16].

4.4 Images as a tool in communication

During the Arts and Crafts Conference in 2013, Liv Klakegg Dahlin gave a lecture on arts and crafts and social media. Dahlin is head of studies and associate professor in the Department of Art, Design and Drama at the Faculty of Technology, Art and Design, Oslo Metropolitan University. In the lecture, Dahlin talks about the development of forms of communication. Before Johann Gutenberg's printing press, people read pictures as symbols and metaphors. They could not read plain text, unlike today where we can no longer read pictures. Going forward, it seems that images will again play an important role in our communication. This is due to our use of digital media, where images and symbols are central. Dahlin emphasises visuals as an important language, and the arts and crafts subject is based on much of this kind of knowledge. She argues that young people should create their own symbols to communicate. Visual means can explain complex things and enable us to understand the world we live in [17].

4.5 Interview

Terese Grøm is secretary general of LEVE (National Association for Survivors of Suicide). LEVE works on suicide prevention and has been involved in developing the Norwegian Government's zero vision for suicide in Norway, which was presented in the autumn of 2020. The organisation is pleased that mental health and life skills are highlighted and discussed. Grøm emphasises the importance of changing the causes of stress and problems among young people rather than just finding a tool. She believes that part of the reason for young people's poor mental health is that society has moved from being a collective society to an individualistic one. One solution may be to cultivate the collective aspect of society. Grøm refers to the book *Nature and Madness* by Paul Shepard, which deals with the value and importance of having a biocentric perspective rather than an anthropocentric perspective. That is, nature is at the centre rather than man. The book discusses indigenous peoples' ways of building themselves up as human beings in harmony with nature, i.e., with their surroundings. Grøm links this to Aristotle's perspective of how as a human being one should treat and live with the environment. At the same time, Grøm points out the difference between the collective thinking of indigenous peoples and the Western world. Indigenous peoples are also characterised by the transfer of knowledge from their elders, which can include knowledge of life skills. Teachers must have learned to live as human beings in order to teach students about it. However, many teachers have not grown up in today's society, and therefore good training in teacher education must be provided. At the same time, society imposes even more responsibility on teachers. Teaching life skills can be developed on the basis of factors from the collective society and from the individualistic society. It should be about being human, that is, acknowledging that life goes up and down, and at the same time mature with it. The term 'life skills' is perhaps misleading, because it is really about anchoring and belonging, according to Grøm. As part of a preventive measure, life skills can offer students a language for articulating their inner life. It is important for individuals and their surroundings to be able to recognise when they experience life as difficult.

5 DISCUSSION A TEACHING METHOD FOR PUBLIC HEALTH

All data were categorised into themes using open coding. This was to make it easier to describe the topic in question [8]. The themes were: prevention, the individual, the community, communication, and pressure and stress. Furthermore, axial coding was used to define interaction between the different themes and subthemes. This provided some indications on which issues and topics the pilot research project should focus on. Mental health prevention is important for public health [5] and can take place in schools [12]. Madsen, for his part, believes that prevention through universal measures does not have sufficient effect [6], as research also shows [5]. Ringereide and Landstad Thorkildsen, however, claim that a combination of a universal and individual-based measure makes sense. They are concerned that coping with life should prevent mental health problems later in life [12]. One issue that arises, however, is whether teaching about mental health will lead to over diagnosing among students [6]. Deprived students are referred to as those who experience problems with difficult family circumstances, substance abuse, bullying, abuse and the like [6]. At the same time, it should be noted here that resourceful students also may experience the above-mentioned challenges. It can therefore be said that all students can

benefit from public health and life skills. The individualistic society is cited as the reason for introducing the theme [6], and the focus of the teaching should be a combination of community and the individual. This language can be a visual language, because it makes it easier to communicate complex themes. The arts and crafts subject can teach this [17], but the programme can also draw inspiration from other creative school subjects [16]. Life skills do not necessarily have to be about mental health, either [14]. According to Grøm, teachers must receive a good basic education in life skills and be able to act as facilitators of discussion rather than teachers of how to master life [12]. As is well known, teachers already have a great deal of responsibility. On the basis of the data collection, this pilot research project proposed how a teaching method for public health and life skills can be developed.

6 CONCLUSIONS

The data collection showed that the curriculum renewal's values highlight creative work, commitment and participation [2]. It is therefore reasonable that the focus on the development of a method should lie here. The method is that a visual language for the inner life can prevent mental health problems. This means that students from first grade in primary school learn how to express their feelings and thoughts through form. A visual language can explain abstract themes in a simpler way. The teaching takes place in arts and crafts [17]. The inner life can be experienced as abstract but concretised by means of form. Also, it can be easier to talk about oneself from a distance, and it can seem as if one is talking about form and not about oneself. As Grøm mentions in the interview, the fact that both the individual and the environment recognise how the individual feels is important in order to mature as human beings. The purpose of the method is to teach students to speak out and recognise how they feel. It is also about learning about and reading others and the value of community.

A preventive measure is one that reduces the likelihood of needing treatment later in life. Some examples of teaching methods have been tested, but the long-term effects have not materialised. They may indicate that public health and life skills must follow students throughout the school year. Creative subjects can be used, and a visual language can be the solution. This knowledge is relevant for practitioners, educators and students within product design and participatory design. Also, the pilot research project shows that this approach expands knowledge about what is valuable design competence in fields other than design, which may contribute to solving the societal issues we face today. This illustrates the relevance of design methodology in interdisciplinary research.

Using a ground theory approach, this study explored how a teaching method for the interdisciplinary topic of public health and life skills can be developed. It has implications for what the further process of development should entail. Furthermore, it is appropriate to examine the theory in practice. In the first instance, this should be done among teachers before being further explored in a classroom context.

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AN ETHICAL APPROACH TO THE IMPLEMENTATION OF BEHAVIOURAL SCIENCE IN THE DESIGN PROCESS

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ABSTRACT
This master's study touches upon the interdisciplinary potential in behavioural design in product design education. The design field is commonly known for focusing on solving the user's needs. However, behavioural design takes a different approach to understand the user by using new ways to analyse the user to solve their needs. Designers engage in devising courses of action to change existing situations into preferred ones. Through a systematic literature review on behavioural science that builds on theories and models rooted in psychology, sociology, and behavioural economics this study explores how designers can apply knowledge from behavioural science to the design process. The results show how designers can use theories and models from social psychology to enhance their abilities to understand their users on a deeper level. Account of how the mind makes decisions is a fundamental part of understanding behavioural science. Such information provided by behavioural models can assists designers in taking their solutions even further using cutting-edge research and information provided by behavioural models. This can promote new solutions by better understanding which behavioural change we want to achieve. However, insights into the behaviour of the user connects to a debate on the ethical implications this may have. The designer can affect behaviour at a certain scale. A key to preventing unethical design can be to utilise measurements and regulations methods, to prevent unintended outcomes.

Keywords: Behavioural design, behavioural science, ethics, social psychology, design process

1 INTRODUCTION

According to Peter Downton, design is a way of inquiring, a way of producing knowing and knowledge; this means it is a way of researching [1]. When it comes to professional practice, few designers receive formal training in research and therefore lack an understanding of what researching entails. Designers can develop as professionals with a broader and more in-depth understanding by incorporating proper scientific research into their practice. The design practice has developed further into cross-disciplinary research; this provides designers with the opportunity and motivation to explore research methods in order to complement their creative skills. Cross-disciplinary research utilises methods such as quantitative market research, personal interviews, experimental design analysis and qualitative research. This study will provide insight into how behavioural science can bring different disciplines together and enrich the designer with a broader understanding of the user [1]. Design is fundamental to solving the user's needs; according to Wendel [2], behavioural design provides a productive approach that encourages the designer to perceive the user as a solvable equation. This mindset allows the designer to further understand the user and his/her goals, which in turn provides data that can reveal details about essential design areas. Designers generally engage in devising courses of action to change existing situations into preferred ones in the design field [3]. This paper will attempt to address how behavioural design can lead to beneficial results by assessing different behavioural models and their underlying terminologies. The rationale for this study is to provide designers with the tools they need in order to help them gain insight into the user and generate successful approaches. This study has conducted research on behavioural science that builds on theories and models rooted in psychology, sociology, and behavioural economics [3]. Insight can be achieved by understanding the fundamental elements that encourage the behaviour. Elements such as habits, intentions, norms, situational influences, cues, motivation and ability are all elements that play a crucial role in how our brain makes unconscious as

well as conscious decisions [4, 2]. However, it is vital to assess the ethical implications that behaviour-changing design might carry. The research question is, therefore: Why should the designer be aware of ethics when using behavioural science as part of the design process?

2 METHODS

This study utilises a qualitative approach by analysing both robust peer-reviewed theories as well as empirical data on the topic at hand. Typically, the audience would benefit from qualitative research approaches such as ethnography. However, this study will perform a case study instead and highlight the different findings through a systematic literature review[1]. The literature has been sourced from sites such as Web of Science, Google Scholar and ResearchGate.

3 ETHICS

A central topic for this study has been the ethical implications which behaviour-changing design presents. In this section, we will look at some ways in which the behaviour change approach falls under criticism due to ethical concerns. Behavioural-changing design encourages strategies that aim to make use of human psychology in order to benefit the service, system or product. However, this approach sometimes falls short when it comes to respecting the individual. With the wrong approach or action, we could risk harming the individual. The major problem with the behaviour change approach is that it allows and endorses manipulative strategies. We find this problem primarily in strategies for social marketing and in 'scare campaigns' [5]. We can split the unethical areas of the behavioural design into two parts. Part one is about creating behaviour from which someone else benefits by persuading, coercing or manipulating the user into something they are unaware of or benefit from. Part two is about how some strategies fail to preserve the user's right to make self-determined decisions. This is done by applying tools such as persuasion, coercion and, especially, authority. Since the goal is to discuss the ethical considerations, this paper will only focus on part two. This is in order to avoid the promotion of ethically questionable strategies such as persuasive technology, used to trick or coerce people into pushing a specific button on a page. Ethical considerations are something designers are encouraged to reflect upon when making their design decisions. The guidelines by Berdichevsky and Neuenschwander's 'Figure 1' were created in a society where other cultural conditions were considered, such as current social factors, policies, and other cultural events from that time. Guidelines created 10 or 20 years ago become less relevant as technology and social conditions change. According to an MIT technology review, even ethics have a hard time keeping up with the rapid development of technological advances [6]. However, in 1999 Berdichevsky and Neuenschwander developed a guideline which builds on how individuals have developed as participants in society. Dr Leyla Acaroglu says: 'Ethics is not a given; it has to be constructed by the participants of society. What we get and what we don't get is decided by implicit and explicit actions to agree or disagree with the status quo of the day.' [7]. As illustrated in Figure 1, Berdichevsky and Neuenschwander has developed a map showing responsibility of intended and unintended outcomes to analyse whether designers could be considered morally responsible for the ways in which their products/services/systems are used [4].

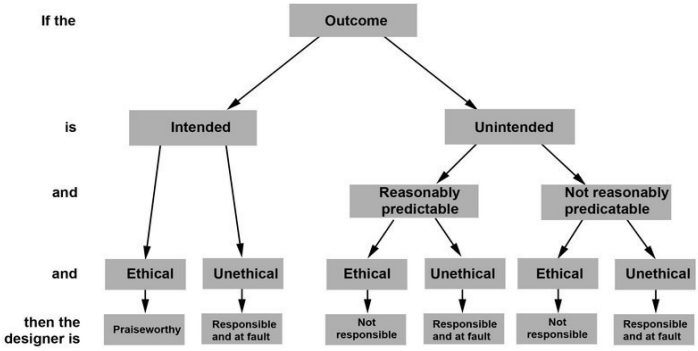

Figure 1. Responsibility of intended and unintended outcomes

Jen Gispen produced a toolkit called ‘ethics for designers’ to help designers incorporate ethics into their design process. This toolkit presents designers with the opportunity to develop these ethical skills [8].

4 BEHAVIOURAL MODELS FROM SOCIAL PSYCHOLOGY

To enhance understanding of the user during the design process, designers have often adopted a method called ‘empathic modelling’. Empathic modelling is generally described as ‘stepping into someone else’s shoes’, however as described in the empathic design. The knowledge provides the designer with an enriched understanding of the user, enabling better design solutions. With behavioural models from social psychology, designers can have the opportunity to enhance their abilities to understand their users at a deeper level [9]. Understanding the models from social psychology requires an understanding of their terminologies. For the sake of interdisciplinary clarity, this study explores a few terminologies that are commonplace in social psychology models.

Our attitudes consist of cognitive, affective and behavioural components. Social psychologists reserve the term ‘attitude’ to refer to our relatively enduring evaluation of stimuli, and the stimuli are called the attitude object. This term originates in the theory of planned behaviour by Ajzen, which specifies the nature of relationships between beliefs and attitudes. Their accessible beliefs determine attitudes about the behaviour, whereas belief is defined as the subjective probability that the behaviour will produce a particular outcome [10]. Subjective norms is another term, which focuses on the individual’s perception about a particular behaviour, and which is influenced by other group or party members such as parents, spouse, friends and teachers [11]. Perceived behavioural control is an individuals perceived ease or difficulty in performing a particular behaviour [12]. It is assumed that perceived behavioural control is determined by the total set of accessible control beliefs. An indication of an individual’s readiness to perform a given behaviour. Intention is assumed to be an immediate precursor of behaviour [13]. It is based on attitudes toward the behaviour, subjective norms, and perceived behavioural control, with each predictor weighted for its importance in relation to the behaviour and state of interest.

Compared to Ajzen’s theory of planned behaviour, the comprehensive action determination model (CADM) ‘Figure 2’ is directly determined by influences from three possible sources: habitual, intentional and situational. The habitual process tells us how the mind takes shortcuts by utilising schemata, heuristics and associations. The intentional processes are similar to the intention from the theory of planned behaviour, which is composed of intentions, attitudes and beliefs. According to Klöckner and Blöbaum, these are interconnected in a hierarchical structure: intention – attitudes – beliefs [4]. The situational influence is an underlying foundation, which affects the habitual, intentional and normative processes as well as behaviour with subjective and objective constraints. The normative processes consist of personal norms that are affected by subjective/social norms and values. This predictor has an indirect effect on behaviour by affecting habitual and intentional processes [4].

Attempts to investigate and understand behaviour in different contexts have resulted in different theories. Two particular theories create a better understanding of behavioural science, namely Ajzen’s theory of planned behaviour and the comprehensive action determination model. According to Wendel’s book Designing for Behaviour Change, Ajzen’s theory of planned behaviour focuses on how our intentions to act are formed. It is a product of attitudes, norms, and perceived control over the behaviour [2]. Jan Egil Nordvik states that this model has been used by governments for several years to produce preventive health information campaigns. The premise of Ajzen’s theory of planned behaviour is intention, but intention does not always lead to behaviour [14]. Klöckner and Blöbaum CADM refers to intention, context and habits as fundamental parts of behaviour [15]. The difference between Ajzen’s theory of planned behaviour and CADM. Is that Klöckner and Blöbaum have included more predictors of behaviour, such as a habitual process, where they introduce habit strength as a third predictor of behaviour. When we look at how Ajzen presents his theory: attitude + subjective norms + perceived behavioural control = intention, where the intention is the only predictor leading to behaviour. In Figure 2 it can be seen how CADM builds on a model comprising four different predictors of behaviour: normative processes, habitual processes, intentional processes and situational influences. The normative process is about how social norms, personal norms, awareness of need, and awareness of consequences, affect behaviour. The situational process is about constraints; it is often identified as perceived behavioural control. The habitual process is about how behaviours are performed with a minimum of cognitive effort [15, 4].

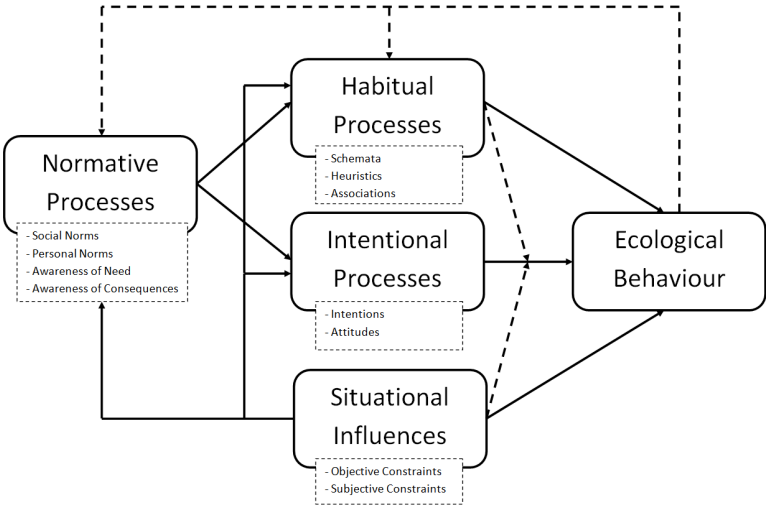

Figure 2. Comprehensive action determination model

5 BEHAVIOURAL TOOLS

Insight into how the mind makes decisions is a fundamental part of designing for behavioural change. This study includes implementing and improving the design methodology, double diamond, which is built on four stages: discover, define, develop, and deliver. According to the Design Council, the creators of the double diamond state that it is a design methodology that has become a reference tool for millions. This is due to the common perception that design is not a linear model, where following the design methodology from A to B guarantees results. Bela Banathy proposed a divergence-convergence model in 1996, which was later updated by the Design Council to add more structure to it. The Design Council recently updated the double diamond, which is now called a framework for innovation. It builds on the old model with a few updates on changes which design is undergoing, such as adding design principles. These four principles are: 1) put people first, 2) communicate visually and inclusively, 3) collaborate and co-create, and 4) iterate, iterate, iterate. The first principle stands for shaping an understanding of the people using a service, their needs, strengths, and aspirations. The CADM is therefore an excellent tool to implement in the discovery phase, which is the first diamond. The discovery phase helps designers to understand the user rather than assuming what the problem is, and includes methods such as primary and secondary research, which involve speaking to and spending time with people who are affected by the problems the designer is studying [16]. CADM will help influence minds and shape behaviours due to the way it promotes a better understanding of human psychology. This will result in insights into why people do what they do. With insights like these, designers can improve their product, service or system with better ideas that the user will not even know they desire, due to more collected data on where to search for solutions. This will eventually lead to better solutions because we know which behavioural change we want to achieve. With the quest for gaining insight to design solutions with a lasting and positive impact on people's lives, we must ensure that our methods are used ethically.

6 ETHICAL IMPLEMENTATIONS

The World Design Organization (WDO) has developed a code of professional ethics. These ethical guidelines are designed to advance the quality of the industrial design profession and can be used for most design disciplines. Back in 2013 when WDO was known as 'ICSID', article two stated 'the role of a designer as one that does not harm or contradict the wellbeing of a user, however, without a deep understanding of the user this is impossible. To understand what 'harm' or 'benefit' means, one has to understand the person, thus, without empathy, any code of ethics may remain dependent upon designers' superficial assumptions.' [9]. With that in mind, the ethical guidelines should be implemented in the development and delivery phases since this is where the designer's insights are translated into ideas. Using Berdichevsky and Neuenschwander's map 'Figure 1', designers can test whether their

concept/product is considered ethical or unethical. However, it is essential to state that designer cannot be held responsible for all of the impact, since they do not make every decision themself, even though they play a significant role in the development of the final outcome [4].

7 IMPLICATIONS FOR PRACTICE

This research consists of insight into how behavioural science can give designers a broader understanding of their design problem. The ethical implications may be challenging to address because design ethics is a topic that has received little attention. This is in addition to a lack of discussion on the topic in the design field. It has been developed some guidelines designers can incorporate into their practice, as suggested in the text. Berdichevsky and Neuenschwander's map to analyse whether designers could be considered morally responsible is an excellent way to test whether a particular design is something the designer finds suitable. Nevertheless, it will not provide insight into faulty areas or how to prevent wrong choices. Jen Gispen's toolkit called 'ethics for designers' would make it easier to spot where in the design process the wrong choice was made. Further studies can dig deeper into how the toolkit could improve design practice, because when it comes to behavioural models, the best models have not yet been adopted. However, the models presented here brings up an important understanding of behavioural models and their underlying terminologies. The selected models were considered to cover the most critical factors, to understand how our intentions are formed. There is often an abundance of behavioural models in product design education, such as Dugg's Habit Model, Fogg's Behaviour Model, the Hooked Model, Self-Determination Theory and so on. However, Ajzen's theory of planned behaviour and the comprehensive action determination model stand out for their similarities as well as for their differences. By incorporating one of these models into the discovery phase, the designer may benefit in all sub-disciplines. This is relevant in many design disciplines because those benefits may also be cross-disciplinary.

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TACKLING CURRICULA REFORMS AS DESIGN PROBLEMS: A REVIEW OF DESIGN CURRICULA PERSPECTIVES

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ABSTRACT
In recent years, the responsibilities of designers have drastically shifted as the world we live in becomes increasingly more complex. Correspondingly, educators advocate for an adaptation of design education in relation to the shifting economy, technological and societal advances. The question therefore is how to design the future of design education in a way that it corresponds better to these shifts. Traditionally, university curricula are updated on a department level together with faculty members. Under this localized practice, programs update one course at a time. During this routine hardly any other stakeholders are involved. By reviewing universities' practices around the world towards reforming their curricula, it was found that design programs can benefit from shifting towards a systemic, design-based, and research-through-design approach, specifically, by using design research methodologies, namely, co-creation, stakeholder involvement, questionnaires, trend analysis, benchmarking, focus groups, interviews, prototyping and the application of an iterative mindset. In agreement with Cross (1982), the authors call for a more *designerly* way of thinking in order to update design curricula. By re-considering conventional approaches regarding curricula reform practices, this paper presents recommendations for designing design education to define future university study programs.

Keywords: Design education, curriculum reform, design learning, design pedagogy, future perspectives, designerly ways

1 INTRODUCTION

It is undeniable that product design and engineering education is currently at a tipping point. Many claim that it must transform, primarily, because the world we live in, inclusive of man-made products and services we create, consume and use, is becoming increasingly more complex [1]. Specific examples that underline this call for change in our education include the in-flux economic landscape, which requires a higher level of problem-solving skills [2], and the important ongoing racism and privilege issues, which requires design engineers to be more aware of their role in society [3]. Moreover, Duy Tan University in Vietnam found that their education should respond better to the technological advances of industry 4.0 [4]. Other examples from higher education institutions too show an agreement on the need to prepare next generation designers for future technological, economical, and societal advances.

As the field of product design and engineering education comes to a shared understanding that the redesign of its curricula is much needed, questions arise on the way curriculum reforms should be executed. In most cases it is the department of a university that is responsible for determining the learning objectives, teaching and learning activities, as well as, assessment means [5]. Similarly, at our university, we are currently in the midst to reform the Bachelor and Master's curricula in Industrial

Design Engineering at Ghent university. However, in setting out to do so, we found there to be a fundamental requirement for employing a methodological approach to curriculum reforming.
Therefore, this paper will report on our search to develop such a reform methodology. First, institutions reform strategies around the world were benchmarked. These institutions might not have found the ideal solution either, as there is not yet a consensus on the best way to address the current need for a reform. Looking at previous tipping points, we might see that the current need for a radical revolution in design education resembles the period around a hundred years ago in the 1920s when Bauhaus disrupted the way we taught design [1]. From Bauhaus, design research established itself as a discipline, creating tools that we can now use to refine our curricula. A critical view of this paper will be to analyse benchmarks, and report on the extent to which they incorporate design research tools by looking into research articles published in Web of Science (WoS) ranked journals. Put differently, how rigid, scientific, and *designerly* are the curriculum reform methods of institutes around the world. What can be learned from past reforms for design departments that want to take actions towards curriculum reforms in the future?

2 TOWARDS STUDENT-CENTERED DESIGN EDUCATION

Through refining the motivations behind the call for reforms of engineering design education, it becomes clear that solely including more domain-specific knowledge will not suffice. Recently, multiple journal articles, have questioned the traditional master-apprentice relationship of product design education as it is a teacher-centred approach [6]–[8]. Although design education relies on this way of teaching to transfer tacit knowledge, it has been argued that traditional modes of teaching lack to assist students in deeper knowledge building. The recommended shift is to move away from teacher-centred towards learner-centred design education. Some claim that the transition to putting the student at the centre of design education will lead to a lower value of complexity in design education. However, this is opposed by the argument that we need to redesign our learning experiences as well. In a student-centred way of teaching, students learn to deal with complexity triggered by personal learning experiences and students themselves need to make sense of real-time changes alongside high-stakes risks [9]. Design engineering is a field in which critical questioning is highly valued, especially when challenging assumptions about the way things are routinely done [10]. Particularly within the interdisciplinary field of engineering product design where a wicked approach of design problems requires a more holistic approach. The recent developments force us to look inside and see that we have failed to include the main stakeholders in the development of our curricula [9]. In order to redesign our curricula for the challenges ahead and reform them following a student-centred way of teaching, we need to co-create the design education of the future together with students, industry, university academics, and society as a whole [10].

3 METHOD

In our search for a common ground to develop future curricula, we found there to be a need for a comprehensive overview of recent curricula reforms. Since a focus on product design schools and industrial design engineering school reforms yields too little results, this research chooses to incorporate design education reforms in within the whole field of design education. This means that reforms within the fields like industrial design, interaction design, transportation design, and furniture design, strategic design were also considered. Although these fields are different from product design and engineering design, they share the same teaching and learning activities (e.g., studio teaching, tutorial sessions, project- and problem based learning), and the same urgency for a reform triggered by the technological, societal, and economic changes discussed. Therefore, a systematic literature review of WoS-ranked research articles was conducted using a two-fold search strategy. First, the WoS database was searched (search strings can be found in figure 1). It was found that although the search-string was refined, many of the returned results did not discuss any field within design education. Second, a similar search-string was used in journals, ranked in the WoS database, specific to the field of design, which led to more qualitative results. Figure 1 shows a schematic overview of the search-strings used and results returned. The returned results were refined based on inclusion and exclusion criteria. Only research that reported on curriculum reforms in higher education was included, and articles focusing on primary and secondary education were excluded. We did exclude results that only focused on art education, however, when they mentioned findings related to any field in design education, we included that research paper. This means that we did not distinguish between fields, such as, textile design, product design, graphic design, or others. It was chosen to only include results from the last 20 years since the turn of the century was also a turning point for new technologies similar to where we find ourselves now. Only articles that

report on the reform of a curriculum as a whole were included, as a consequence, literature on reforms on a course level were excluded. Lastly, duplicate articles were removed. The resulting papers were analysed and clustered together based on themes that arose. Due to the added value of not only discussing these papers on a quantitative level but adding a qualitative analysis to the discussion, the results are combined with the discussion.

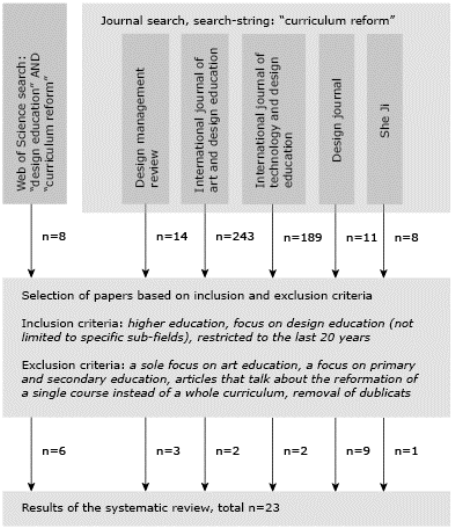

Figure 1. Visualisation of the search strategy

4 RESULTS AND DISCUSSION

4.1 From a traditional approach to a design approach

A total of three papers (n=3) report on the add-on strategy for curriculum changes [11]–[13] which was first described by Gibbs [14] as a way to add an extra course or course-content into a curriculum. Augsten and Gekeler [13] illustrate this idea by claiming that future designers should not only possess typical craftmanship capabilities, namely, design doing and user/design research. They argue that a new design paradigm should be added onto the traditional curriculum that teaches co-creation and design facilitation skills in order to create design experts in communication and collaboration. However, Kolmos [11] claims the add-on strategy might be insufficient and a more systemic approach is needed in which new learning objectives are integrated in a holistic manner. This is achieved through an integration strategy where new knowledge is inserted into a curriculum on a systemic level that leads into a specialization sequence. Moreover, the rebuilding strategy takes this approach one step further by linking new knowledge to an interdisciplinary understanding. In her paper on the integration of more sustainability focused knowledge in a design program, she concluded that a process-oriented approach of remaking a curriculum is required and should involve external stakeholders [11].

This call for involving stakeholders into the curriculum reform process is strengthened as four (n=4) papers state some form of collaboration or co-creation especially with students, is necessary [4], [15]–[17]. More specifically, Schneorson and colleagues [16] report on the use of field observations, interviews, and informal conversations both with students, experienced designers and industry partners. Blau and Shamir-Inbal [17] highlight the use of technology to capture the 'student voice', which is a strategy to listen to and value students' perceptions on their learning experiences. They describe a process in which students are treated as equal co-creation partners for developing future design curricula. These examples suggest that design education is moving away from a traditional university approach where new knowledge is added onto the curriculum based on lecturer's beliefs of what a designer should know and be able to do. Instead design education seems to recognise curricula reforms as design problems and tackle them in such a way by making informed decisions based on co-creation and stakeholder involvement.

4.2 From a pedagogical approach to a research-through-design approach

Three studies (n=3) use the constructive alignment framework as the back-bone for their curricula reform research [18]–[20]. Constructive alignment, first described by Biggs [21], is a method originating in the pedagogical sciences that aligns learning objectives to teaching and learning activities, and to assessment. Soares et al. [18] report on the use of informal talks and linguistic analysis to develop a set of learning objectives for design students of the future. Wilson and Zamberlan [20] argue that in order to arrive at an objective, metric, and quantitative way to assess creativity, we need to involve students in identifying learning objectives. In line with the tendency of moving towards tackling curricula reforms as design problems, four papers (n=4) report on the use of design research approaches to develop learning objectives [13], [22]–[24]. Inayatullah [24] and Kaur Majithia [22] report on the use of future thinking strategies like trend analysis and long-range future-oriented design (LFD) tools. These consist of pillars which are defined as mapping, anticipation, timing, deepening, creating alternatives, and transforming. To strengthen these future thinking outcomes, both Kaur Majithia [22] and Augsten and Gekeler [13] report on the use of semi-structured interviews, informal interactions, and focus groups with design professionals in businesses, education, and industry partners. Lastly Vasconcelos [23] describes the use of design school rankings (Top University, Business Insider, Red Dots, and Domus) as a curriculum benchmarking strategy.

In order to verify their research into learning objectives, research papers (n=4) report on quickly prototyping a section of a new curriculum in order to measure differences with the old curriculum [23], [25]–[27]. Brueggemann et al. [25] report on the use of workshops, Collina et al. [26] on the incorporation of Jams (intensive design-led workshops) in a summer school, Camacho and Alexandre [27] developed a case study within a course in collaboration with industry partners. At Umeå Institute of Design (UID) in Sweden and Aalto University in Finland, this approach was used to handle their curricula reform by prototyping solutions and making future decisions based on these prototypes [5]. By quickly prototyping a new curriculum approach outside of the usual curriculum, design departments have the opportunity to refine this curriculum in iterative cycles that are much shorter then yearly or semester-long cycles.

The approach of developing a solution through iterative prototyping and gathering information cycles is called research-through-design and was first described by British educator, writer, and former rector of the Royal College of Art in London, Christopher Frayling in 1993 [28]. The curriculum reform strategies discussed above show that design education now incorporates this research-through-design strategy in developing new curricula instead of only relying on frameworks for a pedagogical sciences origin. Above all, these findings highlight that design education uses interdisciplinary knowledge from a pedagogical base (i.e., the constructive alignment framework and development of learning objectives) and adds to this knowledge by using design-based methods for information gathering (i.e., trend analysis, future analysis, stakeholder interviews, and benchmarking). Lastly, these research findings are further refined via research-through-design cycles where solutions are prototyped and tested.

4.3 From curriculum reforms at a department level towards systemic change strategies

Traditionally curriculum change is discussed by a select group of lectures within the department [5], however, as recent technological changes call for a fundamentally different way of educating [1], it is suggested that conventional approaches might not be sufficient. Four journal articles (n=4) call for a systemic method for curricula reforms on different levels [4], [19], [29], [30]. Mitchell et al. illustrate this approach through a faculty-wide curriculum change which was enabled by a top-down drive for innovation and a bottom-up support for change. They furthermore describe a method for change at the individual level (micro) and organizational level (meso) which is in line with the strategy of Kolmos and her colleagues [30] for curriculum change. They developed a conceptual framework for systemic response strategies that links back to the add-on strategy, the integration strategy, and the rebuilding strategy as well as incorporating systemic change on a micro, meso, and macro level. Two articles report on the use of Bloom's taxonomy [4], [19], of knowledge dimensions which consists of a ladder with the following cognitive levels: remember, understand, apply, analyse, evaluate, create (from the bottom to top). In their study Truong et al. [4] prototype new types of design education following this framework and make informed decisions based on the percentage of students that achieves better results, and the total time students spent on studying for the class. A similar, yet different framework, was developed

by Wells-Papanek and Pecoraro [9], who created a method for curriculum reforms in five steps: gather information, define problem, build understanding, show understanding, reflect and assess.
It could be concluded that although curriculum changes to design education are usually the responsibility of the department, most universities now recognise the need for a more systemic approach. To structure these reform strategies, multiple universities use different actions on a micro, meso and macro level. Additionally, some universities develop their own strategies based on existing methods (i.e., Bloom's taxonomy) or as an abstraction of their own designed strategies (i.e., the five step strategy from Wells-Papanek and Pecoraro).

5 CONCLUSION, LIMITATIONS AND FUTURE WORK

The results show that the current ways of transforming design curricula, is not sufficient anymore. Instead, methods to redesign design education are shifting towards including more design-based approaches, research-through-design methods, and systemic change strategies. The examples outlined in this study show that recent university wide curriculum changes already incorporate some of these actions. However, reflecting on all the results collectively, the authors argue that a more designerly way of thinking is needed when redesigning curricula. Alas, the term 'designerly' was articulated in the 1980s [31], it is still relevant today by hinting at the use of design specific ways to know things and find knowledge not simply during a design project but for reforming design curricula alike. It should be noted that the findings discussed in this paper, although systematically researched, do not only regard product design education and engineering education. However, since the learning objectives, teaching and learning activities, and assessment means are largely similar between all fields of design education, the authors hope product design and design engineering educators can benefit from this research and continue to collaborate and learn from all fields of design education. Though out of scope in this study, the field of engineering education as a whole (including mechanical engineering), can be as valuable to research in the future because it is as close related with design engineering. In addition, the authors want to point at the potential benefits of involving all relevant stakeholders into the curriculum developing process, especially students, but also industry partners and design experts. Future research should focus not only on looking for a consensus in which methods to specifically use when reforming a curriculum, but also testing these methods in order to evaluate them.

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STRATEGIC DEVELOPMENT OF PERSONAL AND INTERPERSONAL SKILLS

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ABSTRACT
Personal and interpersonal skills are an essential part of design engineers' knowledge and skills, which students rarely feel they work with in a structured way during their education. To improve soft skills, the ideas on developing students' personal and interpersonal skills were implemented in design-implement experience, a 15 ECTS third-year capstone project for bachelor students. Parallel to the design project, students had to identify personal or interpersonal skills that they wanted to develop during the course. Personal development was done in several stages: Identification of personal development areas (PDA), discussion of PDA in group meetings, creating a development plan, personal coach meetings, status update and a final reflection
The results of this paper are based on teachers notes, written documentation and course evaluations. In the analysis, development areas were categorised using the CDIO Syllabus 2.0, where 59% was classified as Personal skills and 40% related to Interpersonal skills. The perseverance subset was the most common one identified. Other areas included lack of self-confidence, conflict mediation, creating a constructive dialogue between team members and time and resource management. Using this approach for three years and analysing the implementation, we can conclude that it has improved students' personal and interpersonal skills. The results also highlight that students like to be challenged to change their professional conduct.

Keywords: *CDIO, soft skills, integrated learning, personal development*

1 INTRODUCTION

Industrial design engineering (IDE) is a Bachelor/Master programme at the Luleå University of Technology. The IDE-programme integrates industrial design with engineering design, using human needs and requirements as main incentives for developing students' products, processes, and systems building skills. By tradition, various subjects such as usability, aesthetics, design methods, ergonomics, human work environment and design theory have been interspersed with more traditional engineering subjects such as math's, physics, solid mechanics, material science. Since 2015 we have been a part of the CDIO-initiative and adapted the programmes to that framework [1]. One of the fundamental ideas of CDIO is integrated learning experiences, i.e., activities that lead to the acquisition of disciplinary knowledge, combined with activities that focus on enhancing personal and interpersonal skills and product, process, and system building skills [2]. Integrated learning experiences are often implemented in real design challenges, something that CDIO calls design-implement experiences.
When developing a programme, it is crucial to have a holistic view and break down the programme's overall goals and create courses that build on each other, complement each other, and a system that supports students to develop their knowledge and skills in a self-regulated way. To support this, a competence profile [3] has been created for the IDE programme to function as a framework supporting both students and teachers understanding of what competencies they need to build to work as an Industrial Design Engineer.
In many of our design-implement experiences, personal and interpersonal skills are visualised and assessed through a workbook approach [4] in which students describe their progress in the projects through cycles of reflection. A typical workbook consists of written text, i.e., literature reviews and methods employed, and sketches and photos illustrating the process and its results. The most important part of the workbook is reflections and learning that deals with learning outcomes in terms of lessons learned, experiences and challenges to address in upcoming projects.

When analysing the programme's courses, it was clear that courses focus on developing disciplinary knowledge and lack systematic development of personal and interpersonal skills. We found that few courses explicitly included personal qualities and professional conduct; feedback was often done on their project skill of being part of a team but not really on the personal level. In evaluations of the programme, students have expressed a lack of developing interpersonal skills, which is unfortunately common in many programmes in Sweden. In a survey of 11,119 students at Swedish universities in 2007, students' experiences of support for professional development are disappointing and that 90% of students perceive that they rarely discuss their individual development with teachers [5]. So, we took this as an opportunity to integrate this into one of our capstone courses.
This paper aims to describe the implementation of a structure to support the individualised development of personal and interpersonal skills.

2 METHOD

The ideas on developing students' personal and interpersonal skills were implemented in design-implement experiences, a 15 ECTS (20 week) third-year capstone project for bachelor students. The first implementation of the development of interpersonal and personal skills was implemented in the autumn of 2018 (9 students) and has since then been performed in 2019 (16 students) and 2020 (6 students).
One of the learning objectives is to improve interpersonal skills for project work. In the course, the students work with a design challenge from an external company or organisation. The challenges are quite diverse. For example, in 2019, projects ranged from an innovative user interface for truss calculation, how to improve the city centre, designing the user interface for satellite control, and designing an enclosure for wideband positioning systems.
This paper's analysis is based on teachers notes from discussions with students, written documentation of their development areas, documentation of meetings, and course evaluations. In the course evaluation, specific questions were designed to focus on the structured work on personal development. For the student's development areas, all individual development areas (n=75) were gathered in Excel and then categorised according to the CDIO Syllabus 2.0 (CS2.0) [6], this categorisation was first done by one author and then reviewed by the other author to reach an agreement of the best categorisation. All student quotes have been translated from Swedish and anonymised by the authors.

3 IMPLEMENTATION

During the project, the student groups were divided into small teams that worked with their Personal Development Areas (PDA) for 20 weeks. Parallel with the design project, students had to identify personal or interpersonal skills that they wanted to develop during the course. Personal development is done in several phases. See Figure 1 and the section below for details.

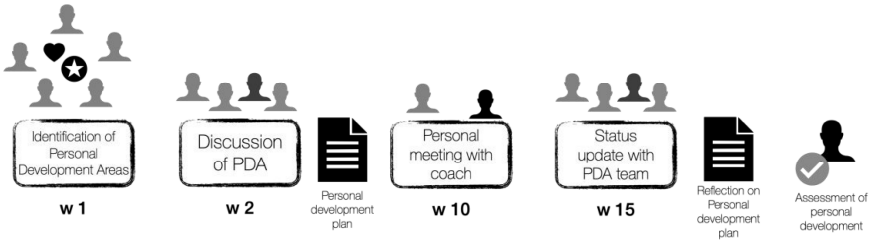

Figure 1 Graphical representation of this process

- *Identification of PDA (week 1)*. To help identify personal challenges, each person in their teams had to write something positive, *"I like…"* and a development area, *"I wish…" about the other team members.* Then, the students had to select areas they wanted to improve during the course. To help them identify the issues, they should prepare at least two areas and describe *What is the issue?, Where is it happening?, When is it happening?, Why is it happening?, How can you overcome this problem? Who do you need to get involved?*
- *Discussion of PDA (week 2).* This was arranged in small meetings with members from other teams. In the discussion, each student got about 20 min each where they presented their development area.

Other students commented to clarify the issue and came with feedback on how they could work with the development area.

- *Creating a development plan* (week. 2), Each student then described their selected development areas, the feedback they got in the discussion meeting and explained how to work with the issue during the course (including prioritisation, goals, means to achieve the goals). The personal development plan was sent to the teachers.
- *Personal meeting with the coach* (week 10) during this meeting, the development plan's status was discussed with one of the teachers.
- *Status update with the PDA team (week 15)*, update current status, how the student has worked with the different areas, and receive feedback from both students and teachers.
- *Final reflection on personal development (week 20)*, reflection on the development process, what has been achieved and how to proceed in the future.
- *Assessment of the development plan* includes the identification and analysis of the PDA, how active the student has been in the discussions, and how they reflect on the progress of their challenges in the course.

4 RESULTS

The overall feedback from students was very positive. From the course evaluation *Overall impression of the course* (student rates the course between 1-5): 4,6 (2018); 4,8 (2019); 4,8 (2020). One student summarises the course as *"I like the challenge of developing something new with my team, and at the same time, have the opportunity to identify and work with some of my weak areas. I needed the input and support from you and other students to dare to deal with my fear of asserting my opinion.".*

4.1 Personal Development Areas

When categorising the student's PDA according to the CDIO Syllabus, 59% was classified as *Personal and professional skills and attributes* and 40% related to *Interpersonal skills.*

Table 1. The categorisation of development areas using the CDIO Syllabus 2.0

CDIO Syllabus 2.0 categorisation	n
2.3.3 Prioritisation and Focus	5
2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty	1
2.4.5 Self-Awareness, Metacognition and Knowledge Integration	2
2.4.7 Time and resource management	6
3.1.1 Forming Effective Teams	2
3.2.7 Inquiry, Listening and Dialog	6
3.2.8 Negotiation, Compromise and Conflict Resolution	2
4.3.4 Development Project Management - Configuration management and documentation	1
2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility	23
3.1.4 Team Leadership	2
3.1.2 Team Operation	12
3.2.2 Communications Structure	3
2.3.1 Thinking Holistically	2
2.5.2 Professional Behaviour	1
2.5.7 Time and Resource Management	4
3.1.3 Team Growth and Evolution	1
Other	2
Sum	75

4.1.1 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility

This is part of the second building block of the syllabus, which describes the personal and professional skills and attributes. In the analysis, the *Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility* subset was the most common ones identified. A common reflection among the students was that they find it challenging to stay focused on their task for an extended period: *"I have also watched scientific TV shows about the brain and what disadvantages social media and digital products have. The knowledge I have gained from these sections is that it is good not to have the phone on the table in front of yourself, because you lose attention to what you are doing when it rings/vibrates or lights up. It thus receives more attention than the project receives.".* Another common type of comment in this area was the lack of self-confidence expressed in their self-assessments, which harms their work. *"All of these are things I have known about before but which I have not really taken to heart. I have always been a person who enjoys giving. If I do not give anything of value, then why should I give?".*

"I have long had a bad self-confidence regarding myself and what I stand for. Maybe that's why I've been afraid of conflict and afraid to call strangers. But when I have taken the time to work on the above points, my self-confidence has also increased.".
The third area of interest in this category was the lack of perseverance, described in different ways: *"The bottom line is that it does not have much to do with the lack of commitment, but to do something that evokes my interest and is in line with what I find interesting."*. *"I have a hard time getting things done if I do not have pressure on me. So, in the future, I will try to put that pressure on myself to do things on time. It is often the case that I am not satisfied with things that I had done before the time ran out, and by putting pressure on myself, I can have more time to be satisfied."*.

4.1.2 Team Operation

The CS2.0 [6] *3.1.2 Team operation* contains more operative elements of teamwork and includes goals and agenda, planning and facilitation of meetings, effective communication, feedback, and empowering team members. In our analysis, this was the second most common area, and within this area, conflict mediation was the most common one. Previously many students tried to avoid conflicts and now challenged themselves to change this behaviour *"I will not wait to act but to take the lead role and act immediately the first time it happens so that you immediately show that it is not accepted and that you do not end up in a vicious spiral by letting it go 'this time'"*. A remedy for this was described by another student *"I have forced myself to start jumping into discussions in a better way, instead of just slipping along, I have chosen to share my opinions if I do not agree with anything. The more I have done it, the easier it has actually become."*. Another student described the balance of creating a shared goal between the team members *"Regardless of what makes the goals among the group members different, the differences will need to be managed for a successful collaboration. To cope with this, compromises and agreements between the group members are required."*. Several students got feedback that they were 'slacking' when they often were terrible at communicating what they had done; "*I also realised that I needed to pull me together and start communicating for NN when I did 'extra' things."*.
Empowering the team and giving positive and valuable feedback was also acknowledged. One of the project leaders encouraged others with positive feedback, which created a positive atmosphere in the group that created an excellent group dynamic. Another project leader reflected on team members' motivation that *"I just touched the surface but missed to understand the root cause. […] I was limited to motivate the person while the problem may have been solved through, for example, a change in work style."*

4.1.3 Inquiry, Listening and Dialog

In the CS2.0 [6] *3.2.7 Inquiry, Listening and Dialog* focus on creating a constructive dialogue between team members, listening, and understanding others, asking questions, processing diverse points of view, and recognising other ideas. Several students described that they sometimes had a problem to explain their point of view, their solutions, or that they started an argument because they misunderstood something. One student described the solution by empowering the team to ask questions if they did not understand *"Instead, I need to involve my group members by asking questions or getting them to formulate themselves in some other way."*. Two other students also described that they often become passive if they were not confident about the area that they were discussing. Their remedy was to ask clarifying questions to really understand the problem, which was a positive experience for the whole team.

4.1.4 Time and resource management

In the analysis, another common reflection was the difficulty to be on time for meetings. In Swedish, there is the concept called *Tidsoptimist,* literally time optimist, a person who (regularly) underestimates how long something takes and therefore gets busy or delayed. In the CDIO Syllabus, there is no clear set of skills that fits this PDA, but we have categorised it as Personal and Professional Skills and Attributes category. Some quotes from the self-assessment were: *"I probably do not prioritise meetings and the like high enough in the morning. I also have such an irregular schedule which makes it difficult to get up early the few days I actually have to do it." "I come in late" "I am often late."*

4.2 Feedback from students

Feedback from the students (formal and informal course evaluations and reflections) indicated that they appreciated the discussion meetings, often similar problems are identified, and they can together work to strengthen their weak areas. Students also appreciate that they spend time and effort on personal development and not just formal knowledge and skills "*also contributed to me having the opportunity to work with my shortcomings but also strengths in 'sharp' mode*" as one of the students described the process *"Good with much more focus on reflection and improvement. It has given room for self-insight, rather than someone else telling you how you are as a person".*

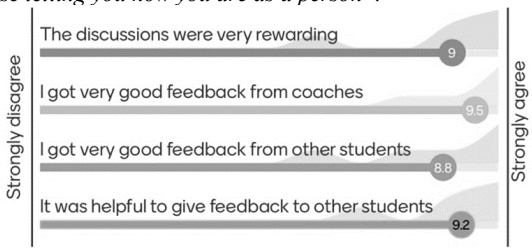

Figure 2 Evaluation of the personal development areas, 2020

Also, it was appreciated was the focus on personal challenges within the project, *"I like that there is an aspect that is more about me as a person and not just my role in the work.*

Compared to a written workbook, students experienced that this approach was more valuable for their personal development. "*It has been very rewarding. In a regular workbook, a lot of time is spent getting the content together. and it is more rewarding to focus on one's own reflections"* another student described the personal development work as the *"Most educational assignment throughout the education.".*

Several students also felt that the openness and the discussions opened up for much more personal discussions within the teams. Everyone was aware that they all worked with various personal challenges during the course. One student described it as *"I feel that some of what I shared with me changed both myself and my team."*

5 DISCUSSION

Lack of self-confidence was a common PDA that surfaced during the discussion sessions. One of the students was not aware of the fact that she avoided contacting unknown people. Once she was aware of this, she challenged herself to actively work with this PDA and an insightful improvement was expressed in her final self-assessment. Discussing PDAs in groups is an opportunity to address development areas and identify areas that the student may not have been aware of without others' help.

Team conflicts are quite common in design-implement experiences and was also a common topic for our students. In this course, the openness and the students' willingness to change the team behaviour and their own behaviour were higher than in a regular course. It was also clear that actions and behaviours that are usually perceived as irritating and in the end lead to conflicts (coming late, personal focus, misunderstandings) was identified and discussed during group exercises, and thereby highlighting actions that could lead to a conflict and been able to act before it becomes a conflict.

Another area that improved the teamwork was the focus on creating a constructive dialogue between team members, to focus on actually understanding different opinions and making all voices heard. All students were aware of it, but they realised that they could do it much better, especially when several students had that common development area.

After the group discussions where 'Tidsoptimism' arose, it became clear that those who were not time optimists pointed out that it was disrespectful not to show up on time. After this insight, a general improvement in the project groups was quickly noticed.

Some of the students highlighted that it was difficult (at the PDA discussion meetings) to give all people the same amount of focus. In some cases, it was one-way communication, and it was much more rewarding for the students that opened up. The structure of the discussion meeting is something that can be improved in future sessions.

Several students highlighted that they liked the group discussions, presenting their development areas, and discussed how they should work with them. They described that they could solve their problems by

taking part in others' experience. It also felt good to confirm that others may have the same 'problems' as myself *"In my case, it has felt positive that others in the class have had similar reflections on their personality, way of thinking or acting."* or that *"One forgets that others may also have difficulties that they work with, very important to pay attention to"*. The students also described that the discussions highlighted the importance to support and empower other students in their teamwork. Working with discussion groups with one member from each project teams also felt like the right approach. The students were more comfortable to discuss problems that arose in their teams. We also decided to put all project leaders in one discussion group, and the focus for those individuals was more on leadership, supporting the team and the individual team members. We also introduced bi-weekly coach meetings with the project leaders focusing on team-related issues and leadership, which project managers much appreciated. As a teacher and leader of the discussion sessions, it felt that we were sometimes scratching on the surface and then revealed something that was a significant personal challenge that students had hidden from others (and even from themselves) for a long time. One of the students described it in the evaluation "*Sometimes it got a little too personal [...], I'm ok with that, but others may not be"*. This is something that the teachers have to be prepared for and have an action plan to get extra support from student health organisations if needed.

The implementation was done in small classes with more than two years of experience working together and can be a challenge to implement in courses with more students. Most of the work is performed in small teams, so it should be possible to achieve with enough teachers to handle the discussion meetings. Parallel to this implementation in this course, we have also introduced the *Habits of Minds* concept [7] in a similar course to enable students to reflect on their own behaviours. The 16 attributes are used as a starting point to identify strengths and weak areas in the course. In the master course, reflection was only performed in a written workbook at the end of the course, and we see that the ongoing discussion throughout the course used in the bachelor course was a better approach. For the following semester, we will use the experiences to improve both courses.

6 CONCLUSION

The background to this paper was that students feel that they were rarely allowed to work with the personal development of both personal and interpersonal skills. The paper describes how we have developed a structure to explicitly work with the students' individual development areas for personal and interpersonal skills. Using this approach for three years and analysing the implementation, we can conclude that it has improved students' personal and interpersonal skills.

The results also highlight that students like to be challenged to change their professional conduct. They get support from both teachers and other students and have to force themselves to work with something that negatively impacts their usual way.

We have identified that this approach can be difficult to implement for larger groups of students because it is important to be able to follow each student's individual development, so one solution is to divide the class into smaller cohorts each coached by a teacher. We will continue to use this approach and compare it with the result from another course using the Habits of Mind framework.

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INTELLIGENT TUTORING SYSTEM AS A TOOL OF FORMATIVE ASSESSMENT IN DESIGN EDUCATION

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ABSTRACT
In times of increasing digitalization, universities are turning to digital media to promote effective learning. In addition to comprehensive learning platforms, on which learning materials and communication options are offered, interactive and adaptive learning programs are also being developed in many subject areas. These so-called intelligent tutoring systems are used as a lecture-accompanying tool to make lessons more varied and thus more efficient.
This paper reports on the use of an intelligent tutoring system that was embedded as a formative assessment tool in computer-aided design education. The system was used by over a hundred-second semester mechanical engineering students to prepare for a design course. The obtained system data is evaluated and then discussed. As a result, it is shown that an intelligent tutoring system within the framework of formative assessment can help students complete open design tasks and lead them to a valid solution through supportive feedback. Furthermore, this paper presents the use of the system data to improve the course by detecting and evaluating knowledge gaps and misconceptions of the students.

Keywords: Design education, intelligent tutoring system, computer-aided design, formative assessment

1 INTRODUCTION

In order to develop problem-solving skills during engineering studies and to consolidate the knowledge acquired during training, students can be offered exercises in which they learn to act independently and to apply their specialist knowledge in professional application situations with feedback that promotes learning [1]. At the same time, individual support, and encouragement in the processing of exercise tasks is often difficult in university teaching due to a lack of personnel and time [2]. Intelligent Tutoring Systems (ITS) can help to enable effective learning with the help of a computer and without the support of a human teacher. For example, the consolidation of knowledge acquired in lectures or the processing of homework can be usefully supported by an ITS [3].
Especially in domains like mechanical engineering, where designers often go back to knowledge from past development projects, the development of a body of experience and routine needs to be an educational objective. These addresses both own design knowledge but also working with knowledge sources and computer aids, like computer aided engineering environments or decision support systems [4, 5].
At Leibniz University Hannover, and ITS has been developed based on knowledge-based engineering systems, which has already been tested and used in engineering design [6]. The aim of this report is to evaluate the use of the ITS and thus find out whether the system meets the criteria of formative assessment and how the system should be further developed in the future.

2 LEARNING SUPPORT BY INTELLIGENT TUTORING SYSTEMS

ITS can provide a personalized approach to learning by taking on the role of a real teacher who adapts and controls the learning process according to the specific needs of each learner [7]. In teaching, ITS have been successfully used for many years in different disciplines such as mathematics and physics, as well as for learning foreign languages. However, the most common application is in computer science [8].
ITS are generally used in a specialized manner and usually cover only certain subject areas of disciplines in terms of content. In foreign language acquisition, for example, ITS are used to practice the rules of punctuation or in law to practice argumentation strategies [9, 10]. The use of ITS can be seen as a

supportive measure to practice specific processes or subject areas and to apply them in depth [11]. Through their abilities to collect and use diagnostic information and to support individual learning through adaptive behaviour, they resemble the basic features of formative assessment.
Formative assessment stands for the evaluation of performance during the learning process with the aim of using diagnostic information to improve teaching and thus individual learning. By knowing the individual performance level and learning growth, learning content can be optimally adapted to the needs of the respective learner [12, 13]. Five key characteristics are attributed to formative assessment by Wiliam and Thompson [14]:
1. Learning objectives and success criteria: Learning objectives and success criteria should be specifically stated by the teacher and communicated in an understandable manner.
2. Learning assessment: The learner's individual learning status should be assessed in comparison to the goal and used as a basis for following steps.
3. Learning feedback: Determined learning levels can be given back to the learner as individual feedback and thus support in the learning process.
4. Training personal responsibility: Activating learners as responsible for their own learning and enabling them to manage the learning process themselves.
5. Activate learners for each other: Learners assess each other's performance, provide feedback, and support each other.
Formative assessment should always be seen as the sum of these features and should not be reduced to a single component such as pure learning status recording. Since ITS evaluate individual steps in the solution process, provide feedback with context-specific hints, and allow for individualized task selection, they can be considered a good tool for formative assessment due to their breadth of possibilities [12].

3 USE OF INTELLIGENT TUTORING SYSTEMS IN DESIGN EDUCATION

An ITS is used at Leibniz University Hannover to support design teaching. The current state of the system is not used for direct knowledge transfer but gives students in the second semester of mechanical engineering an opportunity to apply their theoretical knowledge from the lectures to a practical example [15].

3.1 System structure

In order to use an accompanying tutoring system in a useful way in the basic training of engineers, the system has also been able to handle the requirements of problem- and practice-oriented tasks in design theory. These requirements include the evaluation of open problems and the approach to a valid result. The feedback required for this in the design solution process means that the system automatically analyses the geometry of Computer-aided Design (CAD) part models and compares them with valid solutions from standards and guidelines. For better solution finding, in addition to the sole output of design errors, the learner must also be given hints that support in generating a valid solution [6].

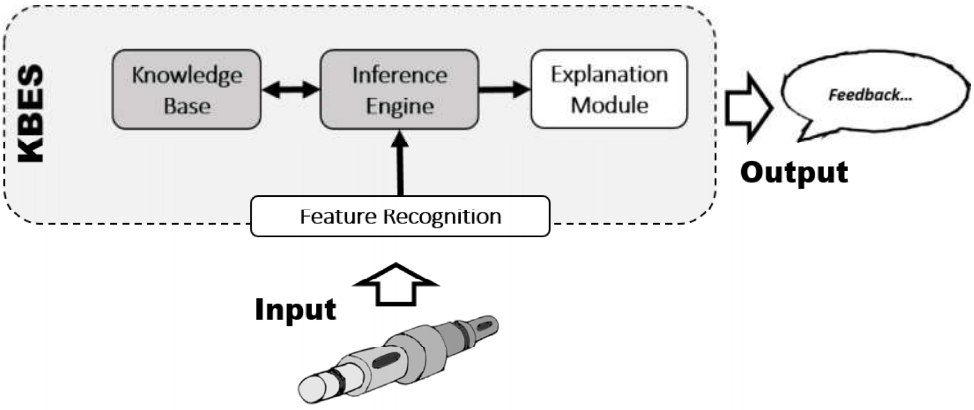

Figure 1. KBES for Design Education

The automatic evaluation of the system is done with a special knowledge-based engineering system (KBES). The system contains a knowledge base in which standards, design rules and restrictions are stored and thus imitates the knowledge of a teacher. As input, the system receives the student's CAD part file, examines the geometry by feature recognition, and then compares it to the knowledge base. Detected errors are provided with hints in the explanation module, so that the output of the system is a detailed feedback (Figure 1).

3.2 Procedure in the Design Project

In preparation for the second design project, the students were able to practice designing with Autodesk Inventor with the help of the ITS. For this purpose, the task was made available to them on a learning platform. The task included the CAD design of a gear shaft, which absorbs the drive torque between two bearings through a pulley and transmits the torque to a clutch at each end. The task was limited with restrictions such as the use of certain standards and components. To vary the task, a minimum shaft diameter for the seat of the pulley had to be calculated depending on the matriculation number. After receiving the assignment on the learning platform, the students created a variant solution in Inventor on their computer. Afterwards, they uploaded the solution to the platform as a CAD file. The system then automatically evaluated the designs and generated corresponding feedback. Before this was sent to the students by email, the teachers checked the feedback for plausibility.

The described learning offer was made available to the students over several weeks and could be used as often as desired. Participation was voluntary and available to all students through free student licenses of Autodesk Inventor. The generated designs and the resulting automatic feedback were saved.

4 RESULTS OF APPLICATION

A total of 115 students participated in the additional learning offered by the ITS. The 277 designs created and the feedback from the system are listed and explained below.

4.1 System data analysis

The system generates individual feedback for each incoming design. This includes different errors from the use of standard parts in different degrees. For example, the width, depth, length, and position of feather keys can be incorrectly designed or completely missing. The errors can be reduced to the categories of feather key, circlip, bearing seat, shaft end, calculation and undercut errors. Furthermore, the ITS assigns two predefined feedbacks. The failure feedback is assigned if the system finds too many errors or cannot interpret the geometry, here the task is referred to again and the basic elements of the shaft design are enumerated. If no errors are found in the design, a final feedback is given, which certifies the student the correct application of the standards and compliance with the task.

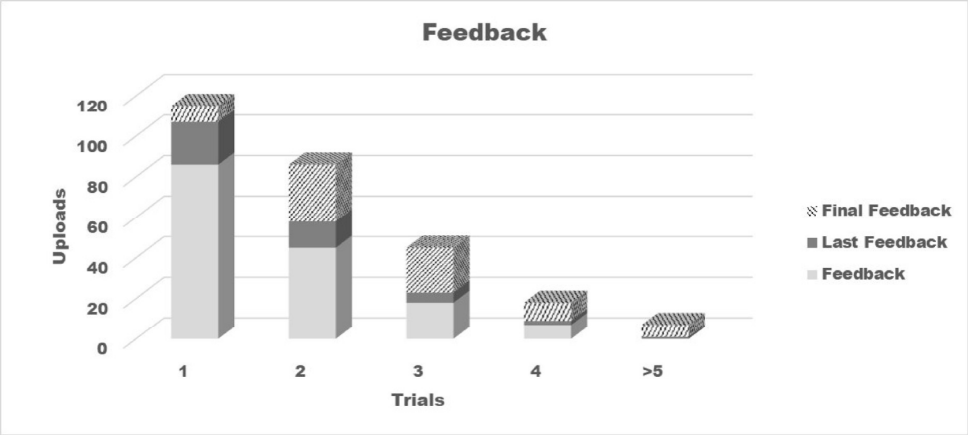

Figure 2. Evaluation of the System Feedback

Of the 115 students, a total of 73 received final feedback, with an average of 2.7 uploading their constructions to the ITS. Figure 2 plots the number of uploads over the number of attempts. The shaded portion of the column shows the proportion of Final-Feedback, the dark grey portion shows the Last-Feedback, and the light grey portion shows solution attempts with feedback that was also worked on by the students. The Last-Feedback contains errors found by the system, but there was no further upload by the student.
It can be seen that after the first upload, 8 students received a final feedback, 86 received feedback, and 21 received last feedback. For the second and third attempts, the number of final feedbacks is 28 and 22, and the number of last feedbacks decreases steadily with the number of attempts.
Among the participants, a total of 15 students received fail feedback back from ITS. Of this group, 6 students finally managed a Final Feedback after multiple correction loops.

4.2 Unexpected designs

The control of the generated feedback by the teachers before sending it to the students showed that not all designs could be evaluated by the system in a target-oriented way and had to be corrected manually. This problem arose when a geometry was generated as a solution, which was misinterpreted by the system due to serious errors in the modelling and occurred 32 times during the entire application period of the ITS.

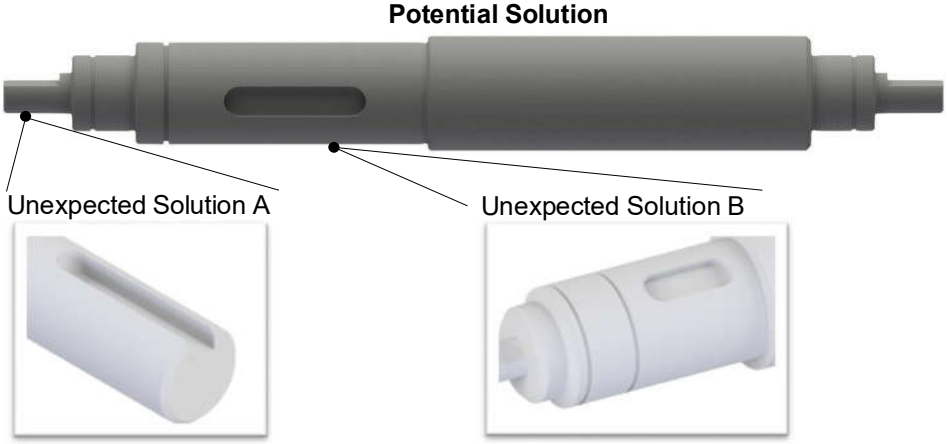

Figure 3. Unexpected designs

Figure 3 above shows a potential solution that the system expects based on its programming. There should be two bearing positions with axial locking, one shoulder for torque transmission, which also requires a circlip groove in addition to a keyway, and two flattened shaft ends for the rotation-free connection to one coupling each. The system is variable in terms of the arrangement of the elements, detects incorrectly designed and missing standard elements, and checks the heels for manufacturability and mountability. In the lower part of the figure, three unexpected shaft geometries are shown as examples, which the system could not evaluate automatically.
Solution A shows the variant of a flattened shaft end, which consists of an open keyway with a semi-circular end. Since the system here detects a flat surface with surrounding tangentially connected surfaces, a keyway and not a flattened shaft end is detected.
Solution B shows a shaft shoulder on which the pulley and a bearing are to be slid together. The machine elements are then secured axially by two circlips on a shoulder. Here, the problem arises that the length of the shoulder cannot be determined, and incorrect feedback is generated.

5 DISCUSSION OF THE RESULTS

It is notable that only 64% of participating students received final feedback from ITS, which could be due to several factors. For many final feedbacks, the number of errors was relatively small, which may have made resubmission unnecessary. On the contrary, it can be surmised that in the case of

simultaneous errors from multiple categories, the large number of errors or fail feedback may be more of a deterrent and prevent re-submission.
The unexpected designs, which were not evaluated by the ITS showed the limitations of the current system and the misconceptions of the students. This makes clear that some of the students' solution attempts are unpredictable and thus cannot be implemented in the evaluation of the system in advance.

5.1 Formative assessment tool

In order to check whether the system is sufficient as an instrument of formative assessment, compliance with the key features from chapter 2.1 is checked in the following.
The task of the ITS was developed together with the learning objectives of the design project. Since almost 90% of the students uploaded an assessable solution and 7% even got a final feedback in the first attempt, the task is considered understandable and solvable but not trivial. Thus, the first key feature of formative assessment is met.
The upload of the designs and the evaluation of the ITS, lead to a direct and individual learning state assessment of each participant directly in the learning process. These learning states are then used to provide personalized feedback. Since the solution attempts are constantly improving through the use of the ITS, the feedback is seen as helpful in promoting learning. Thus, the second and third key characteristics are also fulfilled.
The fourth characteristic describes activation for independent learning. For the work with the ITS, the advantages of asynchronous learning are used, so that the students can access the practical tasks independent of time and location and work on them according to their learning preferences. As feedback for the detected errors, students are not presented with solutions, but for example, hints on standards to improve their design. These features of the ITS further shift the responsibility of the learning activity to the students.
The fifth key feature, with its focus on collaboration, has received little attention in the development and use of ITS. However, it is the embedding of the system in a learning platform that offers many opportunities. Students can exchange information through chats and forums and thus support each other in the solution process.

5.2 Transfer of the results to the course

The data obtained from the application of the ITS will not only be used to optimize the system, but also to improve the course. For example, the incorrect and mostly unnecessary modelling of undercuts as well as the often excessively long design of bearing positions suggest that some students did not fully understand the properties of a functional surface. This topic could be discussed in more depth in design theory. It also became clear that the geometry of a flattened shaft end was not at all clear to some students and will be discussed in the future as an element of the rotation-free connection in the lecture.

6 SUMMARY AND OUTLOOK

The results show that the developed ITS meets most of the features of formative assessment and can be applied as its tool. Collaboration among students has received less attention so far, so that a stronger focus can be placed on this in future applications of the ITS. The framework has already been laid out for this by embedding it in an online learning platform. Increased communication among students could perhaps also help to better absorb fail feedback so that even more students are led to final feedback. Furthermore, the feedback could be revised to issue failures and notices from the system in a gradual manner so that feedback is not generated that is too long and potentially off-putting.
The manual peer review of the system response and the associated evaluation of the unexpected designs shows that the robustness of the evaluation of the ITS can be further optimized. One possibility would be, for example, the detection of individual standard parts by specialized agent systems in the ITS. The advantage would be that the system would no longer interpret the entire geometry of the shaft but would only search for specific geometry sequences. This could increase robustness against unexpected design solutions. However, it could be disadvantageous that unknown geometries are ignored, and thus possible errors are not detected and no longer listed in the feedback. For this reason, the development of the agent system in ITS and a review of the presumed advantages and disadvantages are planned for the future.
After the first application of the ITS, it becomes clear that most students are able to design a gear shaft with the help of the feedback. In the future, the question should be clarified whether the ITS only trains the students to solve the described design task or whether the students also succeed in transferring

knowledge to other tasks afterwards. This finding would be essential to find out whether problem-solving skills can actually be taught with the ITS.

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SOLUTION REPERTOIRE

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ABSTRACT
In this paper, we argue that design 'solutions' such as iconic designs, archetypes and design patterns, ought to be recognized as crucial forms of design knowledge. There is an abundance of literature suggesting solutions play a crucial role in design cognition: they can act as a gateway to understand the design situation better, as a stepping-stone to novel ideas and as an illustration of good practices. Unfortunately, however, the question of what this means for our teaching and our curriculum design has received less attention. How should instructors and design programmers handle solution-oriented knowledge? To spark a more informed debate about teaching solution-oriented thinking, we introduce the notion of *solution repertoire*: "the competence of appreciating and handling solutions in one's design discipline and to use them as an anchor point for design-relevant knowledge that goes beyond the anecdotal experience". This paper sets the stage by introducing and defining solution repertoire and by examining the implications of way of thinking for our own curriculum.

Keywords: Solution repertoire, design cognition, mid-level knowledge, pattern languages, precedents

1 INTRODUCTION

Many of the design instructors in our institute express an ambivalent relationship with examples. They acknowledge the power of examples to illustrate abstract design principles and concepts, but they are also -at times- wary of providing them, fearing that they may restrict their students' thinking. With regard to conceptual knowledge, for instance, instructors fear that examples used to illustrate a general principle will prompt students to reduce that principle to exactly those examples. The ambivalence pertains specifically to using examples of existing designs. Instructors feel that a discussion of existing solutions to the problems presented to their students may lead to design fixation ([10]**Error! Reference source not found.**): as a result of discussing those solutions the range of possible solutions students can imagine will be limited. This last fear is also shared by students: sometimes students implore their instructors to not provide examples for fear of 'getting stuck' and not being able to be 'original' anymore. However, in our view these reservations rests on a persistent set of misconceptions about design cognition.

In contrast to teachers' and students' models of design, design cognition literature stresses the importance of existing solutions (often called *precedents*) and intermediate solution proposals (known as *propositions*) as a central part of design reasoning. Unfortunately, the question of how such solution-oriented thinking is taught has received less scholarly attention. This is remarkable, for if it is important for designers to quickly dream up and adapt solutions in a design process, one would expect a rich discourse in design education on how we prepare for this challenge. Teaching existing designs properly may be key. Instructors need guidance on what existing designs they must discuss with students, how to discuss them, how to teach students to appreciate them, how to draw from such examples creatively, and how to test students' ability to do so. However, this educational discourse seems underdeveloped.

In this paper, we try to redress the balance by introducing the notion of *solution repertoire* which we define as "the competence of appreciating and handling solutions in one's design discipline and to use them as an anchor point for design-relevant knowledge that goes beyond the anecdotal experience". By doing this, we hope to stress the importance of teaching solutions in design education and to be more explicit about the different types of knowledge that complement solutions and act as a stepping-stone to the mastery that needed to speak of a repertoire. In this paper, after a brief review of the design cognition literature, we analyse the educational benefit of the notion of solution repertoire. This helps to critically evaluate some of our practices with regard to teaching solutions. We end with conclusions and an outlook on future developments.

2 SOLUTION-ORIENTED THINKING IN THE DESIGN PROCESS

In a foundation study in design cognition, Brian Lawson compared thinking strategies of students in physics and architecture. Confronted with a problem-solving task, physics students tended to focus their analysis on the problem and the problem constraints, whereas design students laid out several different solutions and tried to improve on them [5]. These disciplinary differences spun off a large body of literature on solution-oriented thinking in design. Indeed, studies of design in action, sketched vividly by Schön in his vignette of design as a reflective activity [6], show how designers follow a line of reasoning in which they propose alternative solutions (propositions) to a problem and evaluate and appreciate each one of them with respect to the problem and their design knowledge and sense of aesthetics. This reflective process was characterized by Dorst & Cross in the early 2000's, as an iterative movement between the problem space and the solution space [7]. It appears many designers start this process in the solution space. Amongst others, Darke has shown that designers use solution templates as a *primary generator* within their creative processes [1]. In her quest to pinpoint the design strategy of arrived architects, she found that they use two types of generators for their designs. First, they use solution examples and their experiences from previous projects to start their thinking [1], and next they develop that thinking with the help of a continuous dialogue between their current design problem and their initial examples [20]. Findings like these posed a serious challenge to the then dominant analysis-synthesis model for design, in which analysis and synthesis were considered as distinct phases in design. It is commonly assumed that students acquire the basics of solution-oriented thinking during their studio classes, where they get to solve real-life projects in a classroom situation [2], which is a dominant model of design education. We do not think this is the complete story. The studio model is a reasonable response to challenge of practicing solution-oriented thinking, but it neglects the question where the solutions students come up with come from in the first place. What is the knowledge base that students employ making all those propositions? The likely answer is that students draw from examples of design that they know either from their own experience or from design education and adapt them to the particular design challenge. Indeed, we know that designers do it this way. Designers are known for their habits of creating collections of inspirational materials [19] and many authors have suggested that existing solutions (*precedents* [3]) play a prominent role in the conception of novel designs. This is not the same for students. A study by Gray & Bollinger showed that while junior designers, too, use precedents, they are not aware of this [9] and as a result their knowledge about precedents does not trivially translate into design schemata. In other words: students need to be taught both that they can start from design exemplars and how such exemplars can inform their design. Solution-oriented design strategies may be nurtured in the studio, but they need to be seeded by our treatment of existing designs. If we ask what the 'content' of design thinking [8] is, the answer minimally should include: the existing solutions within one's design discipline.

3 TOWARDS A NOTION OF SOLUTION REPERTOIRE

3.1 The hierarchical model of design knowledge

How do design teachers conceptualize design knowledge? Recurring ambivalence with regard to the use of giving examples in teaching may have its roots in teachers' thinking about knowledge structures in general and those of the discipline in particular [10].

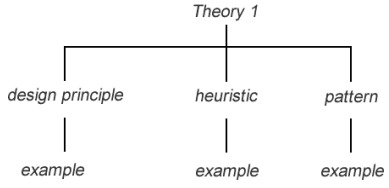

Figure 1. Classical conception of knowledge as a tree: solutions are examples of more important other types of knowledge

Our informal observation is that most instructors still conceptualize (design) knowledge as a hierarchical structure, where high-level theoretical concepts are first operationalized into mid-level knowledge [18]

and then into concrete designs. Mid-level knowledge is knowledge that resides somewhere between abstract theories and concrete designs. Common examples are design guidelines, heuristics, strong concepts [12] and design patterns [13]. Existing designs (precedents) are subsequently selected for their ability to illustrate the higher-level concepts. This hierarchy is illustrated in Figure 1.

This conception of design knowledge is, however, problematic for three reasons. Firstly, the hierarchical model favours abstract, disembodied, knowledge over concrete examples. As stated in the introduction, this is not in line with how practitioners' value and use examples, while it does have an effect on the priorities, we are setting in our design programmes. The amount of attention paid by curriculum design to establish the 'body of knowledge' greatly outweighs the attention spent on the 'body of important design exemplars.

The second problem is of a more conceptual kind: by being featured as 'mere examples' of higher notions, the design examples are related to those higher notions, but never explicitly to each other. Students learn how an interface is an example of a design heuristic, and how a different interface implements a particular design pattern, but they are not asked to relate these different examples to each other. Consequently, students are not taught how to navigate the solution space 'horizontally': they are not trained to think about how solution types might be grouped together, how there may be families of solutions, and, therefore, they receive little help in understanding and navigating the solution space.

Finally, the hierarchical model presupposes a unilateral relationship between theory and design - as if design can be deduced from theory. If students need to navigate the solution space, theory may play an important role, but the relationship between design and theory is never unilateral. In their piece on annotated portfolios [9] Bolin E. and Gray C. M. (2018). Use of precedent as a narrative practice in design learning. In *Educational Technology and Narrative* (pp. 259-270). Springer, Cham.

[10] Hativa N. and Goodyear P. (2002). *Teacher Thinking, Beliefs and Knowledge in Higher Education.* Kluwer, Academic Publishers.

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[14], Gaver and Bowers show that, while designs and the thinking about design form an intimate yet complex relationship, in fact, designs are 'underdetermined' by theory. Theoretical convictions can lead to a wide set of designs. However, the reverse is also true: 'theorizing' is underdetermined by design. That is, each design can be understood from a multitude of theories [9]Bolin E. and Gray C. M. (2018). Use of precedent as a narrative practice in design learning. In *Educational Technology and Narrative* (pp. 259-270). Springer, Cham.

[10] Hativa N. and Goodyear P. (2002). *Teacher Thinking, Beliefs and Knowledge in Higher Education.* Kluwer, Academic Publishers.

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[12] Höök K. and Löwgren J. (2012). Strong concepts: Intermediate-level knowledge in interaction design research. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *19*(3), 1-18.

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[14]. To build the epistemic fluency [15] needed to flexibly understand designs from a multitude of theoretical viewpoints and vice versa, the hierarchical model is simply insufficient.

3.2 The embodied model of design knowledge (i.e., a solution repertoire)

An alternative way of thinking of the role of solutions in a design curriculum is illustrated in Figure 2:

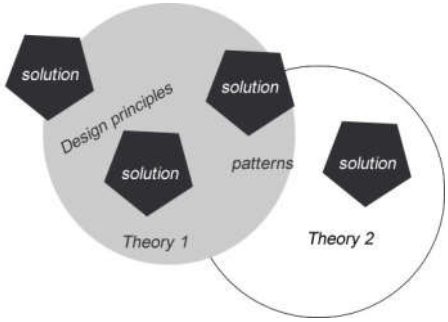

Figure 2. Alternative conception of knowledge: solutions are central concepts interconnected by higher level knowledge constructs: a solution repertoire

This picture, in contrast, highlights solutions as the central anchor point of multiple bodies of abstract knowledge. They are not examples of that knowledge, they can be viewed through different theoretical lenses. Curricula can be built around carefully established sets of exemplary designs that are used as stepping-stones in a somewhat amorphous theoretical space of families of designs, mid-level knowledge constructs and high-level theories. This reversal of the hierarchical picture is not intended to dismiss the importance of theoretical constructs in design – we think theory is immensely important – but to redress the balance between thinking about design in terms of disembodied concepts and the concrete designs that form the embodiment of those ideas. For instance, when the concept of Cialdini's six principles of influences is explained to junior designers, they were provided with examples of live commercial designs that each implemented a principle. However, students would try to understand the theoretical principles by learning the examples. They lost sight, or never gained sight, of how each of the examples embodied more than one principle, and how the examples were actually related to each other in many other ways as well. They were and should have always been regarded as more than just examples of something more important.

Rather than stressing the 'level' of abstraction, with the implicit notion that more abstract is somehow better, the proposal in Figure 2 stresses the link of theoretical notions with concrete designs. The idea of a solution repertoire suggests that theories need to be taught in close relation to specific design exemplars. Abstract ideas about designs make sense in the presence of active knowledge of particular designs that are subject to those abstractions. The designs are central, and the abstractions are needed to think about these designs. The notion of a solution repertoire also stresses the active and personal nature of such solution-oriented knowledge. A *repertoire* consists of solutions that are internalized to such an extent that a designer can develop a personal style by fluently calling on them and then adapting solutions to their needs and the needs of the problem they are facing. Finally, it celebrates the multiplicity proposed by Gaver & Bowers [9]Bolin E. and Gray C. M. (2018). Use of precedent as a narrative practice in design learning. In *Educational Technology and Narrative* (pp. 259-270). Springer, Cham.

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[14]. In our view, 'knowing' a design means appreciating (and critiquing) it from multiple theoretical viewpoints which are easily switched.

4 THE PRACTICE OF TEACHING SOLUTION REPERTOIRE

4.1 Introducing the notion of solution repertoire into our educational programmes

The term solution repertoire resonates with colleagues, at least in the sense that they share the aspiration to train designers who master a set of solutions and can fluently use them to generate new designs. One step towards furthering the notion of solution repertoire is the realization that the role of solutions

changes with the different phases of the design process. In this sense, the mapping of theory functions to a generalized version of the design cycle by van Turnhout et al. [16] turns out to be a helpful aid in our understanding of the use of solutions in design. In this section, we discuss the different roles solutions assume in each design phase.

4.2 Solution repertoire as a strategy for (gateway to) understanding problems

By its very definition, a solution is connected to a problem – a solution is always a solution 'for something'. This means solutions can contribute to the description and explanation [16] of a design situation and aid in what is commonly understood as the analysis phase in design where students build an understanding of the current situation. Following Schön [6] and Dorst [7], the ability to use solutions as a gateway to build a stronger understanding of the problem space is crucial. But in our educational programmes, students are seldom explicitly trained to make this step. The analysis-synthesis model [4] is still very dominant and students are mostly taught to approach the problem with only armed with analytic tools. Teachers wrongly assume that, if students are trained *not* to think about the current design or alternative designs proposals, they will overcome fixation and will be more creative later in the process.

A better way to teach the thinking step that is needed to move from the solution space to the problem space, may be to use design critique as a gateway to building an understanding of the design situation. An example is the vision in interaction technique proposed by Pasman et al. [17] who use a specific interaction design and then systematically train students to use it to describe and explain the situation the current design is responding to, in increasing layers of abstraction. This bottom-up approach may form a better training to build the type of solution-oriented analysis skills that are needed for design than the top-down, disembodied approach that is propagated by the analysis-synthesis model.

Another way to teach students to use solutions as a gateway to problems, is to use benchmarking exercises. Creating a structured benchmark of existing solutions for a given design problem helps students to move from thinking about a single solution to a solution family, with many variants. The structure of a design benchmark typically also mirrors hidden structures in the problem space.

4.3 Solutions as a strategy for (gateway to) explicating design aspirations

As stated in the introduction, existing design solution examples can be used as a stepping-stone to novel ideas and concepts and this use of a design precedent is an important skill for designers. One approach to teach this generative role of design precedent is to teach solution-oriented design systems, such as pattern languages [12] Höök K. and Löwgren J. (2012). Strong concepts: Intermediate-level knowledge in interaction design research. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *19*(3), 1-18.

[13] and design typologies **Error! Reference source not found.**. Although we make use of such systems, we are still struggling with building a meta-cognitive understanding of this material.

This problem is also reported by Boling & Gray [9]. They require their students to actively seek out and consciously use design precedents, and subsequently reflect on how they use those precedents. Their dilemma was, however, that students had a hard time understanding that they already use precedents, a lack of awareness that inhibited students to account for and reflect on their use of precedents. Generative practices such as requiring students to maintain a notebook with design ideas, sketches and insights or brainstorm techniques forcing students to come up with new ways to handle existing objects are useful to train the habit of pursuing multiple solution directions and thinking lines in parallel, but they do not directly help students to connect their ideas with higher level knowledge.

In van Turnhout et al.'s [16] view, the generative theory function is closely linked with the aspirational function. In order to understand the solution space, different design alternatives need to be understood in terms of underlying values and ideals. This links to Gaver's notion of aesthetic accountability: "Instead design can be defined by the aesthetic accountability of its outputs. Aesthetic here does not refer to a judgement of beauty, but to a holistic assessment whether a design 'works', functionally, conceptually, culturally, and aesthetically (in the narrower sense)." [18, pp194]. When it comes to the generative use of precedents in our educational programme, we believe we are paying enough attention to getting students to propose multiple alternative solutions, but not enough attention to teaching the student to account for the underlying values behind these designs. An exception is an exercise in which we ask students to identify a role model (i.e., a famous designer) in their specific profession and to analyse artefacts of their work to get a feel for how the elements in the design work

and start recognizing a personal style. We must expand on this practice and find more opportunities to train students to relate design alternatives to the underlying value systems.

4.4 Solutions as a strategy for (gateway to) finding effective mechanisms in design

A third reason to teach 'example solutions/precedents' in the educational programme, is that they embody proven rules of thumb, requirements, design patterns and guidelines. We convey ideas about what is effective using illustrative exemplars. The way we teach precedents as illustration of effectiveness of guidelines is subject to the critique in the previous section. We act as if design guidelines can be straightforwardly translated into effective design using a limited set of well-chosen precedents; implicitly conveying the linear, top-down, notion of design we are trying to avoid.

At some places, we have adopted an approach that is more in line with the complex thinking needed to incorporate different design prescriptions into a single design, thus celebrating the multiplicity of the solution–theory relationship. For example, we used annotated portfolios [14] proposed by Gaver and Bowers as a way to encourage students to spot design guidelines in the wild. Students had to create an annotated portfolio of original examples – none that were provided in class – for the application of psychological principles, such as social proof, or figure-background gestalt principles, in existing interactive media designs.

5 CONCLUSIONS AND DISCUSSION

In this paper, we have argued that design 'solutions' such as iconic designs, archetypes and design patterns, ought to be recognized as crucial forms of design knowledge: a necessary element of the students' 'solution repertoire'. However, well-known precedents in our field are insufficiently treated as such in academic (interaction) design programmes. By default, they are treated as examples of something else (i.e., a theory, a period), rather than as crucial elements of the knowledge base of aspiring designers in their own right. In this paper, we turned the tables and consider other forms of knowledge as instrumental to the mastery of solutions. This change of perspective allowed us to re-examine the ways we currently teach precedents to students, how we can teach them more effectively and how we can make them more explicit in our curricula.

Our current analysis reveals that our efforts to teach design solutions are isolated attempts in individual courses or initiated by a single teacher without follow-up. Design solutions are hardly used as a gateway to understand the problems we need to solve. They are used as a generative force in design, but with insufficient attention to the underlying values and design ideals – i.e., with insufficient theoretical understanding of the aspirations of those designs. We do use design solutions to teach design guidelines, but we can improve in doing so in a way that celebrates the multiple ways theory connects to design. We need to strengthen the students' understanding of design solutions in different ways. Knowing a solution, i.e., mastering a solution, means understanding it from different theoretical lenses and having ability to switch fluently between such knowledge ties.

We also think there is a need for a more systematic approach to build 'a solution repertoire' across the curriculum. Individual teachers already provide assignments that help students appreciate but we are in need of shared vision, a solution repertoire of the discipline, so to say. In the end students need to build a personal solution repertoire but this needs to be fed by the repertoire of the discipline. For this we need to extend the view on how precedents relate to conceptual knowledge and how this can be translated in productive exercises for students. We can implement a skills track in which students are taught to consider design solutions not just as solutions to an anecdotal problem, but in which they learn to categorize them based on relevant characteristics and to understand how each category (family) affords solutions for different kind of problems. Probably a good place to start would be to compile a 'canon of design solutions', including their family relations and family traits. Students need to understand how sets of design solutions are structured, and they need to learn to restructure those insightfully. This structuring and restructuring process fuels an intimate understanding of design solutions and an appropriation practice and design proficiency. Like any other skill: it takes a concerted and continued effort to make the concept sink in and make teachers and students understand that this goes beyond learning incidental examples by heart and beyond merely understanding the concepts that the examples are meant to illustrate. Existing design solutions are never *merely* examples.

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DESIGN CONTRIBUTION TO CONSUMERS KNOWLEDGE REGARDING HEALTHIER AND MORE SUSTAINABLE NUTRITIONAL CHOICES AT THE GROCERY STORE

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ABSTRACT
In Norwegian grocery stores, consumers encounter many accreditation labels. However, these rarely contribute to healthier or more environmentally friendly nutritional choices. This master's study analyses how product design may contribute to consumers knowledge regarding healthier and more sustainable nutritional choices at the grocery store. This paper contributes with a Norwegian perspective. The study also discusses the role of food and nutrition literacy as well as potential improvements in the educational system. Qualitative research methods such as empirical data collection, literature review and semi-structured interviews with an expert have been used to explore the field and gain insights. The raw data was collected using the empirical data collection method. The literature review laid the theoretical foundation for the paper, and three case studies were chosen. By analysing these cases, three possible product design concepts for the research question were identified: dynamic food labels, traffic light labels and visual clues. Finally, the concept mapping tool was used to visualise this new framework so that it can be used to strengthen cross-disciplinary communication between product designers and nutritionists. Findings from this study show a lack of cross-disciplinary collaboration between nutritionists and designers. This study has focused on understanding the problem area and revealing product design opportunities in the field. Future research may want to further explore the interdisciplinary problem area and consider involving a cross-disciplinary team.

Keywords: Product design, healthy nutrition, sustainable nutrition, labelling, grocery store

1 INTRODUCTION: INFORMATION OVERLOAD FOR CONSUMERS

Technological and societal changes have affected the way food is promoted, sold, and consumed. The number of products has increased significantly, along with the amount of information on the packaging. Some information and labelling is required by law, some is optional, and some is part of a marketing strategy. Globally, there are many different practices regarding the use of front-of-pack information. This paper will contribute with a Norwegian perspective. However, similar local studies should be conducted in other countries in order to understand the overall situation and to find the best solutions.

According to the Norwegian Consumer Council, more than 100 different accreditation labels can be found in a regular grocery store [1]. However, informing through labelling in this way does not seem to contribute to healthier or environmentally friendly nutritional choices by the average consumer. Conversely, a large number of colourful symbols in addition to other front-of-pack information may seem overwhelming. Many of these labels have a commercial look, and few of them inform consumers about what they represent or to what extent a product with a particular label fulfils the accreditation requirements.

According to the expert group behind the report 'Healthier food environments in Norway: Assessment of current policy and recommendations for further efforts' (author's translation), the occurrence of obesity cases is increasing in the Norwegian population [2]. In addition to that, food accounts for over a quarter (26%) of global greenhouse gas emissions [3]. This indicates that something has to be done to help people to make both healthy and sustainable choices. This master's study looks at how design methods can be used to help consumers make more informed choices.

2 BACKGROUNDS: PRODUCT DESIGN EVOLUTION AND NUTRITION

2.1 Product design evolution

The product design profession is constantly changing. Early product designers came from many different backgrounds and they were qualified to a design profession because of their artistic, decorative and constructive abilities [4]. The field of product design now requires other kinds of skills, such as listening, asking, understanding, and drafting new possibilities. The world of product design has evolved from studying things to studying humanity [4]. New product designers tend to be good at understanding complex issues, identifying core problems and selecting appropriate goals [4]. Furthermore, product designers tend to have the necessary tools to analyse information in order to find the best solution to satisfy the needs of all the parties involved in the system.

Design is an ever evolving field which ultimately reflects society [4]. In our technological age, with many complex challenges to handle, product designers play a significant role. The design of objects today is no longer restricted to form, function, material and production [5]. Products today tend to be more complex and more often part of a bigger system with multiple connections. Therefore, to make products that are relevant to society, product designers need to understand the wider, overall perspective. Fortunately, product designers do not stand alone in designing new products. The technological age has given rise to a greater need for and understanding of cross-disciplinary collaboration. While working together with other disciplines, product designers have the possibility to achieve a better understanding of the core of the problem. Examples of cross-disciplinary collaboration models can be found in many sectors [4], such as in communication technology sector, between technology experts and designers from different fields, or in the healthcare sector.

2.2 Challenges regarding to nutrition

Climate change and diet-related diseases in the population are some of the most debated topics today. People are informed about these issues in the media. Nevertheless, it seems that society does not know how to contribute to making the situation better. What is needed to help society overcome these challenges?

Food production, transportation and storage of food waste contribute to greenhouse gas emissions and, thus, to climate change. This accounts for 70 per cent of all water consumption [6], which means that society needs to find more climate-friendly ways to distribute food. However, how do we get people to care about climate changes that they do not see? One way is to link it to something that has a direct impact on them, such as a healthy diet.

Both climate and diet-related challenges have a major negative impact on society. To succeed in combating these, they should be seen in conjunction with each other. The expert group behind the report 'Healthier food environments in Norway: Assessment of current policy and recommendations for further efforts' states that: 'A change in diet will both provide a significant health benefit and may help reduce greenhouse gas emissions.' [2].

In this project, the Norwegian grocery store was chosen as the core of the system. It is a meeting point between the other sub-systems: consumers, suppliers, manufacturers, and the Norwegian authorities. The research question was, therefore, as follows: How can product design contribute to consumers knowledge regarding healthier and more sustainable choices at the Norwegian grocery store?

3 METHODS: UNDERSTANDING THE CONTEXT

3.1 Methodological triangulation and qualitative research methods

In this study, methodological triangulation was used to map the richness of the field by studying it from more than one standpoint and by using several data collection methods [7]. Research methods such as qualitative data collection through observation, a thematic literature review and semi-structured interviews were used to explore the field and to gain new insights. According to Muratovski, such qualitative methods are suitable for gaining an in-depth understanding of a particular problem [4]. Observation was used to collect the empirical data at the very beginning of the project [8]. A thematic literature review was conducted to study what is already known and what has already been done in the field relevant to the research question, as well as to identify areas that need further investigation [4]. Semi-structured interviews were chosen for more natural conversation, using a few pre-written open questions to allow the interviewees to add their thoughts continuously [9]. Finally, all the findings were

visualised using a concept mapping tool. This method helped identify the main findings from all the above-mentioned methods and to analyse the information collected [10]. Data collection and analysis of the findings were carried out in parallel throughout the research process.

4 FINDINGS: LACK OF COMPETENCE

4.1 Empirical data collection through observation: Research in the field

Empirical data collection consisted of observations made in a local grocery store and brief discussions conducted with the employees. This method aimed to investigate how easy or complex it is to buy food that is both healthy and environmentally friendly.

First, an examination was conducted of what kind of environmental and health-related labels were placed on various food items. A large variety of labels was observed, some of them well known, such as the Keyhole label and the EU Ecolabel. However, many of the labels were less familiar or difficult to understand. Examples were found of misleading labels used as marketing ploys.

Another observation made was the lack of knowledge among grocery store employees, who were not required to know about the nutritional content or environmental impacts of the items on sale. This limits the help available to customers while doing their daily shopping.

4.2 Literature review: Existing knowledge and case studies

Relevant and updated literature from 2019 and 2020 was reviewed to gain more information about the state of knowledge in the chosen area of interest. The chosen type of literature review was thematic. The purpose of this type of review is to examine various perspectives related to the question [4]. However, the literature review only provided a snapshot of the current state of knowledge in the field, since it is continuously changing [4]. The main keywords used in the literature search included: 'product design', 'design', 'nutrition', 'food', 'sustainable food' and 'healthy'. Emphasis was placed on literature that focused on both environmental and nutritional information. The Web of Science database was used for the literature search.

The reviewed literature contained the following articles: 'The effect of dynamic food labels with real-time feedback on diet quality' [11], 'Show me more! The influence of visibility on sustainable food choices' [12], 'Traffic light labelling of meals to promote sustainable consumption and healthy eating' [13] and 'Healthier food environments in Norway: Assessment of current policy and recommendations for further efforts' [2]. The reviewed literature laid the theoretical foundation for the paper. Three articles included case studies that contributed to learning from examples of solutions relevant to the research question [14]. In this study, the focus was specifically placed on an article that was published in autumn 2020 and that attracted wide attention from the Norwegian authorities and media. Furthermore, Liv Elin Torheim, Professor of Public Health Nutrition, who has led the research project behind the report, contributed to this master's study by being interviewed.

4.2.1 Case study 1 – Dynamic food labels

The first case study investigated the effect of dynamic food labels with real-time feedback [11]. The chosen arena for analysis was an online grocery store. The dynamic food labels consisted of front-of-pack (FOP) labels with information about nutrition combined with real-time feedback on the overall nutritional quality. The results from experiments conducted by this study indicated that the use of dynamic food labels with real-time feedback had a significant impact on the nutritional quality and had decreased the total amount of sugar per shop. The proposed FOP labels had a nudging effect on a behavioural change towards a healthier nutritional choice. Even though this study had no direct environmental focus, the proposed solution also has the potential to implement sustainability elements.

4.2.2 Case study 2 – The influence of visibility

The second case study investigated the importance of visual clues in an in-store environment [12]. In this study, experts performed a field experiment in a butchery located in a supermarket. The size of the display area and the quantity of poultry products on display were increased, while the size of the display area and the quantity of less sustainable meat products such as pork, beef and prepared meat dishes were decreased. During the nudging intervention, the sales of poultry products increased, while the sales of less sustainable meat products did not change. When the size of the display was reverted to its original size, the sales of poultry products decreased again. This experiment indicates that by changing the size

of the display area and the number of products displayed it is possible to create a shift in consumers' purchase behaviour. However, more research is needed to find out what might reduce purchases of less sustainable meat products.

4.2.3 Case study 3 – Traffic light labelling

This study tested the effect of traffic light labelling attached to different meal options as an indication of their impact on both the environment and health [13]. The chosen arena for analysis was a hypothetical simulated canteen. The results from the study show that, compared to baseline, the presence of traffic light labels led to positive shifts towards lower carbon emissions and lower calorific content meals. The study also found that the best effect can be achieved not by using traffic light labels alone, but by combining these with additional information. Even though this study focused on a canteen, the solution might also be implemented in the grocery store context. The study focused on both the environmental and health aspects, something which few other studies have done before.

4.3 Semi-structured interviews with an expert

To gain a deeper understanding of the theory and to get a professional view on the chosen topic, two semi-structured interviews were conducted with Professor Liv Elin Torheim, a professor of public health nutrition at OsloMet - Oslo Metropolitan University. She is also one of the experts behind the report 'Healthier food environments in Norway' published last year. The semi-structured form of the interviews provided an opportunity to uncover areas and theories that were not identified through the empirical data collection and literature review. The first interview was more general and consisted of an open discussion around the topic of nutrition, theories behind the previously mentioned report, as well as a brief introduction to the design profession. Torheim referred to some relevant research and case studies that were relevant for this project.

The goals for the second interview were to go more in-depth in the areas touched on during the first interview and to ask more concrete questions. In this interview, Professor Torheim explained some of the challenges to eating healthily, such as being more expensive, and because it takes more time to prepare healthy food. Additionally, grocery stores are often designed to push consumers into unhealthy and unsustainable directions by, for example, using appealing packaging or placing products rich in sugar and salt in the add-on sales areas close to the checkouts. This interview strengthened the findings from the empirical data collection in the field. Food chains use design methods to find out what buttons they need to push in order to make us buy their products. Torheim proposed that nutritionists need to use the same kind of tricks to nudge consumers towards more sustainable and healthier nutritional choices. More involvement of design expertise in the nutritional field may be a solution.

5 DISCUSSIONS: PRODUCT DESIGN CONTRIBUTION

5.1 Products as part of complex systems

Data collected during the observations in the grocery store and the literature review show that despite the large amount of different labelling on food items, customers still have issues connected to choosing both healthy and environmentally friendly foods. When several organisations create their own labels, consumers can become confused and overwhelmed. In addition, the interviews with Professor Torheim show that grocery stores are not designed to contribute to sustainable food choice. Conversely, graphic design tools such as visual presentation on products is being used with the goal of selling more and making money. However, there seems to be a need for more product design involvement in the Norwegian grocery store to help consumers make higher-quality nutritional choices.

Products are complex and are often a part of a larger system. Before products arrive at the grocery store, they have to be designed, tested, manufactured, packed, transported, in some cases advertised, before being placed on the shelf.

Many people, sectors and even countries are involved in this system. For a product designer it is more important than ever to understand the whole system in order to make products that are easy and cheap to produce and that deliver profit, meet sustainability goals, comply with regulations, are convenient to use and that look attractive to consumers. In addition to this, product designers have to take ethical considerations into account and think about the usage phase and the end of the product's life. Product design is about much more than just designing a single product.

5.2 Product design contribution to the field

During the interviews, Professor Torheim commented that nutritionists 'do not know what expertise designers have and what can they be used for'. Additionally, none of the analysed case studies from the literature review mentioned designers in their reports. However, there are many possibilities for a product designer to contribute to positive changes when it comes to consumers choosing both healthy and sustainable food items in grocery stores.

Through the case studies, three possible concepts were found: dynamic food labels, traffic light labels and visual clues. These concepts form the foundation for a possible product design solution. Elements from these concepts could be combined in order to create the best solution. The concept map bellow (Figure 1) visualises the connections between the above-mentioned concepts. A visualisation tool was chosen to conceptualise the framework [10] and is intended to be used to initiate cross-disciplinary communication between product designers and nutritionists. Product design was placed in the centre of the map to show that product design expertise can be used when implementing these solutions as well as when developing new solutions based on findings from these case studies.

In the interviews with Professor Torheim, some examples of projects where product designers and nutritionists could collaborate were discussed, such as developing the appearance of a new type of packaging, reorganising grocery stores and analysing the entire customer journey from meal planning to entering the store. These examples were placed in the concept map below product design to illustrate the ways in which they might contribute.

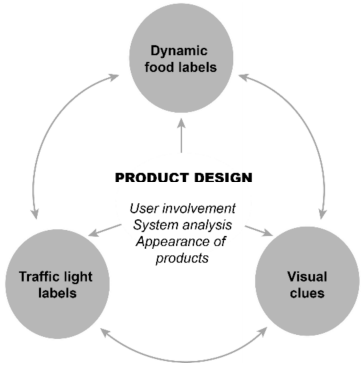

Figure 1. Concept map – visualisation of a new framework

5.3 Need for changes in design education

Grocery items such as prepared meals and pizzas often have packaging with space for illustrations and necessary information. However, grocery items which nutritionists want us to consume more of, such as fish, vegetables, and fruit, do not come with instructions on how to prepare them. Professor Torheim sees a need for food and nutrition literacy. The educational system should contribute to increasing interdisciplinary knowledge in order to promote healthy food making and healthy food eating. Without this type of knowledge, consumers might face many barriers when it comes to changing to a healthier and more sustainable diet. The product designer can help shift the focus to food and nutrition literacy in the educational system with the help of nutritional experts. Many design education programmes have traditionally been modelled on fine and applied arts [4]. However, cross-disciplinary research, technological development and critical thinking in the field of design are creating new opportunities for the new generation of designers [4]. These new product designers can be used in several kinds of projects because of the skillsets they have in analysing complex systems and in using a holistic design thinking methodology and a user-centred approach. Therefore, the professional field of design and design education programmes should enhance communication with other disciplines regarding the new skills and qualities the product design profession can offer, as well as how designers can contribute to different projects.

6 CONCLUSIONS AND SUGGESTIONS FOR FUTURE DIRECTION

Findings from the case studies and the semi-structured interviews show a lack of cross-disciplinary collaboration. Both healthy eating and sustainability are complex issues, and contributions from

different fields of expertise are needed to find the best solutions. By involving product designers in their work, nutritionists may develop solutions that are more appealing to consumers and find creative ways to engage healthy and environmentally friendly food consumption. However, a better understanding of the different professions and their respective terminologies is needed to achieve more cross-disciplinary collaboration. The framework presented in this paper connects existing concepts – dynamic food labels, traffic light labels and visual clues – and suggests using product design expertise when implementing these or new solutions for healthy food consumption.

This pilot study has focused on understanding the problem area and revealing product design opportunities in the field of healthy and sustainable nutrition. However, further research could include closer investigation of what lies behind consumers' food purchasing decisions. Such future research might want to explore the field and problem areas in more depth to conduct similar studies in other countries. A cross-disciplinary approach might be fruitful in further studies of this subject, given the complexity of the field.

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MACHINE DRAWING: TROUBLES AND OPPORTUNITIES IN MANAGING LABORATORY ACTIVITIES IN AN ONLINE CLASSROOM

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ABSTRACT
Since Learning Management Systems (LMS) appeared some 20 years ago, their experimentation grew slowly, compared with the explosion that occurred after the Covid-19 emergency. Due to the closure of schools and universities worldwide, every educational institution and their teachers had to move towards the usage of LMSs for Online Distance Learning (ODL). This obliged the teachers to quickly familiarize with such kind of didactics and every kind of course faced these new opportunities. Machine Drawing is a course that requires much interaction between teachers and students and may not exploit validly many modalities invented in LMS. This paper presents the experiences done implementing online didactics, trying to apply all the online tools to the traditional way of teaching. Mainly laboratory activities, made online, must reproduce the interaction made in-person. Nevertheless, online connections opened new ways to try stricter relationships between the teacher and those students, who have less skill, even shyness, and then may accumulate delays. Differentiating the way in which didactics (lecture and laboratory) may be delivered, some traditional techniques have been improved. Employment the video recording of all activities done has given students the opportunity to repeat the more delicate steps of some topics. The check online of designs and elaborations by instructors allows students to be more concentrated on explanation, which may be done collectively or singularly.
Comparing the results of exams before and after online didactics revealed that the number of students that passed the exam and the average of reached grade grew significantly.

Keywords: Machine drawing, online classroom, virtual class

1 INTRODUCTION

Pandemic Covid-19 emergency has sped up universities towards the adoption of Learning Management Systems in order to avoid the physical interaction of students, among them, and with teachers [1, 2]. Several are the software platforms able to build virtual classes in which the relationship between people is mediated by the web. In the specific case of Machine Drawing teaching, the organization of the course syllabus creates a lot of problems to the three types of conjoint activities that must be scheduled: lectures, laboratory, and tutoring.
Lectures are typically made as one-many relations. Really teachers explain the arguments with little interaction with the audience.
Tutoring is a one-one relation, in which every student has the opportunity to ask for clarification on not understood or misunderstood topics.
Laboratory is the moment in which the hands-on learning activity is performed and when the knowledge of all significant topics related to machine drawing and design is transferred: how to think about an architectural arrangement of components to reach a design solution for an engineering problem.
This last one would have been really problematic if it were not done with in-person meetings. Till now, in fact, the course of Machine Drawing has been performed, always in wide classrooms with many tables with many students around them and with teachers that exchange information with single or few persons at a time. The authors began to employ Microsoft Teams™ to manage the virtual class when pandemic emergency started, with all activities performed online. The paper describes the way in which the whole teaching and overall laboratory has been performed.
In order not to lose the manual nature of most of the activities, the hardware setup continues to be blackboard-friendly. The teacher uses hand drawings, both on a sheet of paper and on the blackboard,

positioning a webcam in such a way that students, online, can follow the talks from a point of view very similar to that of the teacher.
The paper describes the new organization that have been implemented in two courses of Machine Drawing in two Bachelor Degrees: Mechanical Engineering and Management Engineering.
The new courses organization will be compared with the old ones. The assessment of the quality of participation and of the exams result is done only for the Management Engineering course, which completed in the first semester.

2 GENERAL ORGANISATION OF THE COURSES

Both courses of Machine Drawing are positioned at the second year of the Bachelor Degree. It is a 12 ETCS for the Mechanical Engineering curriculum and 6 ECTS for the Management Engineering one.
The Course for Mechanical Engineering is organized along the whole academic year and is divided in two modules.
The first module is addressed to the basis of design, drawing typically single parts. The second module is focused on the assembly design. The topics range from geometric construction to orthogonal projection, from axonometric representation to sections, from identification of true geometric form of objects to the development of their surfaces, dimensioning. The connection between the two modules in which is subdivided the course consists in the first step of the reverse engineering process in which students have to make a drawing from a real object. This activity allows students to apply for measuring by a calliper, recognize the true dimensions, organize the viewpoints for 2D and axonometric representation. Studying the morphologic aspect of an object, the embedded manufacturing processes and their errors are revealed. This allows the teacher to introduce almost naturally the concepts of tolerancing, even dimensional as geometrical. The work continues with design for manufacture, geometric dimensioning and tolerancing, stack up tolerances, identification, and functionalities of typical machine components.
The week schedule is as follows:
3H Lectures – 2H Practice – 2H Laboratory.
3H Lectures held in one day in which the theory is explained with all the elements necessary to implement it.
2H Practice on CAD in which Autodesk Inventor™ modeler is introduced to students with the task to become skilled in solid model and "drawing" of single parts and/or assembly.
2H Laboratory where all the topics are elaborated by examples and performed by the usage of traditional tools or freehand.
All the pre-pandemic activities were performed in classroom by physical interaction between instructors and students.
Due to the pandemic Covid-19 emergency, all the activities have been transferred online. The software employed in this new way of teaching is Microsoft Teams™. Learning has changed the aspect due to a different relationship instructors-students, considering that people do not share the same physical space of a classroom. The classroom has become virtual, and communication was possible only by means of tools and internet connection.
Microsoft Teams was configured for online teaching. The Team "Machine Drawing" contains several channels: Lectures, Practice on CAD, and Laboratory. Students are invited to attend one of these activities in a meeting following the weekly schedule.
The same organization has been provided for the Course for Management Engineering that lasts only one semester.

3 MACHINE DRAWING COURSES: LABORATORY ONLINE

The 2H Laboratory continues to be divided into two shifts [A-L] [M-Z], in order to manage a limited number of students per shift. The numbers of students in the class has historically been the problem that affected the communication for this kind of course. Contrary to all other courses of the engineering studies, to guide students to be skilled for drawing involve a great number of contexts: cognition, abstraction, identification of forms, the relationship between sign and signifier.
The Laboratory is the time where all practical problems are faced and neatly explained to all people for the first time and then, to each people individually how many times is required.
During the pandemic emergency, the laboratory has been performed online, collecting students in channels of Teams, where all appeared in their place with their work in progress. Each webcam was on

to show both the student and his/her work. The instructor had the possibility to see all students in a collection of pictures. Along the time of 1H, each student had the possibility to show his/her work if this required a refinement or if there was any point not well understood.
Collecting the problems that emerged during the first part of the time instructor had the possibility to explain or repeat some concepts not well understood, or correct typical mistakes. This part is oriented to solve collective problems that involve a great number of students.
In case of some very complex mistakes, each student was invited to an individual meeting in a different channel dedicated to "meeting online", where, at a different time, other than that of the course schedule the root of the problem was identified. Such individual meeting is necessary because otherwise, if class time is employed, many other people may distract their attention and the time is wasted. More than in-class teaching, the online performances may have many sources of distractions, that remain hidden to the instructor, that may continue to talk about some topics whereas people may be occupied in others.

3.1 Homework

Every two weeks a new homework is assigned. The task is assigned as an "Activity" on Teams, with a deadline well declared. During this time, students may work at home and during the Laboratory.
After the conclusion of the activity, the works must be loaded on Teams. The works are corrected, and an assessment is sent to students.
Homework's are designed to grow competencies in drawing and are a prerequisite to attend the exam. The assessments done along time do not contribute to the final grade. The drawings assigned as homework are instead used also as a starting point of the discussion in the oral part of the exam. If sometimes, and it may occur, some mistakes remained on drawings, students are invited to correct them in real-time.

3.2 Laboratory activities organization

The Laboratory starts when the instructor opens a session on Teams, in the proper channel. The instructor explains the key points of the drawing, opening a file or an app that contains suitable materials. He/she may draw something by freehand, capturing the scene by a webcam positioned orthogonally to the sheet of paper or the blackboard. Sometimes lectures have been performed by teachers in the classroom alone, without an audience in person, using a webcam that catches what is sketched on the blackboard.
Students, in order to show their works, previously have to take a photo of the drawing on which they are working. The photo must be clear, with no distortion, and well illuminated without shadows. This image file may be uploaded to the repository on Teams, where it may be opened by the teacher using e.g., Autodesk SketchBook™. At this point instructor may write, draw, or highlight the elements that require adjustments, insights, or big changes.
This revision is performed on one drawing at a time, and it is explained to all the audience, i.e., to all the people that are connected at that time.
Really interesting in all the activities performed online is the possibility of recording the event in a video. This may be reproduced by each student at any time in asynchronous mode and repeated as many times as they want.

3.3 Relationship teacher-students

On the contrary of teaching in presence, where all the activities are performed in a classroom and the relationship among the attendees is direct and at close contact, online methodologies physically separate persons and at the same time make their relationship closer [3, 4].
This is a surprising contradiction. Feeling close but being really distant at an unknown place.
What remains always the same is the time when the meeting occurs. People decide to share the time and the meetings became a happening where different relations may be started.

3.3.1 Relationship one-many

Typically, a lecture is characterized as a relationship one-many. The teacher starts the lesson at an established time and waits that all students registered at the course connect themselves to the channel. The talk may be direct, speaking straightforwardly, or opening documents/images to be shown. Each event is recorded by Microsoft Stream™ and reopened at a second time to see it again. It is necessary

to check frequently if the audience is proactive, asking students questions and checking if something requires to be repeated or explained in a different way.

3.3.2 Relationship one-one with audience

The task of the laboratory consists of supporting students to understand the topics they have listened to in lessons and to implement those topics in drawing exercises proposed in assignments. Each assignment has been conceived as a set of steps towards the final management of an assembly. Throughout the year a set of 8-10 assignments are proposed to students. For the Management Engineering course, which lasts one semester, the set is composed of 8 assignments.

One of the assignments, in both courses, consists of generating a drawing of an actual component by means of the reverse engineering techniques. The objects that have been proposed this year have been "Lego™ bricks". Students had to reproduce in a drawing two bricks that they had to measure by a calliper and draw as a single part and as an assembly. The difficulty of such activity is strictly related to "online didactics". Generally, in presence, a limited group of students (a team of 3/4 people), each at a time, uses measurement instruments of the Department workshop. Now, working online, it is necessary that everyone, individually, has a calliper and two bricks available in the place where they are working and are connected. Each student, online, should gather information by taking measurements and organize the representation.

All the assignments have been reviewed in the virtual classroom, discussing the drawings made by students. For each assignment, a set of up to 20 students have been raffled off, which delivered the solution to the instructor for a succeeding discussion in a live online session. All the delivered solutions, previously examined by the instructor in order to find, mark and classify the errors, have been illustrated and commented on. The major and more significant mistakes are presented, examining each assignment delivered and speaking directly with the author. Nearly all the typical mistakes that can be made in each type of task have been identified among all the deliveries. Besides the "one-one with audience" meeting, an *errata/corrige* file that collects all such typical errors in each assignment is added to the repository of Teams, to be consulted by students every time they feel it necessary and commented on by the instructor in the laboratory session.

Observing each drawing, the instructor intervenes by talking with the responsible student, considering that all other students connected have the possibility to listen to suggestions. This kind of relationship, which in presence could have been possible only interacting with very few people at a time, required that such answers should have been repeated many times, boring the instructor with such repetition.

Now new dynamics may be used. The relationship one-one with the audience does not put a limitation on the dimension of the audience. This gives more enthusiasm to teachers, considering that even a question has to be repeated, this can be done from different points of view, and this enlarges the argumentation, even introducing concepts not previously considered. Thinking also to the video recording of the session, all reflections made during the laboratory may be listened to again and this shortens the time of task completion.

3.3.3 Relationship one-one alone

During the laboratory, some personal difficulties may emerge, that teacher observed for a limited number of students. This is the time to activate a personal relationship instructor-student, organizing a separate session, other than the week timesheet of the course. A suitable team of "student receiving" is organized, where these students are invited to attend. During such sessions, more freely, the problems that emerged during the laboratory may be faced. Video recording is not necessary, now, because all the suggestions, that are shown on notebook display, may be directly captured by students.

A typical drawback of online didactics is the loss of discretion, in that a lot of people, when they would ask for something, are conscious in advance that many people can hear that. This kind of people lives badly such loss of "privacy", for shyness probably, and continues to accumulate unresolved problems. This special team has been created to allow such kinds of person to be involved in the process of learning. The time occupied in this activity must not be considered a waste of time, because drawing is a process that requires a special motivation, and this must be sustained in all ways.

3.4 Laboratory activities deployment

In order to achieve the proper preparation for the exam, the student is required to carry out some tasks at home, with increasing difficulty; these consist of 10 assignments, which are made with traditional

tools, and someone in addition with 3D CAD. Each assignment is correlated to the lectures just delivered, which have been presented by the teacher, pointing out the crucial aspects in specific sub-tasks.
The presentation of each assigned homework is done in the virtual classroom according to a typical one-many relationship, conveyed by the web.
Each assignment has a deadline every two/three weeks, along the course, and the process of delivering the files related to the homework (both input and output) is implemented by means of "Activity" in Microsoft Teams™.
Much of the work employed by the teacher consists of reviewing the assignments using a graphics tablet and suitable software and this is also done online, operating on scans of drawings produced by the students, or by showing a live session on the way to solve a drawing problem. All the events may be recorded for offline learning activities.
If the teacher finds particularly scant drawings, he/she calls the correlated student for a one-on-one meeting, in order to solve these major flaws.
The exam can only be accessed if the assignments have been completed, then verified and endorsed offline, step by step, by the teacher.
When the course is delivered over two semesters, the teacher may verify the level of preparation achieved by the students by proposing an intermediate test at the end of the first semester, non-binding for the final grading, in order to assess the possibility, eventually, to recall and refine some topics.

3.5 Practice on CAD

Conjointly to the topics treated during lectures and assigned as homework, the introduction to CAD modeler proceeds with the same scheduling. Every week the 2H of Practice on CAD is organized as a sequence of two or three steps of growing difficulty around the functionalities of Autodesk Inventor™. The practice alternates the explanation of a topic and its application, followed by an exercise that may be performed by students. After a certain time (e.g., 20 min), the exercise is developed by the instructor. The way proposed online reproduces quite the same one as that of the in-person lecture. The only improvement is the video recording of the events, which aids the practice of the right sequence of steps.

4 RESULTS AND DISCUSSION

The comparison of the performances of both didactical methodologies, in-person and online, that have been employed, may suggest some consideration. Data have been collected from the course for Management Engineering that has been delivered in the first semester. Data have been surveyed and compared taking into account two academic years: 2019-2020 (pre-pandemic) and 2020-2021 (pandemic). In Table 1 the following parameters are summarized:
Attending didactics activities. In 2019-2020, an average of 116 students attended the course. In 2020-2021, only an estimation of the attending students may be reported, due to some lacking in the right functionality of the software for checking the presence; so, it may be appraised an average of 122 students attending the course. In this second case, it must be considered also an average of 135 visualizations of each recorded lesson.
Attending examination. In 2019-2020, 113 students attended the exam in Jan-Feb 2020. In 2020-2021, 94 students attended the exam in Jan-Feb 2021. This is not a significant decrease because it may be considered that in the Italian academic year scheduling the exams may be faced also at end of the second semester. So, this data cannot be associated with a student dropout, but just with a delay.
Passing examination. In 2019-2020, 73 students passed the exam. In 2020-2021, 70 students passed the exam.
Percentage of passing examination. In 2019-2020, 64.6%. In 2020-2021, 74.5%.
Achieved grade (in the 30-point scale). In 2019-2020, an average grade of 25.0. This value is almost similar also with those obtained in the two previous pre-pandemic years. In 2020-2021, an average grade of 27.7.

Table 1. Results of the survey on the activities related to the course of "Machine Drawing"

Academic year	2019-2020	2020-2021
Attending didactics activities	116 (certified average)	122 (esteemed average)
Attending examination	113	94
Passing examination	73	70
Percentage of passing examination	64.6%	74.5%
Achieved grade (in the 30-point scale)	25.0	27.7

A certain discordance can be noted for the number of students that attended the didactics activities. In previous years, in presence, the detection happened by a physical device and immediately checked by teachers. Now in online didactics, the attendance may be faked, without any possibility of efficient control.
As it can be seen the new methodology gathers two important outcomes: 10% of growth in the number of students that passed the exam; 11% of growth in the grades obtained at the examination. This last result is almost astonishing because introducing other grades, the identification with letters gives a jump from B to A for ECTS grade or a jump from B+ to A for U.S. grade.
This is not associable with a simplification of the exam, because, as for how the exam is conducted, the possibility of cheating is somewhat limited by the effort made by the examiners in requesting and evaluating skills in practical drawing even during the oral phase of the exam.

5 CONCLUSIONS

The experience described in the paper and the results discussed may suggest that some online methodologies will remain even when the pandemic emergence will be solved. Some new relationships have been proved more fruitful than in the past, even for a course like Machine Drawing where a certain degree of interaction between teachers and students is necessary. Probably without the forced obligation for online teaching, such kind of methodology would not have been willingly used for the course of Machine Drawing. Perhaps also the massive use of smart working created the right condition for a greater amount of time spent by teachers on didactics.
The results presented are associated with one of the two courses on which the experimentation has been performed. It will be interesting to analyse the same parameters for the course that develops over the whole years, after the examination of the next summer session.
A further element of reflection could be the students' opinion, even in terms of teacher professionalism assessment as in terms of suggestions that students may freely offer for further improvements. In the survey of this year, a set of special requests have been added in order to check the impact of online teaching on students' life.
This work aims to be a stimulus for other colleagues to share similar experiences in order to innovate and/or confirm the methodologies of teaching in a course of Machine Drawing.

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STUDENTS PERSPECTIVES ON CHALLENGES WITHIN MULTI-DIVERSE DESIGN TEAMS

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ABSTRACT
In the IPD Master's in Industrial Design Engineering (TU Delft) we see a growing diversity of students. We see the international student population growing, but also see significant differences in prior education, socio-emotional aspects, and competences. Within the Advanced Embodiment Design (AED) course, students work in teams on a client-based design project for a full semester. In 2018-2019, 22 student-teams started out their endeavour, coached by eight coaches. On a weekly basis the coaches tracked the teams' performances by means of six key performance indicators. The weekly logs are aggregated, converted, and visualized in a performance dashboard which was used to lead the discussion on troublesome teams and solutions to get them back-on-track. In this cohort four fields were found: (i) cultural differences; (ii) differences in design approaches; (iii) emotional differences; and (iv) differences in student competences. These typical problems were the result of our own coaches' perspective, and not so much from a student's perspective. To really get a grip on team dynamics and issues involved, we wanted to know what students come across when functioning in a multi-diverse team. In this paper we present our exploration from students' perspective by evaluating the end-of-course reflections. The goal of this research is to learn about the most occurring issues within multi-diverse teams and come to applicable solutions to help teams during the project. We started out with a word cloud to find the most common terms and use those as labels for clustering. 308 unique students' quotations were labelled and clustered into three main clusters based on project management, emotional interaction and interdisciplinary, and 11 subclusters. The clustered data revealed interesting results in terms of (sub)clusters as well as their relationships to each other. Visualizing the associations between the subclusters show for example that lack of clear consensus on leadership causes challenges from various aspects leading to difficulties in role agreements, task concerns and design approaches, as well as managing individual behaviours. Despite initial assumptions, Cultural Differences led to the smallest number of challenges but scored high in terms of relations with other clusters. In this paper we will present our findings on the issues clustered and the prioritization of importance. We will discuss the relationships between the clustered student challenges, and review solutions which can help them out in becoming highly performing teams.

Keywords: Multi-diverse, teams, lessons learned, reflection, team dynamics

1 INTRODUCTION

In the IPD Master at Industrial Design Engineering (TU Delft) we see a growing diversity in students. We see the international student population growing, but also see significant differences in prior education, socio-emotional aspects, and competences. Within the Advanced Embodiment Design (AED) course, students work in teams on a client-based design project for a full semester. In 2018-2019, 22 student-teams started-out their endeavour, coached by eight coaches. On a weekly basis the coaches tracked the teams' performances by means of six key performance indicators. The weekly logs are aggregated, converted, and visualized in a performance dashboard which was used to lead the discussion on troublesome teams and solutions to get them back-on-track. In this cohort four operational problems were found: (i) cultural differences; (ii) differences in design approaches; (iii) emotional differences; and (iv) differences in student competences [1]. These typical problems were the result of our own coaches' perspective, and not so much from a student's perspective. To really get a grip on team dynamics and issues involved, we wanted to know what students come across when functioning in a multi-diverse design team. The goal of this research is to learn about the most occurring issues within multi-diverse teams and come to applicable solutions to help teams during the project, by building a

framework to improve coaching of these teams within the context of this course. We started out exploring the literature surrounding the functioning of design teams and found different models describing the process. A well-known model of teamwork is the Tuckman model [2] of Forming-Storming-Norming-Performing-Adjourning also addressed in Teamwork's [3]. The nature of this model is hierarchical where the following step can only be reached when the previous is accomplished. AED design teams have a more developmental dynamical nature where social processes and context often change. According to Miller [4] groups can be viewed as systems and in today's society and design challenges, personal and group related processes of creativity, introspection and intuition are more prominent [5]. Therefore, to frame team dynamics within the context of the AED course, and identify relevant issues and hurdles within multi-diverse teams we started out with the Lencioni's Pyramid [6,7]. The Lencioni pyramid model is based on his own experience as a business entrepreneur, where he distinguishes five levels for teams to function and excel. Although not scientifically backed up, it is a model embraced in team management. Teams build on trust (level 1), which makes them engage in healthy conflict (level 2), where clear goals help the team member to develop commitment (level 3). Peer to peer contact creates accountability (level 4) where finally team-members focus on the team results instead of personal gains (level 5).

The model of Lencioni has several similarities with the more science-based Theory U developed by Scharmer [8]. Scharmer dives deeper into the reasons behind the functional 'presencing' teams and how to turn around dysfunctional 'absencing' teams. Both provide similar aspects in their framework for teams dealing with differences in competencies and design approaches. According to the Theory U model for team development, all teams go through five stages when developing innovations. There are two opposing processes: (i) Presencing, where teams collaborate and embrace emerging possibilities, and (ii) Absencing, where teams disconnect and counteract in problem solving. Three elements are relevant for both processes and can be either open or closed. The 'mind' refers to the (non) judgement of team members based on prior experiences. The 'heart' refers to either emotional connecting or cynicism between team members. The 'will' involves the ability of teams to act in an instant. Scharmer also identifies a team working in the middle of the extremes where teams are neither present nor absent and just 'muddle through.' The model of Scharmer is a promising model to identify dysfunctional teams and will be used for future cohorts to track the team performance, identifying issues in team dynamics and turn around dysfunctionality.

The design teams consist of students with different preparatory schooling and often have different views on the design approach. Most teams also consist of a diverse group of nationalities which made us include this aspect in our research. In 'The Culture Map', Meyer [9] describes a model that defines eight key areas where cultures vary along a spectrum from one extreme to its opposite. The Culture Map provides a framework when student teams are dealing with cultural differences. By analysing the position of cultures relative to each other, team members are enabled to decode how culture influences their collaboration. The extremes on each scale are a continuum and within the range of behaviours of a given culture, individual differences will occur. The goal of the model is to support team members interacting with each other, to watch more, listen more and speak less.

As the goal of this paper is to build a framework to improve the coaching of multi-diverse student design-teams, we explored whether the above frameworks work, and how they work, within the context of the course. Therefore, we researched the students' perspective on team-dynamics by evaluating the end-of-course reflections from our students of cohort 2018-2019.

2 APPROACH

The first step consisted of collecting students' data, which is useful to get an insight into the student perception and their issues when working in multi-diverse teams. We collected data from 117 master students following the master course Advanced Embodiment Design. Students work in teams of 4 to 6 people, on a client-based design project for a full semester in the period between February to July 2019. The student teams are supervised by teachers on a weekly basis. In addition to the content, the coaches coach mainly on group dynamics. The student teams run their own project within this 21EC course for a full semester. The students follow a complete process of embodying a product from prototype to near-production ripe product and have access to a physical studio to meet and collaborate on the project, simulating a real-life design studio experience. We asked our students to reflect on their work after delivering their course results. To get appropriate and consistent results we introduced our students to reflecting in week 16 of the semester, by means of a lecture to "become the best YOU", based on the

‘Reflective Practitioner’ by Schon [10]. During this lecture students were exposed to three reflection methods they could use, ranging from low-level reflection using Symbols, to medium level reflection using the ‘Kolb Learning Cycle’ or deep reflection using ‘Bateson Logical Levels’ as described by Gordijn [11]. The covered methods guided the students while writing their reflections, but the deliverable was up to their own interpretation, which resulted in rich qualitative information. We received 61 essays, of which 54 students returned individual student reflections and 7 were reflected with their team. All student reflections were based in retrospect on the challenges experienced as an individual and as a team.

To analyse all reflection essays, qualitative coding was applied. This method served the most applicable to gain deeper insights from essay-long textual information [12]. These documents were imported into ATLAS.ti, a qualitative data analysis software for further processing. We used labels to index or categorize text in order to establish a framework of thematic ideas [13]. Using the built-in feature of ATLAS.ti, a word cloud was generated out of the most occurring words from the student reflections which inspired the process of further labelling. After an initial exploration of the first batch of documents, common themes were formulated from the student quotations. Expressions or full sentences were labelled with codes that occurred from the student quotations. Because quotations can be labelled with multiple codes that also enabled the researchers to explore connections between different code groups.

After finalizing all essays and clustering 308 unique quotations under 11 labels, we counted the number of occurrences for each label. This results in a list of priority issues and hurdles for our students when working in multi-diverse design teams.

3 RESULTS

All the students were asked to write an optional essay based on the proposed reflection methods. We introduced our students to three reflection methods and most students followed the Symbol approach. More than half of the students (61) running the course uploaded an essay on our education platform, of which 54 essays were written on a personal level and 7 were group based.

Figure 1. Word Cloud made from all reflection essays

From the student’ reflection-essays we started out with a word cloud to find the most common terms and used this to inspire further labelling (figure 1). These words then served as input to systematically group the labelled quotations and categorize them based on the co-occurred themes. We identified 308 unique students’ quotations, which were labelled and clustered into three main clusters and eleven associated subclusters:

1. **Project Management**, concerning issues with: Client Input; Progress Tracking; Coaching Influence; and Leadership Clarity.
2. **Emotional Interaction**, concerning issues with: Communicating Agreement; Managing Behaviour; Peer Feedback; Task-Related Concerns; and Cultural Differences.
3. **Interdisciplinary**, concerning issues with: Design Approach; and Previous Schooling.

Table 1 shows an overview of the main and subclusters together with the occurrences of these found subclusters in the students' reflection essays. It also gives example quotations taken from our students’ essays to get an impression of issues concerned with the subclusters.

Table 1. Overview of the main and subclusters, their occurrences and example quotations.

Main cluster	Subcluster	Occurrences	Example quotation
Project management	Progress tracking	52	"Besides, the results of the sprints were sometimes poorly documented causing trouble in later stages. All this sometimes led to confusion and loss of information."
	Leadership	31	"Because I like to keep a good overview of things, I felt a bit lost due to this sometimes. This caused me to lose a part of my sense of ownership over this project."
	Client input	21	"We had very little contact with them, while they could have steered us towards their desired direction. However, it must be stated that the client was very vague in what they wanted. They didn't have a clear vision or scope themselves, making it even harder for us."
	Coaching influence	19	"The coach was always on our side, trying to help us solve the issues we had. Whenever he felt like something was going wrong, he told us, and we could change accordingly."
Emotional interaction	Communicati on agreement	39	"This led to parts of the project not always being in sync with each other (e.g., things being interpreted differently by different group members, leading to conclusions/ parts of text that didn't fit together). I think this was partly due to lack of communication on some points."
	Managing behaviour	39	"I know that I am usually louder, so I try to make sure to take a step back and also ask others for their opinion if I feel that they are not being included."
	Task-related concerns	28	"I think we also lacked clear communication on this point, mainly what everyone was working on, how they were progressing and what else can be done."
	Peer feedback	19	"it was brought to my attention that the team noticed my drop in motivation towards the project. I agree that my motivation for it was a little low, as I felt like I was working on a dead end."
	Cultural differences	12	"I learned a lot about how to deal with different people and different cultures. Everyone does things in their own way and you need to find a way to combine those ways of working."
Inter-disciplinary	Previous schooling	27	"I also learned to work in a multidisciplinary team where everybody has a different skill set. Although most people mostly did what they were comfortably with and good at, we also took each other along and taught each other the needed competences."
	Design approach	21	"What I didn't agree with was how emphasis was put on certain things, while other things that I thought were more important were neglected."

A relationship graph was made by adding co-occurring cluster codes (figure 2). The clustered data revealed interesting results in terms of subclusters as well as their relationships with each other. In terms of Project Management, Progress Tracking proved to be the most challenging (22.7%) for students, while for Emotional Interaction both Communicating Agreement as well as Managing Behaviour takes

up 17.0% of the quotations each. Within Interdisciplinarity previous schooling (11.8%) within the project team seems to be an aspect to consider.

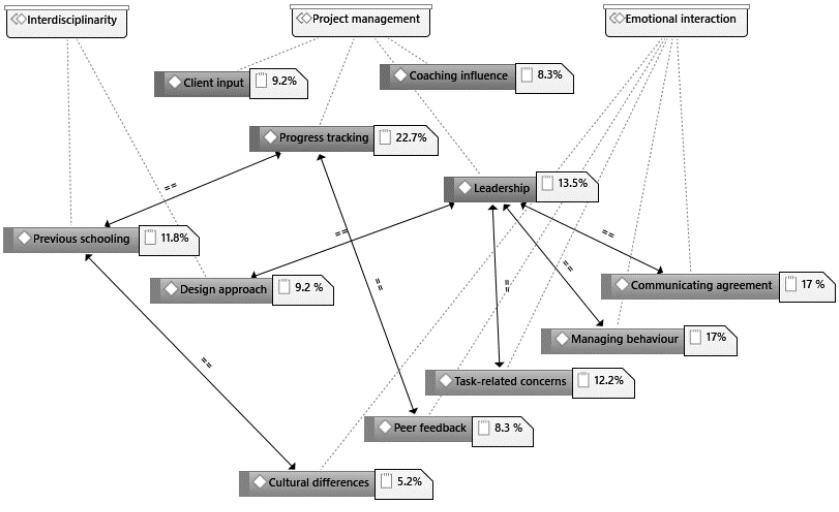

Figure 2. The relationship graph of all students' quotations clustered in three main clusters consisting of eleven subclusters

Starting the network with the main clusters, typically three or four subclusters are associated with each other by being mentioned in the same quotations. For example, the ability to be efficient in Progress tracking was associated with Previous Schooling which in its term was also related to Cultural Differences. The labelled data revealed that Progress Tracking is closely related to giving feedback among peers and previous schooling. Visualizing the associations between the subclusters shows that lack of clear consensus on leadership within the design team causes challenges from various aspects, e.g., leading to difficulties in role agreements, task concerns and design approaches, as well as managing individual behaviours.

Despite initial assumptions, Cultural Differences led to the smallest number of challenges (only 5.2% of the quotations referred to these challenges) but scored high in terms of relations to other clusters. In comparison, Client Input also has a smaller number of related quotations (9.2%) but also did not prove to be associated with other clustered challenges, and thus is of lesser importance.

4 CONCLUSIONS & DISCUSSIONS

In this paper we have discussed the students' perspective on team-dynamics and the issues they come across. In our previous research [1] we identified the key issues concerning four types of diversity (cultural, design approach, emotional and competencies). In the current paper we have researched the student perspective on issues when working in multi-diverse design teams. By qualitative coding of 61 reflection essays, we identified 11 subclusters of issues, where three subclusters were identified as the most troublesome to student teams: Progress tracking, Communication agreement and Managing behaviour. In general, this means that the coaches need to pay attention to the following aspects while coaching the student design teams: (i) project planning and tracking their progress during the run; (ii) finding a way to communicate with each other on task level but also on trust level; which is closely related to (iii) the last issue where students need to manage their own behaviour, sensing each other better. The Theory-U seems to work very nicely in tracking these aspects in the process of a group of students becoming effective design teams.

Despite initial assumptions, Cultural Differences were indicated as the least challenging part of working in a design team, where only 5.2% of the quotations referred to these challenges. This can be caused by the often-low-level reflections in the written essays but can also be caused by ethical issues where

students will not mention cultural indifferences in an official document. Several key-areas as discussed by Meyer, like communication and leadership, are key issues in groups of students becoming effective design teams. When communication is bad, and leadership is low, students tend to either be absent or 'muddle through,' as described by the Theory U [8]. Therefore, we expect that cultural differences are an underlying aspect of the three main subclusters and will keep this in focus when coaching design teams.

The final deliverable for a team consists of an embodied design of a product. However, the major learning is not in designing the product, but in working together and inclusively in the multi-diverse design-team. The experience of differences between team members and learning to trust each other is the basis of a functional team. To support our students in a safe way during this process, we need to professionalize our coach team and focus more on team dynamics, getting in flow with the project team, and experiencing a higher level of collaboration.

In the upcoming years we will increase the knowledge and skills of our coach team on topics like Dialogue and Theory U, to help our student groups in their process of becoming highly effective teams. To be on top of the students' performance, and indicate when student teams are running off-track, we are further developing our KPI based tracking system. To increase the reliability of the reflection data, we will improve the quality of the students' reflection essays.

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RESEARCH OPPORTUNITY IDENTIFICATION: A PEDAGOGICAL FRAMEWORK FOR DESIGN RESEARCH

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ABSTRACT
"Where do I start from?" More often than not, design researchers face this question early on in their research projects. The initial ambiguity frequently results in jumping quickly into the project, which leads to a shift in research focus time and again. To set the initial direction, a researcher needs to have an open mind-set and explore the latest changes occurring in the present world, always thinking about innovative opportunities. Finding new/innovative opportunity areas for carrying out research and defining the initial boundaries of a research space are some of the foremost priorities of a researcher. Although the approach followed by design students is more intuitive and opportunistic to solve any problem, the method followed by other disciplines such as STEM is usually more organized. This often leads to tension when a design research project demands the collaborative work of an interdisciplinary team. In this paper, we share an outcome of a study involving an interdisciplinary team working on identifying an opportunity area for design research. The current investigation is used as a case study to illustrate the key phases and their attributes involved in the framework to identify a significant area for conducting a design research project. The framework developed is found to be handy in organizing our thoughts and setting our initial research intent. Based on the study, we propose a pedagogical framework to better equip design researchers to work in collaboration for recognizing the field and scope of a design research project.

Keywords: Research intent, collaborative work, research gap, design research, design education

1 INTRODUCTION

A research gap can be defined as a topic or area for which insufficient knowledge restricts researchers' capacity to arrive at a conclusion for a given question [1]. Identifying a research gap or area for investigation often turns out to be difficult for researchers and academicians [2] not because of the limited number of issues available for study but due to the complexity involved in formulating a relevant research gap, which is unique and researchable. For designers, the task becomes more challenging due to a defining factor called as 'design attitude'. Design attitude is working in a manner that is more 'assertion-based rather than evidence-based' [3]. Furthermore, for a researcher, 'scientific attitude' encourages working, which is more evidence-based supported by conclusive facts and observations [4]. Design attitude and Scientific attitude appear to be contrasting approaches. An interdisciplinary team's operations could become challenging when members of the team function with such conflicting approaches and working styles. In this regard, not much focus is evident in design education. Thus, it is essential to develop a systematic approach in identifying research gap or area of an investigation while functioning as a team consisting of members from different educational backgrounds. This paper aims to explore and propose a new pedagogical framework to address this issue through investigations where an interdisciplinary team is working to identify opportunity area or research gap for design research. The proposed framework (as shown in figure 3) consists of four stages explore, categorize, summarize, and evaluate. At each stage, specific team members take the lead to steer the process.

2 FORMATIONS OF AN INTERDISCIPLINARY TEAM AND TEAM ROLES

For the current study, an interdisciplinary team originated at the Indian Institute of Technology Guwahati in Assam, India, to identify an opportunity area for conducting design research. The team consisted of a diverse mix of members from Product Design, Interaction Design, Human Factors,

Engineering, and Architecture. According to Belbin, any team has two parts, a functional role, and a team role. The functional role is nothing but the specialized skills a member possesses to perform a profession-based task, and the team role is the attitude and behaviour of a member that is put to use for the effective working of a team [5]. Further, Belbin stated nine team roles that can be grouped in three broad categories: action-oriented roles – Shaper, Implementer and Completer Finisher; people-oriented roles – Co-ordinator, Team worker, and Resource Investigator; cerebral roles - Plant, Monitor Evaluator and Specialist [6]. These team roles at the different stages of the proposed framework are as shown in figure 1.

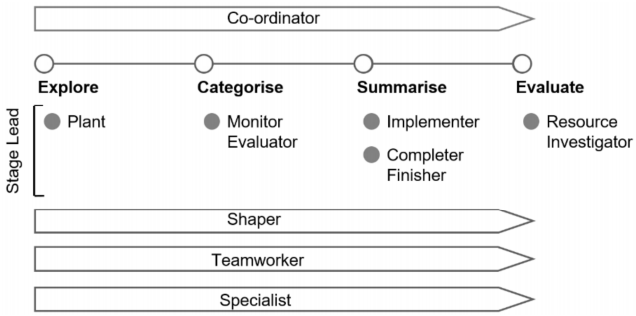

Figure 1. Team Roles

In the interdisciplinary team formed, the team roles are well-defined, and the necessary members are involved at the required time by the Co-ordinator. The role of a Co-ordinator is to oversee the entire process and assign appropriate people to lead at different stages of the process [7]. Only required people at each stage will mean less frustration (and fewer time-consuming meetings) for everyone involved. Designers often play the role of a Plant in a team. Plants are effective in tackling complex early stages of a process innovatively through their creative thinking skills. The Shaper keeps the project stick to the deadlines. Teamwork is essential for empathy and averting friction, and the Specialist is necessary when in-depth understanding is called for. The Monitor Evaluator team role, which is to see all the options, strategize and judge accurately [5], would be best suited for the Categories stage to lead the process. Implementer and Completer Finisher can be considered to lead for the Summaries stage because of the qualities like the ability to turn ideas into practical action-based tasks and deliver on time. The Resource Investigator is assigned as a lead in the Evaluation stage, which requires the development of contacts and communication with people through interviews and surveys.

3 THE PROCESS OF RESEARCH OPPORTUNITY IDENTIFICATION

To set the initial direction, researchers need to examine various areas, and it requires a lot of reading and analysing the material from multiple resources. This initial exploration follows a repetitive loop of search, communicate, and group think. As Tom suggested, "First, you need to identify and select relevant information sources, which will mean looking at books in the library, catalogues, databases and on the Internet" [8]. The Plant leads the Explore stage.

3.1 Explore

Search - Researchers need to dedicate specific time to search present-day information from various sources keeping an open mind for all kinds of latest information without any bias. An unbiased outlook, in the beginning, can help to find new directions.

Communicate - The information collected gathered from the sources should be compiled. The compiled information can have a format that can be easily understood and quickly shared with others to add comments and highlight critical points while going through it (figure 2).

Group Think - Team discussions with a set meeting agenda and specific time limit allow the ideas to exchange through sharing thoughts. It will create understandings of how information is gathered and steer the project in a definite direction. The team can go back to search for information about the trends that emerged during group think.

Area	Keywords	Key Points	Source
Transportation	Electric Vehicles, Self-drive, Air Pollution, Batteries, Clean Energy, Safety	1. The spread of EVs may open up opportunities to provide storage support for renewables via the so-called "vehicle-to-grid" (V2G) option. 2. There could be significant advantages from using vehicle-to-grid and associated home-based smart power and storage systems. 3.Whether autonomous self-driving car takes off remains to be seen. Safety is a key issue, with some high–profile and fatal accidents occurring with early versions.	PhysicsWorld (https://physicsworld.com/a/an-electric-car-future/) Accessed on: 20-11-2019
Healthcare	Artificial intelligence, Virtual Reality, Augmented Reality, Trackers, Sensors	1. Google's DeepMind created an A.I. for breast cancer analysis. The algorithm outperformed all human radiologists on pre-selected data sets to identify breast cancer, on average by 11.5%. 2. VR is being used to train future surgeons and for actual surgeons to practice operations. 3. In case of medical professionals, AR might help medical students prepare better for real-life operations, as well as enables surgeons to enhance their capabilities	The medical futurist (https://medicalfuturist.com/ten-ways-technology-changing-healthcare/) Accessed on:

Figure 2. Sample compiled information with critical points highlighted

3.2 Categorize

The initial efforts to explore the latest information would generate an extensive database of current issues (raw data). This information needs to be organized into a limited number of relevant areas. These areas can emerge through team discussions. Articulation of relevance of these areas and type of information each area would contain helps to manage time and keeps focus on the suitable context of the research. Moreover, an additional search could be conducted in the focus area. In the current study, five areas emerged: technology, society, culture, policy, and business. The relevant area of research was decided to be related to 'smart wearable technology' through team discussions. Further, to dig deeper into the area, several queries are raised about constraints, goals, and desires of the category. For example, what are the technology constraints? what are the technology goals? what are the aspired applications of the technology?

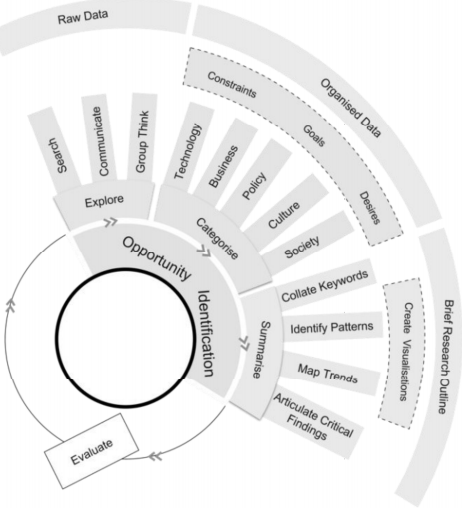

Figure 3. Research Opportunity Identification Process Workflow

3.3 Summarize

At the end of the analysis of the latest information gathered in Explore and Categorize modes, we put together the keywords, critical observations, emerging patterns into an integrated summary of research relevant areas. It presents a concise overview of the context and reveals hidden details, trends, insights. It also explains the basic logic behind the research direction. Summarizing the findings is done by collating keywords, identifying patterns, mapping trends, and articulating critical findings.

Collate Keywords - Keywords are nothing but context-specific principal terms that can be used for further search. The use of keywords made the search easier and focused on obtaining relevant information through an extensive database. Analysis of keywords can uncover interesting insights from multiple perspectives. The current investigation identified a total of 1103 relevant research studies to collate keywords. These studies are shortlisted based on the following inclusion criteria: published in

English from the year 2005 to 2019, indexed in Scopus, screening keywords in their title/abstract/keywords section. The screening keywords used are 'Smart Wearable Devices' and 'Design'. How the identified research documents are distributed is as follows: journal articles (432), conference papers (598), reviews (69), books (4). The identified studies contained a total of 9553 author keywords and index keywords.

Identify Patterns - Identification of the patterns within a dataset is essential to understand the most relevant and evolving areas for the research. One way to find patterns is to cluster the keywords based on their number of occurrences in the articles. Visually representing these patterns becomes an effective way of drawing conclusions and communicating the findings. A total of 171 keywords with a minimum frequency of 15 are selected out of total keywords to generate a network visualization using VOS viewer. The generated network visualization is analysed to discover patterns within the keyword's dataset.

Analysis of the network visualization shows that the selected keywords predominantly form three clusters (represented in red, blue, and green colours). In a cluster, the size of a node (circle) and its label scale represents the weight of an item. Central nodes of these three clusters are identified as 'wearable technology design' (red), 'textiles' (blue), and 'human (physiology monitoring)' (green). The distance between any two nodes represents their relatedness in terms of their co-occurrence in the literature. In other words, the closer the nodes more is their relatedness in terms of co-occurrence. From the network visualization, it appears that the nodes 'product design', 'human-computer interaction', 'human engineering', 'watches' are closely related to the 'wearable technology design' node. Based on this, it is appropriate to believe that product design, human-computer interaction, ergonomics, etc., are the central issues in wearable technology design. From the network visualization, it also appears that the importance of the other two clusters, 'textile' and 'human (physiology monitoring)', is also noteworthy. The 'textile' cluster is more related to smart textiles, use of innovative materials, use of 3D printing, etc. and issues in the 'human (physiology monitoring)' are closely connected with the design of algorithms for the physiological study of people of different age groups, gender, etc. The team decided to focus research on the issues related to product design, human-computer interaction, ergonomics, etc., in the wearable technology design cluster.

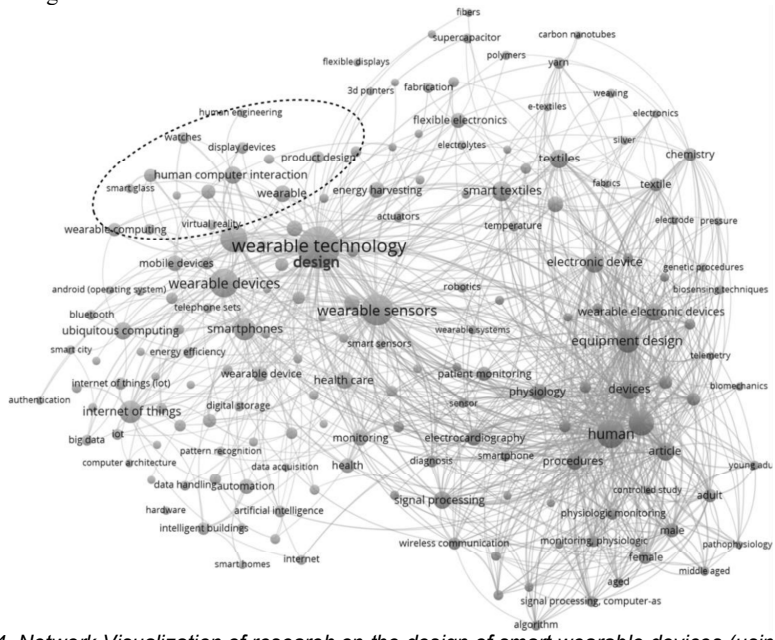

Figure 4. Network Visualization of research on the design of smart wearable devices (using VOS viewer)

Map Trends - Trends reveal a general sense about the most common areas of research opportunities. Recognizing and understanding trends gives a possibility to position the research so that the research findings would indeed be relevant in the near future. The trend search for the current study shows that

the smart wearable devices market is heavily dominated by wrist-worn devices. Moreover, in the past, shipments of smartwatches were way more than that of wristbands, and the trend will continue to be similar in the future [9]. Thus, the focus object of the current design investigation was determined to be 'smartwatch'.

Articulate Critical Findings - Organizing the critical findings of keywords, identified patterns, and mapped trends in a comprehensive, fact-based format that can be shared with the research team gives a higher-order overview of the interest area of the research as well as forms the rationale for it. It also helps to establish the extent of boundaries of the research landscape. The critical findings of the current case of smart wearable technology design are as follows:

Explosive growth in wearable technology is witnessed in recent years. Smart wearable devices are eventually going to become an integral part of human life [10]. When looked at the current wearable market scenario, the companies in this domain appear to have a strong focus on technology-driven innovation. However, as the market enters the maturation phase, the technology penetration becomes high, and technically similar products co-exist [11]. In such a situation, technology starts losing its potential to become a differentiator, and companies can no longer rely only on technology to gain the upper hand. Therefore, to attain sustainable competitive advantage, companies are desired to set their focus on design with the user at the centre. Emerging technologies like smart wearable devices offer new opportunities for designers to cultivate, enhance, and implement their thoughts and imaginations.

3.4 Evaluate

After a full understanding of the intended research area is developed at the end of the 'summarize' stage, the focus moves towards an evaluation through a more context-specific action such as field visit, expert opinion, online/offline survey to gain as many insights as possible through the industry, professional, expert interaction. Here, the primary purpose is to identify practical, "real world" problems that may be understudied or ignored within academic circles and to make research findings more relevant to practice. The evaluation of the currently selected case of smart wearable technology is explained below.

Globally, the smart wearable market devices market is dominated by multinational corporations like Apple, Google, etc. In India, it can be observed that more and more start-ups are venturing into this territory of wearable tech devices. To get recognized in the competitive market, these start-ups hold out against multifaceted challenges. To get further insights on the design challenges encountered by these organizations, expert opinions are gathered through a few informal telephonic interview sessions with practitioners in wearable devices start-ups. The following table shows the particulars of the conducted interviews.

Table 1. The particulars of the conducted interviews

Sr No	Company Name	Application Area	Location	Designation of interviewee
1	Ducere Technologies	Fitness and Wellness	Telangana, India	Industrial Designer
2	Ducere Technologies	Fitness and Wellness	Telangana, India	Manager- Product Design
3	Lazy Co.	Fashion/Consumer Electronics	Bangalore, India	CEO & Industrial Designer
4	Actofit	Sports/ Health/ Fitness and Wellness	Navi Mumbai, India	Founder & CEO

It was quite evident from the interviews that the smart wearable devices industry in India, which is still in infancy, is relying on the designer's abilities and experience in seeking design solutions. However, it takes a lot of practice and professional experience for a designer to gain confidence in decision making in industrial projects [13]. Although traditional design methods have always helped designers deal with practical situations and challenges, what is not paid sufficient attention in these design methods is the complication of contemporary design concerns. Through industrial interaction, it is quite evident that the contemporary design industry (particularly start-ups) needs a novel design method for the ideation stage, which enhances the designer's idea Generation Ability & Creativity.

At the end of the 'research opportunity identification process' following brief research outline is obtained for the current case: Research gap – The wearable devices start-up industry is in need of a novel design method for the ideation stage which enhances designer's Idea Generation Ability and Creativity; Focus object of design investigation - smartwatch. At this point, the research team can again go back to the

first stage, i.e., Explore and follow the same loop of explore-categorise-summarise-evaluate in order to further investigate the obtained research gap and gather more profound insights. This process can go on till a refined research gap statement is generated, which satisfies the researcher's interest. Moreover, to cut-short the time consumed in executing the framework, tasks in the multiple stages of the framework can be performed simultaneously, instead of one stage at a time.

4 DISCUSSION AND CONCLUSION

This paper proposes a framework for identifying research opportunities describing the key stages and their attributes, explained with a specific case of smart wearable technology design. The proposed pedagogical framework encourages design research students to perform the task of identification of research gap in a much more structured way. Moreover, it is observed during our study that the framework also assists in dealing with the enormous amount of data gathered by organizing it into research relevant areas and thereby reducing the confusion of deciding on which area to focus. This systematic approach in identifying the research gap serves to set the initial point of reference for the research and form the logical basis for it. Thus, the direction of research is evident in the preliminary stages, which helps to refrain from a shift in research focus at later stages.

Interdisciplinary teamwork is becoming the standard in every field as it offers an opportunity to formulate a more comprehensive understanding of an issue that any single discipline may be unable to provide. Designers are increasingly integrated into such interdisciplinary teams because of their creative abilities and skills to humanize technology by thinking beyond functional needs. However, it was observed during the study, the functioning of an interdisciplinary team often turns out to be ineffective due to conflicting working styles and behaviours of the members. In this regard, Belbin's project team model provided insights for building a team with a balance of the team and functional roles. Further, it assisted in assigning appropriate stage leads at different stages of the proposed research opportunity framework. Most importantly, it illustrated how the variations in the team and functional roles could be utilized constructively in an interdisciplinary team.

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DESIGN AND CREATIVITY FOR DEVELOPING DIGITAL MATURITY SKILLS

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ABSTRACT
The emerging technologies of our century - such as Artificial Intelligence, Machine Learning, IoT, Virtual Reality, etc.. - are transforming the industrial economy requiring companies to start a process of digitalisation and transformation toward Digital Maturity. One of the main obstacles to digital development initiatives is the company cultural level and the identification of adequate digital talent with the right skills to manage digital innovations. Design and Engineering education has a key role in the development of such skills. They urgently need to co-evolve with the human, technological, and cultural evolution of the digital era we are facing.
The paper aims to present the theoretical DC4DM model that integrates the skills identified as in line with Digitally Mature companies' needs and, therefore, relevant for training cross-functional teams of future digital talents. Indeed, an important part of innovation success is the individual and team's creative abilities when designing for digital innovations.
New teaching methods and practices should be developed in design and engineering education considering the evolving and emerging needs of students and industry, addressing the development of the new set of skills and training future "digital wise" professional that can drive the Digital Maturity.

Keywords: Digital creative abilities, digital maturity, individual creativity, cross-functional team creativity, training box

1 INTRODUCTION

The influence of digital technology on companies' complexity has reached its acme in the last decades, with technological innovations directly acting on strategy, anticipation, and sustainability.
The emerging technologies of our century - such as Artificial Intelligence, Machine Learning, IoT, Virtual Reality, etc. - are transforming the industrial economy requiring companies to start a process of digitalisation and transformation toward Digital Maturity.
Only 1 out of 5 companies across the EU are highly digitalised, where around 60% of large industries and more than 90% of SMEs lag in digital innovation. Only 14% of Italian companies have a good level of digitalisation, 49% are laying the foundations for digital process management, while about 37% are in an initial phase of digital transformation. The gap between small and large companies is marked, as 70% of the latter have a defined development plan and have introduced innovative technologies within the company (EY Digital Manufacturing Maturity Index, 2019).
In this context, the NextGenerationEU will be dedicated to supporting the transition towards more sustainable and resilient economies and societies, ensuring that technology serves people and adds value to their daily lives. Digital technologies and digitalisation processes are in fact recognised as a key enabler for achieving the UN Sustainable Development Goals for a sustainable, inclusive, and better future for all.
The spread of digital technologies within organisations is having a massive impact on the type of skills needed by their employees. By 2025, at least 50% of employees will need to have digital skills as well as human skills such as complex problem solving, strategic and creative thinking, critical thinking, emotional intelligence, communication and negotiation, relationship, and network building abilities [1]. Indeed, one of the main obstacles to digital development initiatives is the company cultural level and the identification of adequate digital talent with the right skills to manage digital innovations.
Design and Engineering education have a key role in the development of such skills. They urgently need to co-evolve with the human, technological, and cultural evolution of the digital era we are facing.

New teaching methods and practices should be developed considering the evolving and emerging needs of students and industry to address developing the new set of skills and train future "digital wise" professionals that can drive Digital Maturity.
This is the main objective of the Erasmus+ project, "Digital Creativity for developing Digital Maturity future skills". The project aims to implement and spread an educational box called DC4DM Edu Box with the right tools and methods train cross-functional teams of design, engineer, business students to face the complex real-world challenges brought by digital transformation. The box empowers Digital Creativity that refer to the human ability to create an innovative and original digital outcome strategically exploiting the opportunity of digital technologies [2].
The paper aims to present the theoretical DC4DM model on which the Edu Box will be built. The DC4DM model indeed integrates all the Digital Creativity skills identified as in line with Digitally Mature companies' needs and therefore relevant for training future digital talents.
The paper briefly presents the first configuration of the model that, thanks to co-design actions within the Erasmus+ project consortium, have been implemented, evolved, and adequately described in its new shape in section 3.

2 FIRST CONFIGURATION OF THE DC4DM MODEL

The DC4DM model has been developed considering the main Digitally Mature company's needs [3] that have to i) strategically apply digital technologies to develop new business, to digitalise operation and processes ii) face complex challenges that require the knowledge of employees with different functions, that should work together also remotely on collaborative digital platform iii) face future sustainable and social challenges, planning long term strategies to be competitive even in an uncertain future.
For each identified need, the model integrates the specific set of skills defined as Digital Creative Abilities (DCA) that empower people to express their creative potential and think and act in a non-predictable digital world. The model has, therefore the aim to enable and empower students in:

- acquiring competencies and mindset to understand the potentialities of digital technologies and apply them to design digital solutions with a human-centred approach.
- developing individual abilities of creative self-enhancement, and a digitally-minded culture, as well as the team ability to communicate and share knowledge with others with a different background.
- acquiring skills in future and anticipatory thinking, developing a mindset that can generate a long-term strategic vision and help companies face complex challenges by envisioning future scenarios.

Digital talents should be prepared to face the diversity of uncertain futures, anticipate possible scenarios, and take full advantage of the innovation capacity of digital technologies.

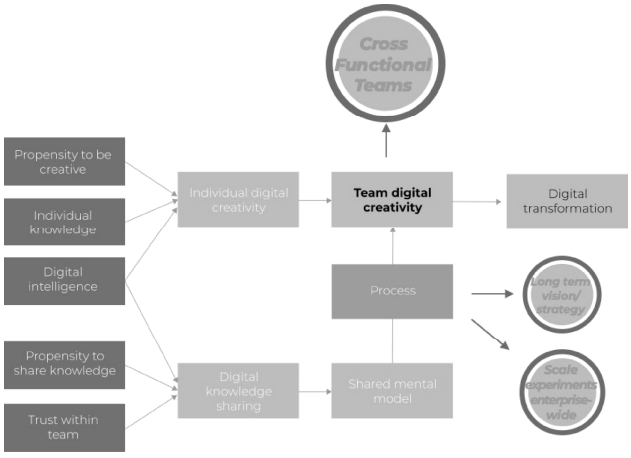

Figure 1. First version of the DC4DM model.

Within the model, the Digital Creative Abilities are structured along four main dimensions: i) individual creativity that includes an individual's propensity to be creative, meaning the cognitive, motivational,

attitudinal, knowledge and emotional abilities fundamental for individual creative empowerment. It also includes individual knowledge ii) team knowledge sharing, meaning an individual's propensity to share knowledge and trust within the team that includes social and emotional abilities and dynamics to empower winning cross-functional teams iii) Digital Intelligence, that affect both the previous individual and team dimensions and includes the ability to acquire and apply new knowledge and skills related to digital technologies, to improve operational efficiency and outcomes quality [4] iv) process, including the ability to analyse driving forces to map possible alternative scenarios, and to solve problems/challenges strategically.
The complexity of the model is evident considering that it needs to be transferred to educators, learners, and companies immediately and straightforwardly. Thanks to co-design actions pursued with around 20 people amongst educators, researchers, and designers within the DC4DM project consortium, important consideration emerged that sparked reflections on implementing the model. The four primary reviews that have determined a turning point for the model are i) simplify the reading of information within the model, providing a sequential order of skills to be developed concerning the highlighted dimensions ii) highlight the importance of the process as a central ability that allows people to understand and strategically apply the potentialities of digital technologies and generate innovative solutions iii) integrate a dimension, currently not present, which encompasses the social, environmental and ethical responsibility skills as well as a future mindset that are relevant when developing a strategic vision of the future iv) highlight the importance of a circular and growth learning.
Based on this consideration, a new model configuration has been proposed, presented in the next section.

3 DC4DM MODEL: A NEW SKILLS ORGANISATION

Therefore, a new model configuration has been developed, considering the reflections that emerged during the co-design workshop. The main implementation has been done to reorganise the skills within the model, providing a sequence in the skills empowerment and simplifying the adoption and use of the model itself. Indeed, the model should empower cross-functional teams of students to creatively and strategically solve challenges exploiting the opportunities provided by digital technologies.
Therefore, the first step was to reorganise the model dimensions considering the *process* dimension at the base and as central to the model. The other dimensions precede and follow the process. In this way, the model has been divided in three sequential phases:

- *Pre-process:* this part of the model includes the knowledge and skills that are propaedeutic to the process and that are needed by cross-functional teams to go through the process. The pre-process consists of the individual digital creativity dimension and digital knowledge sharing, and the operational knowledge required to work with digital tools and collaborative platform. These become, therefore, antecedents of the model.
- *Process:* the design process is based on a creative and design thinking process that generates innovative ideas. It is a divergent and convergent process deconstructed in stages, steps, activities and thinking style. For each step of the process, specific digital creative abilities intervene that are responsible for the originality of the output and both the individual and team performances during the process. The tool developed to empower and train the model is the Digital Creativity Framework that maps the factors that intervene in a specific moment of the process and allows to define design actions and tools to empower it, enhancing the factors. The framework allowed to map the less rationale creativity factors emphasising their interconnections with the different steps and activity of the process.
- *Post-process:* in this third phase, the team has finally reached a shared mental model and a knowledge structures – related to equipment and tools, task, goals, other members' skills, expertise and abilities, appropriate team interactions - that are shared among team members. This part of the model includes the skills that allow to create continuous learning cycles to further develop and nurture the skills they acquire, continue to learn, and scale the skills to other people within the organisation. These post-process skills will help people to iterate and continue to add value to their abilities to the organisation they are part of and the system.

Another important implementation is integrating some relevant knowledge and skills that have been considered fundamental and missing in the previous configuration. These can be regarded as transversal to the three phases becoming the pillars on which the model is based. A new dimension called "Digital Sustainability and Responsibility" has been added that includes the future, ethical and sustainable thinking skills considered relevant when dealing with uncertain digital futures.

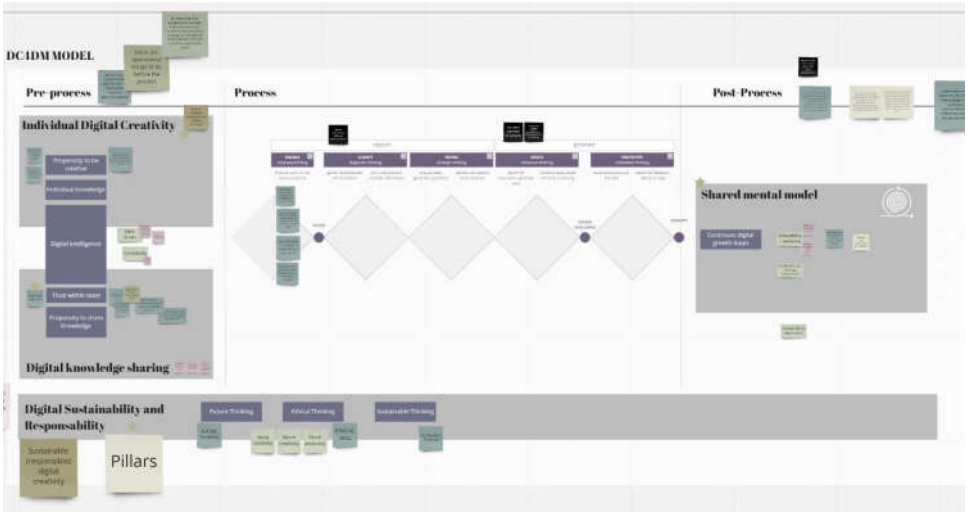

Figure 2. A new skills organisation defined during a consortium co-design workshop.

The next section focuses on the pre-process phase, highlighting and describing the main dimensions that have been included and integrated in this new starting phase of the model.

4 PRE-PROCESSES: FROM INDIVIDUAL TO TEAM CREATIVITY A SEQUENTIAL APPROACH TO LEARNING

Intervening in a group's creativity training implies considering team composition, namely its number of members and personalities. Thus, members bring the group their related backgrounds, experiences, and professional aspects and their traits and social characteristics. Then, team climate is based on collaboration; this is not immediate and needs to be built around the process of working together. Finally, the external environment can influence interactions amongst members and their performance during task fulfilment.

The concept of team creativity is strictly related to its individual dimension, as the collective process is composed of participants with their unique characteristics that they share and blend during the collaboration. To support team creativity, it needs to consider individual members' creative personalities [5], to examine how the team produces ideas starting from individual creativity, considered as input factors, based on the assumption that the innovation process initially came from the individual. Individual creativity is the fundamental resource that each group participant makes available for the collective, with the purpose of its combination and integration to address the project problem-solving. Consequently, the blending of team members' personality with their embedded aspect as creativity constitutes a collective resource [5].

Team creativity results from both individual creative personality and the pooled resources that team participants make available to others [5]. Team creativity is considered a synergetic progression that occurs during a social process of sense-making and collaboration. One individual's actions may inspire the team to devise, thus following a more creative strategy to address the problem [6]. The result of this phenomenon is higher levels of creativity because team members become exposed to divergent information and opinions and a variety of unusual ideas that may have a beneficial effect on individual creativity. Individuals' contributions provide the team with its "raw material" [4]. However, team creativity is more than the combined individual creativity of team members; other factors influence the contribution of each member and the interaction among the group.

Creativity can be fostered in teamwork due to the inclusion of diversity in team members' roles [5]. Indeed, this heterogeneity can affect creative thinking amongst the group through the exposure of team participants to a wider variety of unusual ideas [7]. Diversity in team members is related to their background, openness to others' ideas, constructive collaboration, communication, and commitment to

the project. Namely, a group that includes diversity embraces the idea of cross-functional collaboration to increase performance in terms of improving the opportunities for creativity to occur.
Therefore, two main dimensions contributing to team creativity are preconditioned in the education before moving on to the process. The former is the individual sphere, while the latter is the collective sphere that occurs when members interact within the teamwork. Individual creativity leads to group creativity.

4.1 Individual Digital Creativity: the individual dimensions

This first dimension includes the DCAs, which allows the individual contribution that provides the team with its raw material to start and iterate the process of team creativity. It comprises three main elements, each one defined by specific DCAs. According to Boughzala (2020) [4], the first element to consider in the pre-process phase is an individual's *propensity to be creative*, defined by personal ability, personality, motivational variables, and cognitive process that anticipate and result in individual creativity. It also involves skill sets that encourage creativity and the ability to remember a large amount of information accurately to recall it when needed to improve the capability to create links between different and ideas to solve problems. As a result, individual knowledge is the second element that contributes to building individual creativity. *Individual knowledge* is the basic raw material and the foundation for all creative work. It refers both to the factual knowledge about a problematic phenomenon and technical skills for specific procedures. The third element is *digital intelligence* meaning the ability to acquire and apply new knowledge and skills related to digital technologies to improve operational efficiency and outcomes quality. This element is also relevant for the Digital Knowledge sharing dimension.

4.2 Digital knowledge sharing: the collective dimensions

The second collective dimension is composed of the propensity to share knowledge in a group setting and the trust between members during teamwork. Combining these two elements contributes to the knowledge sharing practice needed to build a shared mental model among team participants, it is useful to create a common language that enables more creative interactions. Considering that the model was created to train DCAs in cross-functional teams as an essential key to achieving DM, it is necessary to consider the specific characteristics of this type of team before describing the two elements that constitute digital knowledge sharing.
A cross-functional team needs to include proactive employees who can work well independently and in the group dimension [8]. Cross-functional teams benefit from the unique mix of skills and talents each member brings to the project. Thus, working in a group context of information exchange and skills integration is the basement on which is possible to build additional foundational elements that need to be proper of a cross-functional team member. Indeed, when team members understand their role in the process, they are more prone to work cross-functionally with others to achieve the goal.
The team is mainly influenced by trust within members, the propensity to participate and share knowledge of the participant and the willingness to integrate the knowledge shared into a common language for the group building shared mental models.
The propensity to share knowledge is a crucial aspect of teamwork because it is the condition that allows a member to actively take part in group collaboration with his or her knowledge and expertise. It is necessary to explain what knowledge sharing represents to understand its importance better. It is a practice that occurs when team members spontaneously and actively exchange information and expertise to reach a broader understanding of the problem. It is a critical aspect for a creative team because it incorporates individual-level knowledge into team one is to solve problems and complete tasks for the related project. More information from multiple and diverse sources provides the group with a wider range of notions and perspectives that enlarge the possibility of creating new and innovative ideas.
Consequently, being willing to share is the base to collaborate efficiently in a team setting. Trust influences how knowledge is shared, viewed, and integrated by team members. Team trust, in its essence, represents the predictive understanding of another's behaviour. Trust is the basement of teamwork, thus of cross-functional collaboration. Indeed, Sinek stated that "a team is not a group of people who work together, a team is a group of people who trust each other". If team members feel safe in the team environment, they are prone to interact with each other. A high level of trust leads to higher levels of productivity and effectiveness (Forbes, 2019), due to the encouragement of questioning among members that leads to better decision making. In addition, trust benefits interpersonal relations minimising misunderstandings and conflicts, consequently improving communication. The most

important factor in guiding team success is to build psychological safety amongst members through trust. Team workers need to feel safe and vulnerable in front of others to be able to take risks. As introduced before, trust embeds the willingness to be vulnerable in terms of having positive expectations about the behaviour of the other group members and eagerness to rely on others [9] as a basement to guide and stimulate a risk-taking attitude.

5 REFLECTION AND FUTURE ACTION

The paper presents and discusses the integrated DC4DM theoretical model to develop creative and strategic skills that future digital talents should develop to design and innovate in cross-functional teams. The main point regarding the concept of cross-functional teams is its peculiar composition of members from different functional background of the organisation. This aspect is defined as functional diversity. It consists of the differences amongst individuals in knowledge, skills and abilities, values, beliefs, attitude, personality, and cognitive and behavioural style [10]. Therefore, an essential phase of the model – the pre-process phase - is dedicated to highlighting and giving values to the individual differences and training people in understanding how to integrate those differences to achieve successful results during the consequent process phase. The DC4DM model represents the theoretical model of skills translated in educational training methods, activities, and tools for design, management, and engineering students. The theoretical model will become an action model, namely DC4DM Edu Box, that will include educational and innovative resources to develop the right skills to drive companies toward Digital Maturity. However, the complexity and the abundance of skills included in the model, makes difficult the integration of learning resources dedicated to empowering each skill. Therefore, future activities will be dedicated to identifying and select a specific and fewer set of skills within the three consequent phases and to develop specific educational resources for them that will be part of the final Edu Box addressed to both educators and students.

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MITIGATING GROUP DISCUSSIONS IN DESIGN ACTIVITIES FOR JAPANESE HIGH STUDENTS DURING COVID-19 PANDEMIC

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ABSTRACT
The purpose of this study is to clarify the factors that affect effective group discussions when using online whiteboard during face-to-face design activities for high school students in the classroom during the pandemic. Using a case study approach, the research was conducted at Fukusho High School in Fukuoka, Japan. Through the questionnaire survey, face-to-face discussions when combined with the use of online whiteboard, offers real-time verbal and non-verbal feedback that enabled effective group discussions during the design process. In addition, students' competencies in using digital devices may not influence the effectiveness of communications during group discussions and their motivations in using online whiteboard. The current findings may provide a useful hypothesis for further study to verify the correlations between students' competencies, effectiveness in communications when using online whiteboard during face-to-face discussions, and students' motivations in using online whiteboard.

Keywords: Design education, design activities, online whiteboard, communication skills

1 INTRODUCTION

The Sustainable Development Goals (SDGs) are central to achieving the 2030 Agenda for Sustainable Development adopted at the United Nations Sustainable Development Summit on 25 September 2015 [1]. In 2019, the SDGs Design School was established as a team in Kyushu University, Faculty of Design, to propagate SDGs awareness to the local community through design educational programmes. Adopting the design process used in industrial design, the SDGs Design School has been collaborating with Fukusho High School in Fukuoka city to develop design-based educational programmes into the *Global Management Programme* as part of the school curriculum to raise SDGs awareness in students [2]. In 2020, the Covid-19 pandemic has caused unprecedented impact to how education is being implemented in the classrooms. Since June 2020, schools in Japan have fully re-opened but continue to operate with a note of caution by adhering to new health and safety guidelines. Face-to-face lessons are allowed to be conducted. Before the Covid-19 pandemic, it was common for students to work in groups during design activities to share opinions and bounce off ideas by writing directly or putting Post-it Notes on flipchart papers. Due to the pandemic, working in groups with close proximity is not advisable. To mitigate the impact of maintaining social distancing during group discussions, distance learning techniques may be tweaked and applied to such circumstances.

Distance learning for design has been on-going for quite some time at university level [3]. Design studios in design education form an important platform for design conversations and discussions. Moving away from the physical environment, design conversations and discussion may take place in virtual studios [4][5][6][7]. Currently, most examples of virtual studios involve design students at university level.

Thus, the SDGs Design School faces a challenge to consider using distance learning techniques to implement meaningful and effective design programmes for high school students. The current challenges encountered by the SDGs Design School will be relevant for local and overseas institutes of higher education to consider the implications when implementing design programmes at high school level during the post-Covid-19 and with-Covid-19 conditions. The purpose of this study is to clarify the factors that affect effective group discussions when using online whiteboard during face-to-face design activities for high school students in the classroom during the pandemic.

2 LITERATURE REVIEWS

2.1 Synchronous and Asynchronous Online Mode

As a form of communication, in general, computer-mediated communications (CMC) are described as communications, mediated by interconnected computers, between individuals or groups separated in space and/or time [8]. CMC can be categorised into synchronous (real-time) and asynchronous (delayed time). Synchronous online learning generally includes real-time dynamic social interactions. On the other hand, asynchronous online learning involves social interaction that are not real-time [9]. As for asynchronous online learning, students may participate in their own time through threaded video-based discussions and interactions that do not happen in real time, such as online discussion forums [10][11].

2.2 Social Presence Theory

With regards to interactions, communications and collaborative learning during online learning, the concept of social presence may be used to guide the evaluation on the effectiveness online learning.
First introduced by Short, Williams & Christie [12], the social presence theory describes social presence as the extent to which a person viewed a social interaction in a technology mediated interaction as authentic. Social presence involves two key factors, intimacy, and immediacy. Intimacy is influenced by factors such as physical distance, eye contact, smiling, and personal topics of conversation. Immediacy is a measure of the psychological distance which a communicator puts between himself/herself and the object of the communication. Immediacy may be conveyed non-verbally or verbally. Non-verbal factors may be conveyed by such as physical proximity, formality of dress, and facial expression.
Building on the conceptualization of the social presence theory, Gunawardena & Zittle defined intimacy as the quality of interpersonal relationship between individuals in the technology mediated interaction [13]. Thus, humour and sharing of personal experiences may improve the quality of social presence. In the aspect of immediacy, it was believed that the longer it took an individual to receive a response, the less social presence they perceived and the less engaged they were likely to be.

2.3 Technology Acceptance Model

Technology acceptance model (TAM) has been widely used to study user acceptance of internet-based learning systems. The TAM assumes that the perceived ease of use and usefulness of online learning system (also include online discussion forums) are major influences on an individual's attitude towards such as system; and thus, are related to the intention to use it and in turn, to its actual use [14]. According to Davis, Bagozzi & Warshaw, the perceived ease of use can be referred to the degree that a person perceives the use of the system is effort free [15]. In addition, the perceived usefulness can be referred to as the degree a person perceives the use of the system would enhance job performances. The perceive usefulness is dependent on the perceive ease of use and the intention of using the system. Adding on to the TAM, perceived ease of use and usefulness may be influenced by external factors such as motivation, academic background, income level, age, and user's experience [16][17][18].

3 RESEARCH METHODOLOGY AND IMPLEMENTATION

3.1 Research Questions

While online learning techniques may operate using synchronous and asynchronous environment, the current study operates in a face-to-face environment where offline and online real-time social interactions may be achieved. Under this context, the research questions are as follows.

1) Can technology such as online whiteboard contribute to the effective communication among high school students during face-to-face design activities?; and
2) What are the factors that may affect students in communicating their opinions or ideas during design activities when using the online whiteboard?

3.2 Research Approach and Method

The current study employed a qualitative research approach where a case study method is used as an educational tool for understanding pedagogical processes as described by Aaltio and Heilmann [19]. The current study was conducted at Fukusho High School in Fukuoka city, Japan. To clarify the two research questions, the SDGs Challenge Project in *Global Management Programme* was used as the

platform for research. The considerations for selecting Fukusho High School as target school was based on the following considerations: a) school is a typical public high school and b) consists of mixed student academic abilities. Using a typical Japanese high school will position the outcomes of this study to be much more applicable to a broader range of high schools with similar profile as Fukusho High School.

3.3 Participants, Research Design, and Implementation

Participants were high school students (about 18-year-old) with no prior design experience. Participants formed the sub-units and data from each sub-unit was pooled to answer the research questions within this case study. The data is collected through a questionnaire survey that focus on opinions and attitudes. The questionnaire is structured to first find out students' personal competencies in using digital devices. Next, the students' motivation in using the online whiteboard is surveyed as their motivation may influence their perception in the usefulness of the platform which in turn implicates enhanced performance in the activities as mentioned in TAM. Finally, students perceived effectiveness of the online whiteboard during group discussions is surveyed. Refer to Table 1. The survey was conducted after the completion of the SDGs Challenge Project with a collection rate of 24 out of 28 students in the class.

Table 1. Question items in each part of the questionnaire survey

Key Focus	Questionnaire Survey Items	Question Types
Part 1: Individual competency in using ICT	Q1: *I am good at using digital devices* Q1-1: *Reasons for Q1*	Q1. 5-point Likert Items from Strongly disagree (1) to Strongly agree (5) Q1-1. Open-ended
Part 2: Personal motivation in using online whiteboard during discussions	Q2: *I would like to continue to use apps like MIRO in the future when doing group work in the corona disaster.* Q3: *I would like to continue to use apps like MIRO in my classes in the future when we do group work, even if the corona pandemic has subsided.*	Q2 & Q3. 5-point Likert Items from Strongly disagree (1) to Strongly agree (5)
Part 3: Effectiveness related	Q4: *We were able to conduct discuss with social distance in mind.* Q5: *We had a lively discussion while using MIRO.* Q5-1: *Reasons for Q5*	Q4 & Q5. 5-point Likert Items from Strongly disagree (1) to Strongly agree (5) Q5-1. Open-ended

As face-to-face lessons are allowed to be conducted, one of the ways to reduce close contact is to introduce the use of online whiteboards, such as Miro, to facilitate face-to-face group discussions. Miro was selected as the tool because:

a. sketching and notes during the discussion can be shared in real-time without much time lag
b. the application can be easily installed onto tablets such as iPads
c. ease of use and variety of functions that are useful during group discussions

To use the online whiteboard, iPads or Windows tablets are used as the stylus pens enable students to write and sketch in Miro more easily than laptops. Students would work in groups of 5 or 6 to identify design problems within the community and then propose the most appropriate design concept. The brief outline of the programme plan can be presented in Table 2. As some students might not be as IT savvy as others, usage instructions and templates for online whiteboard were provided before each online activity. A short briefing was also conducted before each online activity. During the project, students would switch between off-line and a hybrid of off-line and online activities. Off-line activities were mainly individual assignments where students would write their findings, reflections and ideas on a worksheet booklet developed for this project. The hybrid of off-line and online activities were mainly in-person group discussions. Refer to Figure 1.

Table 2. A brief lesson plan for the SDGs Challenge Project

SDGs Challenge Project Programme Plan		
Day	**Lesson Plan**	**Remarks**
Day 1 17 August 2020 Lesson Duration: 3 Hr	□ Each student identification of design problems in the community □ Sharing of design problems to group members □ Each group to discussion and select on design problem to engage □ Group discussion to deepen understanding of problem □ Identify existing solutions related to the selected problem □ Present selected problems and findings on existing solutions	Students may work individually or in group
Day 2 18 August 2020 Lesson Duration: 3 Hr	□ Each student explores ideas to solving the problem □ Each student critiques his/her own design ideas to gain deeper understanding on solving the problem □ Sharing of design ideas to group members □ Discussion and selection of an idea to work on further details □ Conceptualise the idea and present to the class	Students may work individually or in group
Day 3 19 August 2020 Lesson Duration: 3 Hr	□ Seeking other point of views on selected idea □ Improvement of idea □ Creation of prototype or concept poster □ Presentation of final concept	Students may work individually or in group

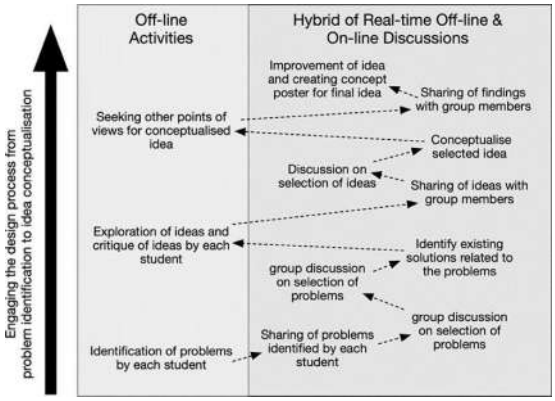

Figure 1. The switch between off-line activities and a hybrid of real-time off-line and online discussions

4 FINDINGS

The responses for the questionnaire are presented in Figure 2 and Table 3. When asked about their competencies in using digital devices, refer to Q1 in Figure 2, about 45% of the students agreed that they are competent in using digital devices. Some of the main reasons are due to the exposure in using computers at an early age and opportunities to using ICT devices. Although almost 30% of the students are neutral about their competencies in using digital devices, almost all of them felt that they are somewhat not knowledgeable or not good at using computer devices. About 25% of the students felt that they are not competent in using digital devices. Some of the main reasoning are due to the lack of exposure or opportunities to use computers. In general, slightly more than 50% of the students believed that they are somehow not good at using digital devices.

Although it may be deducted that there are more students who are not very competent in using digital devices, more than half of them have indicated positively about using Miro and also in future group activities, refer to Q2 and Q3 in Figure 2. This may suggest that students' competencies may not have a strong influence on their motivations in using online whiteboard during face-to-face group activities.

In addition, almost 80% of the students indicated that they were able to conduct discussions with social distancing on mind, based on responses for Q4. At the same time, over 90% of the students had indicated that the discussions were lively when using Miro, refer to Q5, which may suggest effectiveness. Based on the responses for Q5-1, the factors that influence effective communication may be consolidated in Table 3 under three major themes. As such, it may be assumed that most students perceived to achieve effective communications while using Miro during face-to-face group activities without gathering in close proximity. In addition, the current findings may also suggest that even though most students may not be very competent in using digital devices, this may not influence their motivation in using online whiteboard and the perceive effectiveness of the online whiteboard for group discussions.

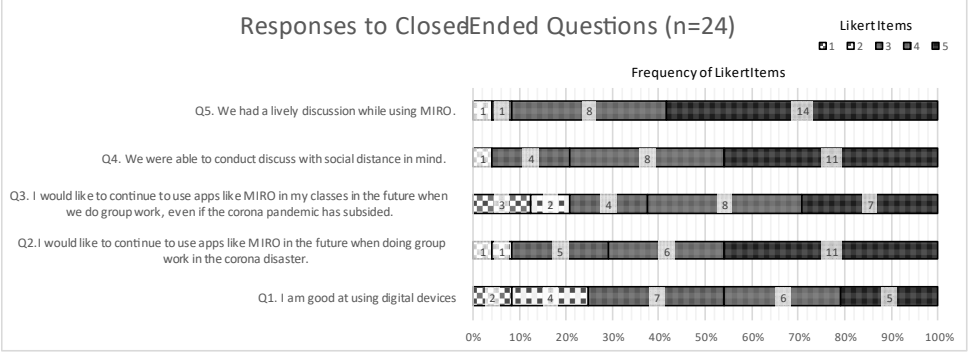

Figure 2. Responses of students for Question 1 to 5

Table 3. Open-ended responses in Q5-1

Main themes	Key points gathered with respect to students' perception to Q5
Technical Issues related	Some students encountered disconnection from the online whiteboard at times.
Usability related	Requires time to get used to using the application; especially when constant switching between offline and online activities. Online whiteboard is easy to use and has variety of functions. The post-it function within the online whiteboard is useful for gathering opinions. The process of face-to-face discussion, coupled with the use of online whiteboard is useful for students to organize their thoughts. Within the online whiteboard, students can see many opinions at once.
Effectiveness in communications related	For students who are used to using the application, they may voice out their opinions verbally. If not, they may remain silent during the discussions. For students who are not good at voicing out their opinions, the online whiteboard allowed them to express their views. While using the online whiteboard, many decisions can be made during the discussion. The content in the online whiteboard can generate lively conversations. Ideas can be exchanged effectively as information can be shared through online whiteboard concurrently during the discussions . While maintaining social distancing, ideas can still be exchanged effectively.

5 DISCUSSIONS

The approach in this study combined face-to-face design discussions and online synchronous mode of social interactions via online whiteboard, such as Miro. As discussions are done face-to-face, real-time immediate verbal and non-verbal feedback, may provide students with little lag-time in terms of communicating their ideas to each other. In a way, this condition may satisfy factors related to intimacy and immediacy under the social presence context, which influence the evaluation of online learning. Furthermore, conversations in design are important to generate discussion on a certain thought process [20]. Thus, by enabling students to conduct conversations in design, and providing the conditions for intimacy and immediacy in these conversations may contribute to students' positive evaluation on the effectiveness of communication when using online whiteboard during group discussion.

Currently, to reduce social contact within the school during Covid-19, lessons may be done remotely through synchronous, asynchronous or hybrid modes. This study presents an example of face-to-face design activities conducted without close gathering. Perhaps, to allow effective communication in activities similar to current study, the following suggestions may be considered. Firstly, the online whiteboard should contain functions that are easy to use and allow students to consolidate opinions. Secondly, teachers may need to set routines for students when conducting group discussions when using the online whiteboard. This is because, the constant switching between offline and online activities may cause confusion to students during the group discussions. It may be necessary for teachers to allocate sufficient time for students to write their opinions in the online whiteboard and follow by off-line face-to-face group discussions. Although students' competencies may not seem to influence their motivation in using the online whiteboard and their perceived effectiveness of group discussion in current format, more support in terms of training sessions before lesson activities in using online whiteboards may be necessary. Especially if online learning in design lessons is to stay for an unforeseeable future.

As limitations to this study, the current participant size is too small to clarify any statistical correlations between the different Likert item variables in the survey. Thus, the current assumptions that students' competencies in using digital devices may not influence their motivations in using online whiteboard and their perceived effectiveness of communication through online whiteboard will offer as hypothesis for further quantitative study. To study more deeply into the effectiveness of online whiteboards during face-to-face design discussions, a more rigorous study may need to be done by engaging students into complex projects that include complex design drawings and modelling processes.

6 CONCLUSIONS

As a conclusion, face-to-face design discussions when combined with the use of online whiteboard, provide students with real-time verbal and non-verbal feedback which offer effective group discussions during design activities. In addition, students' ability to use digital devices may not have direct influence on the perceived effectiveness of group discussions and their motivation to use online whiteboard during design discussions. To facilitate effective communications in activities similar to the current study, some suggestions such as choosing an easy-to-use online whiteboard with functions that allow ideas to be consolidated, setting up instructional routines in group discussions and providing training sessions before lessons activities may be necessary.

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A STUDY ON THE COMMUNICATION METHOD FOR ONLINE PARTICIPATORY DESIGN WORKSHOP

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ABSTRACT
The rapid outbreak of COVID-19 pandemic has accelerated the adoption process of digital online tools for social communication across disciplines regardless of cultural backgrounds. Design to had to quickly migrate a considerable portion of its activities to the Internet, making it the preeminent platform in which a large portion of workshops take place nowadays. This swift change from a 'face-to-face' to 'online' reality is by no means without problems and hurdles, a significant one among these, is the scarcity of academic documentation that deals with the workshops from a communication point of view (beyond the technical aspects). This study aims to identify communication problems within 'Online Design Workshops' allowing the organizers to reroute efforts, from a technical and administrative point of view to the quality of the design output itself. The research method adopted was participatory research praxis based on the comparison of survey outputs taken during 'face-to-face' and 'online' workshops conducted between years 2012 ~ 2019, and 2020, respectively. Using the SMCR model as a framework of communication analysis it was discovered that the most critical aspects are those related to 'understanding' (between participants, of the online tools, and of the contents). Accordingly, a first attempt at optimal heuristic paths to the improvement of design stages within online workshops with focus on communication are proposed. Further design workshops can be approached using the process outlined in this paper, adding to the robustness of the heuristics.

Keywords: Design workshop, online workshop, communication methods, SMCR model

1 BACKGROUND

Participatory social innovation workshops, hackathons, and similar design-sprint events oriented to solve social issues are held more often than ever before around the world. These events provide fresh and trans figurative methods to increase democratic and bottom-up approaches to innovation, in which participatory models of design has been found to be useful for sustainability and business [1]. In Japan, regular workshops organized by the i.school of the University of Tokyo [2], or social innovation activities by FUJITSU Limited [3] are two well known (among many others) of such events which congregate large numbers of participants from all sorts of professional backgrounds. A design workshop (dWS*), in general terms, differs from other workshops not only, as stated above, in its inclusion of participants with different groundings, but also in the utilization of a 5 stage approach towards finding solutions to problematics: (1) understanding, (2) problem identification, (3) idea development, (4) testing (prototype production), and (5) proposal presentation [4].

*The following denominations are adopted from now on, dWS refers to 'design workshop'. Although the next two are design workshops, both differs in their delivery and are denominated accordingly. f2fdWS refers to face-to-face design workshop', and odWS refers to 'online design workshop'.
This research presents insights on communication via an examination of a series of workshops implemented between years 2012 and 2020. In the period 2012~2019 the workshops carried out were of the f2fdWS type, and in the year 2020 of the odWS type.
Since the classification as a pandemic of the newly detected Corona Virus in 2019, the world has become a virtual (figurative and real) battlefield against the disease. The struggle to regain some sense of normalcy has been fought with all the arsenal at people's disposal, and no other 'weapon' has become more widely used than online communication tools. Although the massive adoption of this new medium

has been done fairly quickly, it has not been without hindrance. Most of the effort has been concentrated in the deployment of these tools, and in the case of dWS on how to utilize them, however, one would expect the general public to be exposed to a proportional number of resources that deal with communications issues, especially barriers that can affect the workshop's output. Although material of a specialized nature related to the communication process itself can be found using scholarly dedicated methods, a fairly simple and quick search using common and widely available search engines reveals a very different availability. In other words, how the design process is influenced by the use of online tools at a communication level in workshops would greatly benefit from more research being done.

2 AIMS

Firstly, this study aims to understand communication issues arising during odWS previously conducted by the authors, leading to heuristics to improve the experience of diverse participants. These would allow the organizers and participants, to focus on the design problematic, as well as creative human interaction, thus increasing the overall quality of the workshop output. Secondly, the study outlines frameworks for identifying issues, and improvements, so that the heuristics may be improved upon with further input.

3 RESEARCH METHODOLOGY

The overall methodology was to take the empirical dWS work conducted by the authors/co-organizers, to extract the characteristics of f2fdWS and odWS through the lens of a communication model. Points were then identified to make improvements to communication in odWS. It is important to highlight that as the authors are co-organizers of the dWS, the approach is participatory research praxis. The following subsections explain the methodology in detail.

3.1 Communication breakdown: applying the SMRC model

First, multiple models and methods of communication were considered from the literature, in terms of applicability to f2fdWS and odWS. Among the many existing communication models, each one of them focused on a different aspect of the process, being this technical, perceptual, or even psychological [5], [6], the SMRC model was adopted, as proposed by David Berlo [6]. The characteristics and rational for selection are described as follows. In the SMRC model, Berlo defined communication as composed of 4 basic elements, Source, Message, Channel, and Receiver, as shown in Figure 1.

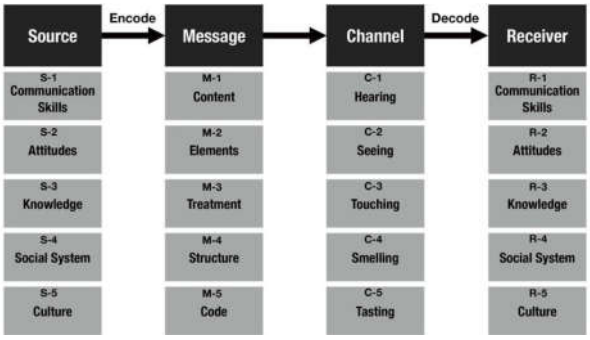

Figure 1. SMCR Model (adapted from businesstopia) [7]

Breaking down the model, the first element of the model is the Source (from here on denoted as <S>): The sender who originates the message. Second is the Message <M>: The content that is being sent by the sender to the receiver. The third element is the Channel <C>: The medium used to send the message. This is compromised of the human's five senses which are the channels for the communication. The final element is the Receiver <R>: The person who receives the message sent.

The reason for adopting the SMCR model in this study is that:

(1) the SMCR model takes into account the combination of spoken language and non-verbal language such as gestures <M> and the five senses <C>. It is therefore a model that captures the types of communication undertaken during dWS, and can highlight the differences between cases, as well as allow for a framework for improvements.

(2) Compared to f2fdWS, an odWS is not person-to-person but digitally mediated communication. Non-verbal communication such as gestures in <M> and communication through the sense of touch, taste, and smell in the <C> channel are greatly inhibited. Considering all of the above, the SMCR model provides a useful framework to characterize odWS as compared to f2fdWS.

3.2 Gathering perspectives

The subjects of the study were the participants and organizers of the f2fdWS conducted between years 2012 and 2019, and odWS in the year 2020. The total number of f2fdWS participants from 2012 to 2019 were 197 in total, with 38 participating in the 2020 odWS.
1) Questionnaire surveys were conducted, composed of structured (multiple choice) and non-structured questions with the inclusion of a Likert-scale in order to measure attitude and predisposition toward the experience of the workshop participation. 2) In order to obtain an organizer perspective that could shed light on the reasoning behind a particular form of communication, structured interviews with a delimited non-dependable set of questions were conducted among the odWS facilitators.
Based on the above survey results and the communication framework provided by the SMCR model, the factors that hinder odWS communication are clarified, the positive points on the odWS communication and the underlying causes are discussed. From these findings, a communication method unique to odWS is proposed.

4 RESULTS

4.1 Questionnaire survey of participants

In 2020 odWS there were 38 participants of which 31 participants respondents were asked a series of questions regarding their workshop experiences. From these respondents, 7 had also participated in previous f2fdWS, and were administered additional questions about their previous f2fdWS experiences, as seen in Table 1. They were asked to reflect on the differences between the two formats, as well as their backgrounds.

Table 1. Summary of survey results by participants of both f2fdWS and odWS

age	job	sex	when you joined a past GGJ	Please select reasons you felt this year online GGJ was more difficult than offline	What new learnings occurred during this year online GGJ, compared to offline
35	designer	f	f2fdWS:2016- 2019 odWS:2020	none	Total process / Workshop methods / Online communication tools
59	NPO owner	f	f2fdWS:2018, 2019 odWS:2020	none	Workshop methods / Refresh activities / Online communication tools / Teamwork
14	High school student	m	f2fdWS:2019 odWS:2020	Online communication tools / Teamwork	Online communication tools / Teamwork
25	University student, foreigner	f	f2fdWS:2018, 2019 odWS:2020	Breaks and lunch	Teamwork
25	Government office staff	m	f2fdWS:2019 odWS:2020	Breaks and lunch / Online communication tools / Teamwork	Total process / Workshop methods / Refresh activities
42	Company owner	m	f2fdWS:2018, 2019 odWS:2020	Breaks and lunch / Online communication tools,	Refresh activities / Online communication tools
23	University student, foreigner	m	f2fdWS:2018, 2019 odWS:2020	Teamwork	Refresh activities / Online communication tools

Of the 7 participants, 5 faced difficulties during the odWS. 3 found the odWS communication tool to be a challenge. 3 found the workshop break time and schedule setting to be a challenge, and 3 found difficulty in the teamwork dynamic. Regarding what new learning occurred in the odWS, among the 7 participants, 3 said they learned a lot about odWS methods, 5 said they learned a lot about online communication tools. 4 said the 'refresh activities' were good. This last term, refers to a new activity that was experimented on during the first odWS in 2020. Four of these kinds of activities were introduced to facilitate communication: Tai Chi exercise, radio exercise, mindfulness, and sound meditation. These engage the participants/organizers through physically and mentally embodied which elicit a 'mental reboot', a focus of attention displacement away from the workshop content as described in the literature. The respondents gave positive ratings to these activities. 31 participants who responded to the odWS in 2020 survey gave an approval of 63% very good, and 27% good.

4.2 Questionnaire survey results from facilitators of odWS

The 7 facilitators were interviewed regarding the f2fdWS and odWS. The issues and possibilities of odWS compared to f2fdWS are summarized in Table 2.

Table 2. Summary of survey results by facilitators of odWS

Challenges of odWS	Advantages of odWS
Channel • The loading of Miro is slow. • Prior training is necessary. • We may have put too much emphasis on the use of Miro. • The earphone jack and the place to charge the battery are not enough. Also, the earphone jack and the place for charging are the same, so we cannot do it concurrently. **Source/Receiver** • There were many absences without notice which create additional stress for the organizer. • The intensity of the discussion is worse than face-to-face. • Need to provide support for various participants to meet their different needs. **Overall** • It would be better if there were a mechanism to encourage interaction between teams. • The digital communication tools still pose as an issue for the future, though it has been easy to use multiple devices and displays.	**Channel** • It was easy to refer to the contents, and data collection is much easier. • Broadcasting on YouTube allowed families and stakeholders to watch. • Slack all odWS active communication and easy viewing after the event. • Real-time visualization of other people's work with Miro. **Message** • No need to write. • The possibility of designing an online experience that demonstrates communication, such as gestures, which can only happen in person. **Source/Receiver** • Because it is online, even those who cannot move or live across regions can participate. • The combination of different cities and online allowed the possibility for developing activities in a larger scale.

5 DISCUSSION

Based on the SMCR model, the following facts were understood: The challenges faced using the Channel's communication tools are significant. This may be due to the dWS participants having different skills-abilities, and coming from diverse backgrounds, which consequently has shown different levels of proficiency in communication tools.

The break time and schedule are related to SMCR in general. One particular challenge which was manifested not only in the participant themselves but also at the planification-coordination level was the 'timing' of the programme. The odWS actually takes a toll at a physiological and psychological level of a person required to work in a mostly sedentary mode with long amounts of screen time.

Another particular challenge discovered, was the one related to the teamwork communication skills and attitudes of <S> and <R>. Unlike f2fdWS, in odWS the communication is done through a device. A portion of <S> and <R> participants did not show their faces on the screen, this may have affected the intensity of the discussion depending on the participants' attitude.

The facilitator's role is to work from a relatively objective standpoint to facilitate the progress of the overall dWS and group activities when these are carried out and to help the groups perform. Looking at the survey results from this operational support role, further points were highlighted.

Table 3. Summary of factors that inhibit communication in odWS compared to f2fdWS

	(1) Understanding	(2) Problem Identification	(3) Idea Development	(4) Testing (prototype production)	(5) Proposal Presentation
Source	S-1 S-3 Lack of online encode skills and knowledge S-2 S-4 S-5 Insufficient understanding of other participants	S-1 S-3 Lack of online encode skills and knowledge S-1 S-2 S-3 Low participation in discussions	S-1 S-3 Lack of online encode skills and knowledge S-1 S-2 S-3 Low participation in discussions	S-1 S-3 Lack of online encode skills and knowledge S-1 S-2 S-3 Participation in prototype production depends on PC skills	S-1 S-3 Lack of online encode skills and knowledge S-2 S-4 S-5 Lack of understanding of participants other than team members
Message	M-1 M-2 M-3 M-4 M-5 Main information from visual and audio M-1 M-2 M-3 M-4 M-5 Lack of non-verbal gestures and vocal variety	M-1 M-2 M-3 M-4 M-5 Main information from visual and audio M-1 M-2 M-3 M-4 M-5 Lack of non-verbal gestures and vocal variety	M-1 M-2 M-3 M-4 M-5 Main information from visual and audio M-1 M-2 M-3 M-4 M-5 Lack of non-verbal gestures and vocal variety	M-1 M-2 M-3 M-4 M-5 Main information from visual and audio M-1 M-2 M-3 M-4 M-5 Lack of non-verbal gestures and vocal variety M-1 M-2 M-3 M-4 M-5 Prototype in the form of video only	M-1 M-2 M-3 M-4 M-5 Main information from visual and audio M-1 M-2 M-3 M-4 M-5 Lack of non-verbal gestures and vocal variety
Channel	C-1 C-2 C-3 Depends on online environment, equipment, and software C-1 C-2 Difficult to collect information other than sight and hearing	C-1 C-2 C-3 Depends on online environment, equipment, and software C-1 C-2 Difficult to use much software at the same time C-1 C-2 Difficult to collect information other than sight and hearing	C-1 C-2 C-3 Depends on online environment, equipment, and software C-1 C-2 Difficult to use much software at the same time C-1 C-2 Difficult to collect information other than sight and hearing	C-1 C-2 C-3 Depends on online environment, equipment, and software C-1 C-2 Difficult to prototype though five senses	C-1 C-2 C-3 Depends on online environment, equipment, and software C-1 C-2 Difficult to collect information other than sight and hearing
Receiver	R-1 R-3 Lack of online decode skills and knowledge R-2 R-4 R-5 Insufficient understanding of other participants	R-1 R-3 Lack of online decode skills and knowledge R-1 R-2 R-3 Low participation in discussions	R-1 R-3 Lack of online decode skills and knowledge R-1 R-2 R-3 Low participation in discussions	R-1 R-3 Lack of online decode skills and knowledge R-1 R-2 R-3 Participation in prototype production depends on PC skills	S-1 S-3 Lack of online decode skills and knowledge S-2 S-4 S-5 Lack of understanding of participants other than team members
Overall	• Difficult to plan the workshop with diverse participants. • Difficult to provide technical support to diverse participants. • Difficult to provide emotion support to diverse participants.				

For the <C> issues, unlike the results of the first survey, the facilitators viewed the issues not only from the perspective of the communication tools, but also from a larger perspective of the internet facilities and participation environment. In the case of <S> and <R>, more support was needed for the various participants. At the same time, the facilitators had to spend a considerable amount of time getting acquainted with the technical aspects (usability) of the digital tools, which added to their scope of responsibilities, requiring extra effort. The surveys also showed the possibility of new methods of active <C> and <M> processing in odWS and the necessity of new methods suited for the online medium.
From the above results, the odWS communication compared to f2fdWS showed concrete deficiencies from a technological perspective <C>, teamwork between participants <S/R>, and the overall design process communication performance was negatively impacted at all levels <S/M/C/R>, including the 'non-structured' (casual) communication at break times. The summary of the factors that hinder communication in odWS are listed for each process in Table 3.
A dWS is an activity that if correctly implemented may be able to not only provide concrete output in the form of services or products, but also create a powerful base for social impact, however, the issues highlighted in Table 3 show that odWS have many issues that need to be addressed to reach its potential. The heuristic paths to improvement have been summarized below in Table 4.

Table 4. Proposed methods to improve communication for diverse participants in odWS

Understanding	Problem Identification	Idea Development	Testing (prototype production)	Proposal Presentation
• Share information such as hobbies, motivations for participating in WS advance. • Share information for participating in WS, language and computer skills with team members in advance. • Create a support system in advance according to the communication skills of individual participants. • Share the program and other details of the WS in advance. • Share the online communication method video • Hold a training session on online communication tools such as Zoom, Slack, Miro, etc., in advance, or hold multiple sessions if necessary.	• Provide activities that allow participants to share their thoughts. e.g., 5 whys • Incorporate refresh activities for the body and mind to relax. e.g., Tai Chi exercise, Mindfulness • Personalized support for online whiteboard tools. e.g., Miro	• Incorporate refresh activities for the body and mind to rest. e.g., Radio Exercise, Sound Meditation • Personalized support for online whiteboard tools. e.g., Miro	• Technical support for participants' work assignments. • Introduce a variety of prototypes in advance. Share the online technical method to make prototypes.	• Interaction between teams. • Technical support for presenters. • Sharing of other teams' presentations.

• Provide an environment with a network. • When forming teams, consider the diversity of participants in terms of skills, gender, and age.
• To have a facilitator for each team to support and facilitate communication according to participants' needs.
• To assign a communication skill supporter to each team to provide individual technical support and emotional support to participants who need it.
• Share the rules for participation in advance to prevent participants from the cancellation or to leave the room without informing.
• Prepare multiple communication tools for emergency contact. • Create a system for facilitators to understand and share the overall situation.

The table organizes the dWS into five stages with common issues listed in the square underneath. It is worth mentioning important factors in each stage. In order to have good communication, at the first stage, understanding must be of a pre-emptive nature, that is to say, good comprehension among participants, of the concept, of contents of the dWS, and of the online communication tools at a technical level should be done prior to the problem identification where the focus should be concentrated of the design issues itself. At the problem identification and idea development stages, it is important to ensure each participant with enough online resources, so ideas are easily conveyed and omnipresent (constantly visible and accessible by all participants) this facilitates awareness, idea diffusion, and convergence.
'Refreshing activities' such as Tai Chi exercise, mindfulness, among others, should not be taken lightly, although reduced in their scope and direct influence at the design level itself, their impact could greatly amplify the quality of the ideation stage in which focused analytical, yet highly abstract thinking is necessary.
Prototyping, even in f2fdWS is a complex issue. More often than not, participants misplace the focus of this stage on the technical aspects related to 'make the design solution work (as in function)' rather than in conveying 'how the product under a particular set of circumstances should operate'. In an odWS, participants should be provided with the technical means necessary to communicating the optimal operational conditions of a design solution. Organizers should confirm the correct understanding and usability of any prototyping tool in advance, even to the workshop itself (e.g., registration period).
In the Presentation stage, technical expertise and total (as much as possible) control over the technical aspects of the delivery (signal, connection, sound, image quality, etc.) is crucial. An unpredictable or unstable environment not only will hinder the communication by reducing the effort invested in the workshop to useful but undeliverable information, but also could potentially exert a hard impact at an emotional and psychological level of the participants preventing them to take part in these kinds of

events again. Organizers should prepare a 'plan B', made known to all participants in advance, in the case that optimal online live delivery cannot be secured.
In addition, it is very important to create a fair, democratic, interactive, and open environment in which every participant and team can express, share, and exchange ideas and feel accepted regardless of their background, and specially in odWS, their connectivity. Activities which are designed or adapted to be carried out in online environments can be benefited by the adoption of a communicative approach based on the SMCR model. At first, it may not be easy for the participants to reach an optimal level of performance at the <C> due to the multiple layers of computing requirements. Hence, it is of core value to design an understanding of what an optimal <M> should be for an online domain, especially one in which the bidirectional interaction between Source and Receiver is flawlessly realized. This kind of understanding requires a wide and novel array of approaches. Case in point, the 'refresh activities' incorporated in the odWS in 2020.

6 CONCLUSIONS

This study is a first attempt to extract problems identified during odWS using the SMRC model and suggest paths to improvement through along a five stage dWS framework. The proposed method for improvement increases the chance of success communication during online participatory workshops with diverse participants. Thus, enabling the workshop organizers who focus on elements of the workshop that are more critical for the qualitative outcomes.
Considering the survey analysed data, when compared to f2fdWS, since odWS is not person-to-person but (computing) device-mediated communication, Non-verbal communication such as gestures and communication through the sense of touch, taste, and smell in the <C> are greatly inhibited. In order to improve it, coordination in <S, M, R> is crucial, and for <M>, It is suggested that taking advantage of online digital tools to collect information and assemble it in a way that is psychologically and emotionally relevant to the participants at <S> and <R> ends is key (pre-emptive understanding).
As a first attempt, the proposed heuristics suggested in this paper are by no means final. Further dWS can be approached using the process outlined in this paper, adding to the robustness of the heuristics.
Finally, under the dawn of the massive vaccination programmes currently under implementation, the world will eventually regain some semblance of similarity analogous to a pre-pandemic condition. However, even with paths to improvement at hand, we should be prepared for the scenario that the need for online activities, including workshops, increase and diversify. The significance of this research is a direct contribution to the diverse stakeholders of dWS equally across education and for/non-profit sectors.

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THE DESIGN OF A MORE SUSTAINABLE TRAVELLING EXHIBITION

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ABSTRACT
Design and engineering education requires continuous adaptation to the existing environmental and social challenges. The design of sustainable and socio-ethical new solutions that involve not only the design of industrial products but also services and systems that combine products and services is currently considered in several studies as a satisfactory way to work.
This study shows how practical methods considering sustainability principles are applied to design a more sustainable cultural service. A project dedicated to the development of a travelling exhibition is addressed. Sustainability has been evaluated using the Life Cycle Sustainability Assessment (LCSA) method that takes into account the environmental, economic, and social dimensions. A set of sustainability indicators have been used and impacts associated with each dimension have been obtained in the three main stages established within the service life cycle: implementation, operation, and dismantling. Factors that cause the highest impact have been identified and design alternatives to improve the sustainability of the service have been proposed. To prove if the new service design generates less impact, a comparison between sustainability indicators of both initial and new service has been conducted.
Promoting the improvement of sustainability in design projects is increasingly required. This kind of final degree project underlines the responsibility the designers have to be aware of the impacts of their designs as well as allows the students to gain experience in an area in which they can practice the profession.

Keywords: Sustainable design, cultural service, design methods

1 INTRODUCTION

The cultural sector represents many employment opportunities for the designers and the concern about sustainability in this sector is growing. In the last decades, notable efforts have been observed in museums and institutional buildings, in which transformations towards reducing its environmental impacts, especially the energy demand [1, 2] have been performed. Initiatives as Leadership in Energy and Environmental Design in the USA [3] had helped to establish criteria for building environment improvement. The environmental and human health impacts have been also addressed in a study of exhibitions at the Museum of Fine Art in Boston [4].
On the other hand, Life Cycle Assessment (LCA), standardized in ISO 14040 [5], is already applied to multiple products and processes across a wide range of sectors. LCA requires databases that define the impacts of each material, product, and service. Nunberg et al., [6] are developing one dedicated to cultural heritage preservation and exhibition practices. The above-mentioned research is a pioneer in LCA application to the museum's permanent exhibited objects. Museums use also temporary exhibitions to engage with the public, make local audiences' return to the museum, and help to attract sponsors and media attention [7] and maintain ticket pricing [8].
In the context of Higher Education, a movement to adopt the Sustainable Development Goals (SDG) [9] and sustainability can be observed. The Association of University Leaders for a Sustainable Future [10] and the Association for the Advancement of Sustainability in Higher Education [11] were created to encourage a commitment to teaching and research in sustainability. Multiple declarations to introduce sustainability in the agenda of higher education institutions have been published [12].
The Final Degree Projects (FDP) represent a great opportunity to the students to apply knowledge in an interdisciplinary field, introducing new methods and techniques that can respond to the constantly

evolving environmental and social situation. In the case of a Bachelor's Degree in Industrial Design and Product Development Engineering at the University of Zaragoza, students have the option to enrol in the elective course focused on SDG, but it does not equip them with practical tools for addressing the evaluation and improvement of the system's sustainability. A group of professors teaching in this degree decided to offer FDP that include sustainability assessment. Those tutors are researchers in the field of sustainability and cultural service design and offer to the students the tools considered most adequate for the scope of the projects. FDPs are realized by students individually and are tutorized or co-tutorized by chosen professors during approximately 5 months in weekly sessions. The FDP corresponds to 12 ECTS, the object is chosen by both student and teacher and it is approved by the degree academic commission that checks if the object and scope of work are adequate.
In this work, FDP focused on temporary travelling exhibitions is presented. The sustainability of this system has been analysed, based on a real case with authentic inventory and improvement options have been explored theoretically. In particular, a new design of the exhibition area has been projected. The sustainability of the initial and new designs has been, finally, compared. The presented case study aims to respond to the following research question: Can FDP be treated as a try for new content implementation to Engineering Industrial Design Degree, with the special focus on LCSA methods applied to the cultural sector?

2 METHODOLOGY

In order to achieve more sustainable systems (products or services) taking into account a life cycle perspective, a methodology organized in three main phases is applied in this work (Figure 1):
Phase 1 - The sustainability of the initial design is assessed according to the Life Cycle Sustainability Assessment (LCSA) [13] approach. Environmental impacts, economic aspects and social issues are evaluated by compiling inputs and outputs of the system object of study and using a set of suitable indicators. The impact spots are detected.
Phase 2 - A more sustainable design is projected taking into account sustainability results obtained in the previous phase and without compromising specifications already established in the initial system. Several sustainability strategies can be proposed. A new inventory should be performed to obtain the sustainability indicators of the new design.
Phase 3 - Comparing designs. The sustainability of both initial design and redesign is compared to detect if improvements have been achieved. The parallel presentation of individual indicators as well as the use of an aggregated sustainability index to obtain a global evaluation can be carried out.

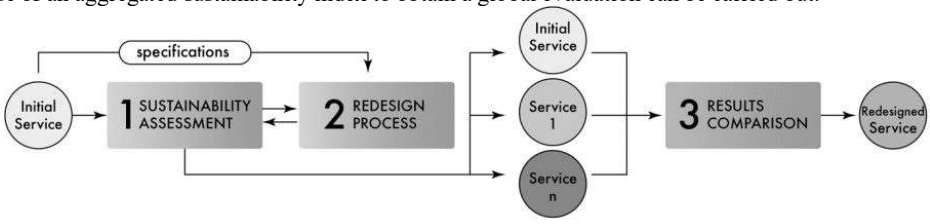


Figure 1. Phases of a redesign of more sustainable services

Different indicators are proposed in this work to quantitatively assess each of the three sustainability dimensions. The Global Warming Potential (GWP_{100}), which represents total emissions of the greenhouse gases calculating the radiative forcing over a time horizon of 100 years, is the environmental indicator selected. The Execution Cost (C_E) or total cost to develop an activity is used in the economic dimension and the average Working Time (T_W) is the indicator selected to value the social impact (the category of workers is selected according to UNEP's guidelines [14]).
Complementary tools were used to obtain these indicators: the Cype Software that provides data of costs and working times in construction, assembly/disassembly and transport activities; the CE3X local software, which is used to estimate energy consumptions due to air conditioning in buildings taking into account both geographic location data and constructive features; emission factors of electric commercial companies [15] were applied to evaluate greenhouse gas emissions from electric consumptions; finally, data of greenhouse gas emissions of a number of materials used in the creation of the exhibition area were obtained through the Gabi software.

3 CASE STUDY - ITINERARY EXHIBITION

Methodology was applied to improve the sustainability of a temporary travelling exhibition, in which historical contents are exhibited. After its inauguration in Madrid, the exhibition will travel to seven different European destinations. The service lifecycle has been divided into creation, provision, and end of life stages (Figure 2) and detailed inventory has been carried out using primary data collected during the creation, provision, and end of life stages of the exhibition in the first destination.

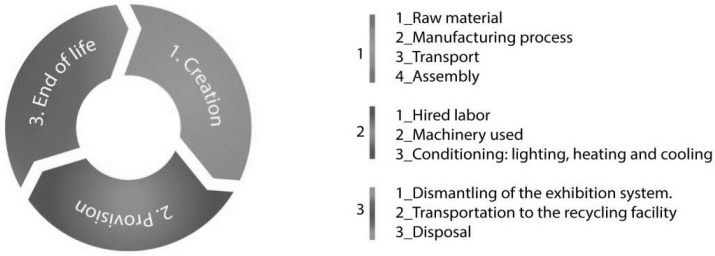
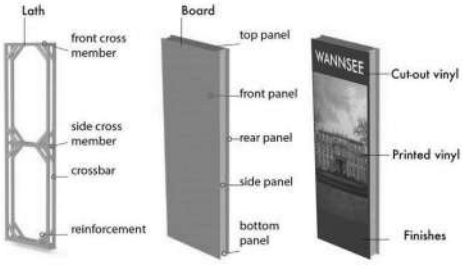


Figure 2. Life cycle stages and research scope

The exhibition is open every day for 11 hours for 6 months. Activities of ticketing, public attention, coordination, gift shop and cloakroom are developed in two shifts of 5.5 h each day. The security of the exhibition is organized in three shifts of 8 h (3 workers in each one) and cleaning activities (including daily vacuuming of the carpet) are carried out before opening in one shift of 3 h. Suitable lighting, heating, and cooling conditions (for the exhibits and visitors) are created in the exhibition. 205 MWh were consumed by heating, 24 MWh by refrigeration and 76 MWh by primary lightning. A total number of 300,385 visits were registered during 6 months in the first destination of the exhibition. Each visitor spent on average 3.25 h and an elevated number of visitors (70%) used an audio guide system. The recharge of audio guides supposed a consumption of 14.3 MWh.

The preliminary conditioning of the exhibition area involves the construction of a modular walls system with the printed material displayed on them (printed and cut-out vinyl) as well as covering the floor with a polyamide carpet. A total of 415 modules of 1x3x0.2 m each one, are conveniently distributed in the exhibition area. The structure is made of wood slats, joined by dowels and adhesives, and later covered with medium-density fibreboard (MDF) panels (Figure 3). Printed vinyl (372.87 m^2) and cut-out vinyl (83.73 m^2) are attached in some of these modules. A polyamide carpet thickness 6 mm, fixed with a flooring adhesive, is used to cover the floor in the exhibition hall. To prevent damage during modules assembly and painting processes, the carpet includes a plastic protector, which is removed before the exhibition opening.



Raw material (BS_1)

Element	Units	
Lath (30 x 50 x 3000 mm)	2,947.00	pcs.
Board (19 x 2100 x 3660 mm)	479.00	pcs.
Dowels (Ø 10 x 30 mm)	23,240.00	pcs.
Lag screws (Ø 3,5 x 35 mm)	35,654.00	pcs.
Printed vinyl	372.87	m2
Cut-out vinyl	83.73	m2
Transfer Paper	83.73	m2
Ink	5.18	l
Adhesive	4.47	kg
Finishes	2,490.00	m2

Figure 3. Temporary wall structure and raw materials inventory used in the original service

The manufacturing process, transport to the exhibition hall and assembly on site of the modular walls system was examined. The sequence of activities performed by the team of carpenters as well as the materials required to the full preparation of the exhibition area, were determined [16]. In each destination, dismantling activities after the exhibition was closed, were also analysed. Exhibition display panels are not reused, so that these are classified into appropriate categories and transported to waste

management plants. On the other hand, the transport of artifacts (historical objects and art pieces), showcases, wall cases and frameworks as well as reproductions, facsimiles, models etc. between different destinations is carried out through 110 flying cases and 3 trucks. A total volume of 172.55 m^3 and a total weight of 19,600 kg are transported an average distance of 578.14 km. To limit the complexity of the study, the creation process of the artifacts, showcases and audio-visual content of the exhibition are not included within this research.

The quantitative measure of the impacts in each sustainability dimension was carried out using the indicators previously defined. Results are summarized in Table 1. The creation stage has an important impact. It includes raw materials, manufacturing processes, transport, and assembly. The raw materials used in the preliminary conditioning of the exhibition area accounts for 61.7% of the total service greenhouse gas emissions. Costs due to the use of raw materials in the previous preparation of the exhibition space are also relatively important (23.8%). In consequence, this is a very significant factor affecting the sustainability of the system.

In the second phase, improvement strategies are applied taking into account initial specifications of the system. Particularly, the itinerary exhibition requires that the assembly/disassembly activities could be easily carried out in each destination. It is also necessary to keep specific aesthetics giving an illusion of continuity in the exhibition space, to ensure appropriate attention to visitors, and to guarantee the security of the contents exhibited. The sustainability results obtained reveal a significant impact factor of the raw materials used in the preliminary assembly of the exhibition area- materials used for walls, carpet and display supports. These materials are discarded after the exhibition finishes at each destination so that a new modular walls system (415 modules) and a new carpet (around 2,500 m^2) have to be manufactured in each location. Thus, the use of a new modular walls system that could be transported and reused in different locations is proposed as a sustainability strategy. The new modular walls system consists of standard anodized aluminium profiles assembled with quick joints and covered with two panels made of polyester fabric with a silicone guide in its contour (Figure 4). The fabric will be printed so there will be no need to attach vinyl on it. Since the walls will not be painted and assembly will be done dry, a 3 mm thick carpet made of polyester without a protector is proposed to cover the technical floor. The carpet is fixed with flooring adhesive.

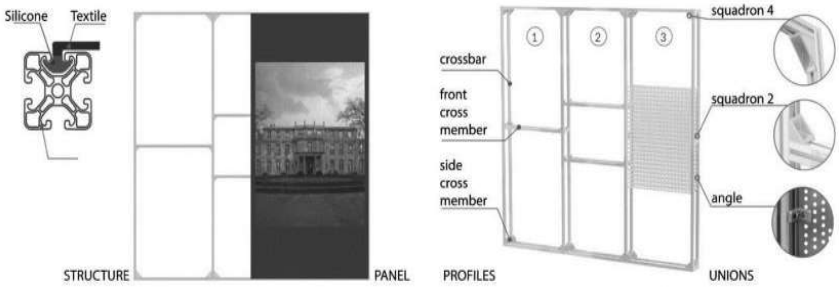


Figure 4. Temporary wall structure used in the redesigned service

Applying this strategy, only the carpet (which has to be replaced in its totality), and textile panels containing text (10% have to be replaced because of the language change) are newly manufactured in the second and subsequent locations where the exhibition is open. The total replacement of carpet is needed as the fair carpet is being used and after the intensive exploitation - more than 300.000 visitors in one destination it does not maintain the aesthetic and other characteristics needed for the new opening. Most of the elements used in the exhibition conditioning can be reused. The total volume of materials, which is required throughout 8 destinations, is greatly reduced from 793.3 to 99.1 m^3. Materials can be transported in 2 trucks, which are included in the transport service.

As all destinations are within Europe and transport has a limited impact on the whole system (1.5% in the case of GWP_{100}, 0.4% in C_E and T_W indicators) the same transport model has been applied in the redesigned proposal. Finally, the third phase of methodology is carried out, and the comparison between indicators of original and redesigned is conducted (Table 1).

Table 1. Sustainability indicators of original - redesigned service (data expressed per visit)

	GWP_{100} (kg CO_2)		C_E (€)		T_W (h)	
	Original	Redesigned	Original	Redesigned	Original	Redesigned
CREATION	0.39	0.05	0.55	0.23	0.0023	0.0011
PROVISION	0.22	0.22	1.20	1.2	0.0032	0.0032
END OF LIFE	0.0013	0.0003	0.04	0.02	0.0005	0.0007
TOTAL	0.61	0.27	1.78	1.44	0.0060	0.0049

Figure 5 shows a comparison between the environmental, economic, and social indicators of original accommodation and its redesign. The applied strategy resulted in the impact reduction registered in all dimensions. Taking into consideration the redesigned service its impact has been reduced by 55.21%, 19.13% and 18.2% respectively, calculated in GWP_{100}, C_E and T_W indicators compared to the original service. The major reductions take place in the creation stage; in the environmental dimension the GWP_{100} indicator has been reduced by 86.53% of its original value, in the economic dimension the cost has been reduced by 58.83%, and in the social dimension the working time is reduced by 53.64%. The provision stage impacts have not changed as no modification in this part of the life cycle of the service has been applied in order to provide the unchanged visiting experience to the public. In the end of life stage, the impact has been reduced by 76.41% and 50.28% respectively, calculated in GWP_{100} and C_E indicators compared to the original service, however in T_W indicator the value has increased 30.14% as the disassembly is more time demanded in the redesigned system. Nonetheless, the impacts of the end of life stage in the whole life cycle are not of great importance: it represents 0.2% of the whole system in the case of the original design, and 0.05% in the case of the redesigned system. The transport of the modular system between different destinations has no significant impact.

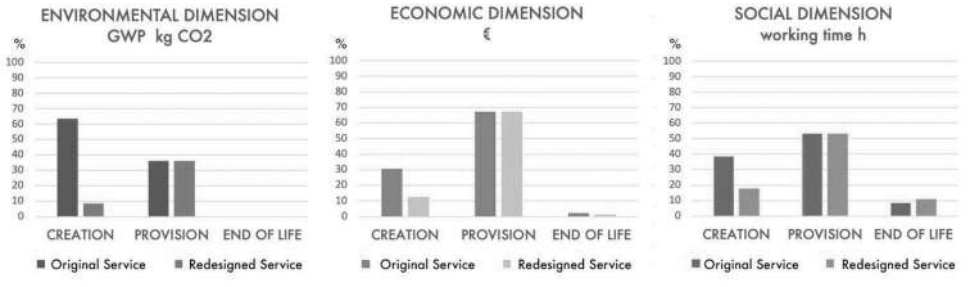


Figure 5. Comparing indicators of original- redesigned service

The overall improvement in the sustainability of the system can be determined by applying different weights to each dimension. 4 possibilities have been considered and results have been collected in Table 2. In all cases, the results are positive, which indicates favourable results.

Table 2. Sensitivity analysis to the weighting of the sustainability indicators

		C1	C2	C3	C4
Indicator	Variation (%)	Coefficient			
GWP 100	55.21	0.33	0.50	0.25	0.25
Costs	19.13	0.33	0.25	0.50	0.25
Working time	18.20	0.33	0.25	0.25	0.50
		Sustainability improvement			
		30.85	**36.94**	**27.92**	**27.69**

4 CONCLUSIONS

The sustainability of a temporary travelling exhibition has been assessed applying LCSA methodology and a more sustainable option has been proposed. The originally used modular system of wood and MDF walls has been replaced in each destination of the exhibition. It has been compared with a

redesigned exhibition system made of aluminium and textile that could travel and be reused in all destinations. Also, the carpet material has been modified to lower the environmental impacts. The results show a decrease in the indicators in the redesigned system across eight European destinations. As the number of destinations increases, the profitability improves, and emissions decrease comparing both systems; being the environmental dimension the most influenced. The main factor of influence is the raw material reusing.

The introduction of sustainability assessment in FDP was interesting for the students, who had the opportunity to prove their competencies in design activities while acquiring LCSA knowledge and have their first experiences in the cultural service design. The presented project has been defended in front of the members of the FDP commission and has been assessed with a score of 9 out of 10, which is a very positive academic result. The student feedback was positive, highlighting the fact that the sustainability assessment gives a new perspective in the design and redesign process, because of the consciousness of the sustainability impacts of design choices. The FDP resulted in an opportunity for the teachers to include new content to the students which otherwise would require a modification of the study program which is an administrative and time costing procedure. The FDP can be therefore perceived as a field of exploitation of new topics that in the future can be used for adaptation of teaching curricula. Student's feedback is vital and valuable, especially that they have reached certain professional maturity and can assess the value of new contents from the whole degree perspective.

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UNDERSTANDING AESTHETICS IN DESIGN EDUCATION

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ABSTRACT
One of the more pressing issues that the product design profession faces today is that of sustainability. Within design education this is mainly addressed with a focus on the three r`s: recycling, reuse and repair. In her book entitled *Aesthetic Sustainability: Product Design and Sustainable Usage,* Kristine H. Harper argues that another way to create sustainable products is to obtain aesthetic durability that provides the user with an emotional connection or aesthetic nourishment [4]. Such an approach requires both broad and in-depth knowledge of aesthetic ideas, something on which contemporary product design education can focus in new ways. This paper explores the challenges of aesthetics in design education through a pilot study that aims to identify possible problem areas and further research opportunities by asking the following research question: What are the challenges with teaching aesthetics in a product design programme at bachelor level, and how do the applied teaching methods provide students with versatile tools that can facilitate innovation through design? This study uses a phenomenological approach with a focus on qualitative methods, consisting of in-depth interviews with two teachers as well as three students in order to also capture the students' points of view. This method was triangulated with a literature review and an analysis of a variety of descriptions of aesthetics in the learning outcomes attached to each subject in the bachelor programme included in this study. The goal of these methods was to capture a multitude of perspectives on how aesthetics is taught and to discuss how this can empower students to use aesthetics in creating innovative and sustainable design solutions.

Keywords: Design, aesthetics, education, innovation, sustainability

1 INTRODUCTION

In this paper, the challenges of aesthetics in design education are explored through a pilot study aimed at identifying possible problem areas and further research opportunities. The author is a master's student with a background in product design. Despite being interested in the role that aesthetics plays in the creation as well as the enjoyment of products, the complex nature of aesthetics has made it difficult to obtain a holistic understanding of the subject. In his article entitled 'Models of design: Envisioning a future design education' [2], Ken Friedman discusses the challenges which designers may face in the future, as well as which tools they will need in order to tackle these challenges. He argues that the increasing demand for designers to work in a more interdisciplinary way requires a more flexible approach on the part of the designer. He suggests that designers should be proficient in science and technology, design, art and hermeneutics in order to provide valuable solutions to complex problems. This article will focus on the art aspect within design, which will be referred to as aesthetics throughout this paper. Aesthetics is a complex field of study that extends beyond the borders of design and is a central topic in the fields of art and philosophy [3]. Part of the challenge of aesthetics within product design is related to how it is defined and understood. This leads to the research question for this pilot study: What are the challenges with teaching aesthetics in a product design programme at bachelor level, and how do the applied teaching methods provide students with versatile tools that can facilitate innovation through design?

Initial discussions with postgraduate students in product design indicated that some students may feel a lack of confidence in their aesthetic knowledge, and that the level of aesthetic understanding can vary within the student base. The design students who were interviewed in this study reported that they considered the use of aesthetics to be very important for creating innovative and sustainable products. This raises the question of whether or not the teaching of aesthetics is providing students with the tools they need to create innovative products or whether new approaches should be considered and explored.

An example of how aesthetics can be applied to complex problems within the context of design can be found in Kristine H. Harper's *Aesthetic Sustainability: Product Design and Sustainable Usage*, in which she conducted extensive research into a wide variety of aesthetic theories and practices, including an aesthetic strategy model which can be used to create meaningful design solutions [4].

2 METHODS

This study uses a phenomenological approach [1] in order to create an in-depth understanding of how students and educators experience the teaching of aesthetics within design education. The empirical data collected consists of in-depth interviews with two teachers and three students to also capture the students' points of view. The in-depth interviews with the students include survey questions, where the students evaluate their learning outcomes with regard to aesthetics as well as their attitudes towards the subject. This interview method was chosen in order to better understand the relationship between the teacher's intention and the resulting learning outcomes for the students. The abovementioned method was triangulated with a literature review and an analysis of references to aesthetics in the learning outcomes attached to each subject in the entirety of a three-year bachelor programme. The analysis was conducted in order to determine what knowledge the students are meant to have at the end of each subject course and is then compared to the self-reported evaluations of the students who were interviewed. The goal of these methods is to capture a snapshot of a multitude of perspectives on the challenges of teaching aesthetics and to determine to what degree these methods empower students to use aesthetics in creating innovative design solutions. The literature review was conducted prior to the interviews in order to establish background information and an understanding of the context of aesthetics in education. The literature review consisted of *Aesthetic Sustainability: Product Design and Sustainable Usage* [4], Arts and cultural education in Norway 2010/2011: Report [5] and two articles that focus on aesthetic exploration through crafting within the context of design education [6, 7].

3 RESEARCH

3.1 Analysis of learning outcome

The analysis of references to aesthetics in the learning outcome, attached to each subject in the bachelor programme are categorised by reference type to show how much attention is given to aesthetics in each subject. The graph shows the number of references as well as the type of reference. The subject codes and names have been anonymised for ethical reasons to protect the interests of the institution and the participants in this study. However, the numbering of subjects is chronological and indicates the progression of the bachelor programme.

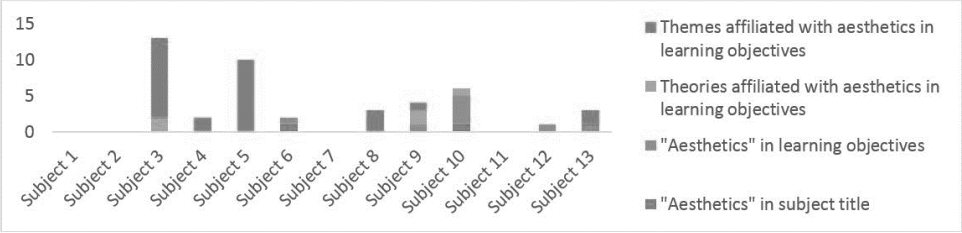

Figure 1. Visualisation of the analysis depicting aesthetic references in learning outcome

As can be seen from Figure 1, few explicit references are made to aesthetics in the learning outcome, although there is a lot of aesthetic content. This may result in subliminal learning, where students may unconsciously have retained aesthetic knowledge and practice, possibly with limited ability to articulate those insights. To examine this, the students were asked to rate their experiences of the teaching of aesthetics as mostly direct or indirect on a numerical scale.

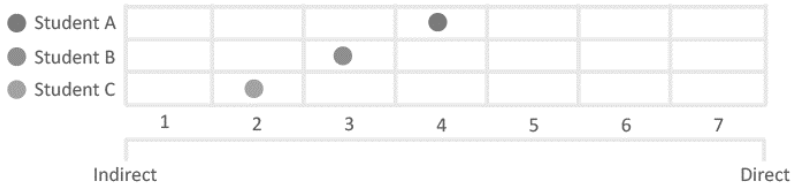

Figure 2. Visualisation of students' evaluation of aesthetic learning as direct or indirect

As Figure 2 illustrates, the three students who participated in this study reported that they experienced the overall approach to teaching aesthetics as more indirect, meaning that aesthetics was not mentioned specifically. Aesthetic principles, devices, methods and theories that touch upon the field were included in the teaching of subjects with another focus rather than directly, meaning that they were explicitly communicated through lectures, literature or delivery criteria.

3.2 Student evaluation of aesthetics in learning outcomes

Three students were interviewed during the course of this study. The students have been anonymised and will be referred to as 'Student A', 'Student B' and 'Student C' throughout this paper. Student A and Student B have completed the bachelor programme. Student C has yet to complete the bachelor thesis but has reviewed the other subjects. The students that were selected represent a variety of perspectives within product design. Each interview lasted for approximately one hour. The interviews with Student A and Student B were conducted by video conferencing, while the interview with Student C was conducted in person.

Student A is currently undecided about their specialisation and has a more commercial view of aesthetics in design. The interview reveals that the main emphasis for aesthetics in their work is stylistic.

Student B is mostly focused on design of medical equipment, and their view on aesthetics is geared towards creating emotional relationships between the user and the product and on facilitating functionality.

Student C is more artistically inclined. As a ceramicist their work on aesthetics is experimental and explorative. This student has engaged actively in aesthetic design and has developed distinct expressions that challenge the concept of 'the beautiful'.

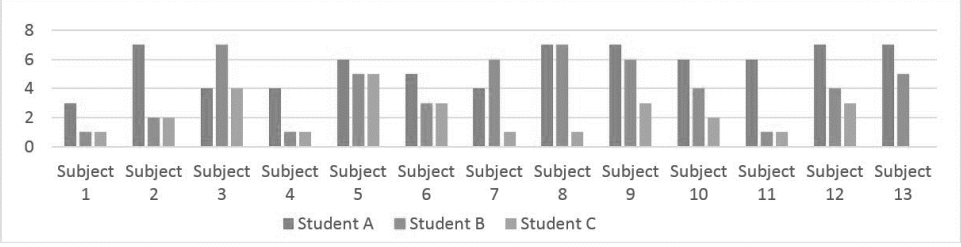

Figure 3. Visualisation of student evaluation of aesthetics in learning outcomes

Figure 3 visualises the self-reported evaluation of the aesthetic learning outcomes for each subject. The results in this graph were not correlated with the results in Figure 1 showing the number of aesthetic references. The graph in Figure 3 shows the students' evaluations when asked to rate their aesthetic learning outcomes on a numerical scale [1] ranging from 1 to 7 where 1 indicated the lowest learning outcome and 7 the highest. These results show that the students have very different experiences of each subject. A possible reason for this may be that the answers from each individual may be influenced by their level of confidence but may also be a consequence of how the subject was presented to them. These subjects are primarily project-based and offer students a high degree of freedom in pursuing different focus areas. Student A rates most of the subjects at the top end of the scale and defends these evaluations on the basis of enjoying the flexibility of project work and being able to explore aesthetics.

Flexibility is important. In some of the subjects I have not given a 7 because I feel that it has not been enough. Or the course leader has not been interested enough to participate in a discussion about aesthetics, maybe because it does not interest them or maybe they don't have time. Still, I think that the structure of the subject enables you to explore questions about aesthetics. Student A.

Student A valued the freedom of the project-based teaching programme, though felt that it lacked direction. The following quote from Student A indicates that although the subjects were rated at the high end of the scale, more theoretical input was desired.

I want a clear and distinct context in which aesthetics can be applied. Are there principles or tools that I can apply to only physical products? Digital products? What is the limitation? I really feel that the bachelor is put together so loosely. That when you finish the bachelor thesis, then presumably, you are really only at the beginning stage of your design education. I feel that my final outcome after the bachelor's degree is a little too open, a little too vague. Student A.

These thoughts were reflected in the following responses from Student C:

I think aesthetics shouldn't just be something that you learn on your own. Well, this is a bachelor degree that you have to research. I think something should be handed to you as well. I actually talked about this with my partner the other day and he's like, you don't really have enough tools in your toolbox as a designer. I'm good at figuring out problems, I can fix it and I can design anything from a chair to a lamp to a wheelchair, but the reason I say I can do anything is because I will research the problem and design from that. But I feel like I lack depth within me as a designer, what I should know for example about aesthetics. Student C.

Student B also made some reflections about the structure of the subjects and the desire for more specific theoretical input. Student B suggested that a reflection lecture might be implemented at the end of each subject, where teachers and students could engage in reflective discussions about the learning outcomes and experiences gained through the course module. Student B believed that the structure of the subjects did not need to be changed in a significant way, but that there was a need to find a method that could facilitate the conversion of unarticulated learning into conscious learning.

That's what I feel is a bit lacking in the programme. We don't get the baking mix, basically. We only get the ingredients without the recipe book. It's a bit like that, and sometimes it's okay to just get the ingredients and experiment, but feel free to give us the cookbook afterwards so we can find out what we did wrong, how we could have done it better. It's a bit like craftsmanship, you can never experiment with a method, such as clay or glazes if you don't know the basics. If you don't know how the composition of the clay works, then you might not understand how the chemistry behind a glaze works. As a result, you can't explore and experiment because you don't know the basics. Student B.

3.3 In-depth interviews with the teachers

During the course of this study, two teachers were interviewed in person, for approximately one hour and forty minutes each. The teachers have been anonymised and will be referred to as 'Teacher 1' and 'Teacher 2' throughout this paper. These teachers were chosen to provide broader insight into the subject, since Teacher 1 is focused on teaching practice-oriented approaches and Teacher 2 has more of an analytical approach.

Teacher 1 has a background in practice-led research and teaching in subjects related to aesthetics, culture, form and materiality.

Teacher 2 has a degree in design history and has extensive experience in analysing aesthetic elements in commercial products viewed in a historical and cultural context.

Both teachers expressed a strong interest in aesthetics, although they admitted substituting terminology with regard to aesthetics when communicating with students, as illustrated in this quote from Teacher 2.

I don't think I often use the word aesthetics; I don't think I do. but I talk relatively often about quality. No. You probably use other terms such as balance or it exudes something specific, instead of calling it something with aesthetics, you argue for what you have done. Teacher 2.

Teacher 1 also reflects on substituting the term aesthetics, both in the communicating with students and in writing research papers.

There has been a bit of resistance to the term aesthetics. But you know it's probably just that

we've been weaned off using that word. There are a number of other areas, subject areas and concepts that have somehow taken over a bit and then it is overshadowed so that one might not talk about the tools. Because I think it's a part of it, that you don't have the tools grounded in you and it is not communicated well enough. Teacher 1.

This possible tendency to substitute aesthetics with another term may be detrimental for students who are endeavouring to learn about aesthetics. It may make it difficult for students to make the connection between aesthetics as a field and the theories and methods the students are learning about. However, substituting the term aesthetics is not necessarily limited to the institute involved in this study. Two articles that were included in the literature review, 'Values of crafting in design education' [6] and 'Ugly as a concept in craft to examine alternative futures' [7], both explore fascinating approaches to teaching aesthetics in design education. Interestingly, the term aesthetics does not appear in the heading or as a keyword in these articles. If the substitution of aesthetics as a term is an industry-wide phenomenon, it may make it difficult for students to locate and access literature and research on this subject unaided. The quote from Teacher 1 also resonates with an earlier statement from Student C in section 3.2 on student evaluation of aesthetics in learning outcomes. Both the teacher and the student recognise that the students may have a need for more in-depth learning of aesthetic tools.

4 CONCLUSIONS

The empirical data presented in this research paper is subject to a small selection of participants and is therefore to be considered a pilot project. Although the participants were carefully chosen to provide a broad spectrum of perspectives, there is not enough representative data to conclude anything definitive about design education in this institute or in general without further study. The aim of this research project was to explore what challenges are connected to teaching aesthetics in a product design programme at bachelor level. The data collected indicates that the students experience the overall approach to teaching aesthetics as indirect. Interviews with students reveal that they would welcome more aesthetic theory, but that a combination of theory alongside practice and reflective discussions would be preferable. The empirical data did not reveal a conclusive answer to the second part of the research question: how do the applied teaching methods provide the students with versatile tools that can facilitate innovation through design? However, the feedback from the students was collected and is presented in the following bullet points:

- Design direction. Student A expressed insecurities about how aesthetic tools, theories and methods can be applied within different branches of design. It could be interesting to conduct a study of students' views about implementing aesthetic elements differentiated between design specialisations that have different focus areas and purposes.
- Cultural analysis. The students gave positive feedback on the subjects that combined cultural understanding with aesthetics. This is an example of an approach that works well. Further research could be conducted in order to see whether the aesthetic strategy model described in *Aesthetic Sustainability: Product Design and Sustainable Usage* [4] would improve students' learning outcomes.
- Practical knowledge and theoretical knowledge. As mentioned above, the students included in this study believes that a combination of a stronger theoretical framework with practice and reflective discussions would be beneficial to students' learning outcomes.
- Linguistic definitions. Feedback from both teachers and students as well as findings from the literature review [6, 7] support the assumption that the term aesthetics is used infrequently. In addition to the concerns already raised in this paper, it is worth considering that design students often work collaboratively. Clear comunication is a key aspect of any collaberative design project, and it is therefore vital that terminology is used and understood in largely the same way by all participants.

As mentioned in the introduction, part of the challenge of aesthetics within product design is related to how it is defined and understood. Based on the feedback from the students regarding their learning outcomes, the preliminary conlusion for this pilot study is that the term aesthetics is largely undefined. This may partly explain why the students report having difficulties with holistically comprehending the nature of aesthetics, specifically how aesthetics can be used as a tool to further their work. These preliminary findings indicate that the design profession might benefit from re-establishing ownership of aesthetics as a term and as an asset by defining its characteristics and meaning for the field of design. In

the pursuit of innovation as well as of creation of ethical and sustainable products, the field of design can scarcely afford to disregard such a potentsially useful tool as aesthetics.

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COMBINING COLLABORATIVE USER EXPERIENCE DESIGN WITH CROWD ENGINEERING: A PROBLEM-BASED LAB COURSE FOR (UNDER-)GRADUATE STUDENTS

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ABSTRACT
This paper proposes a university course centred around a problem-based laboratory called "Crowd Engineering (CE)". As a result of the COVID-19 pandemic, collaborative work had to be moved predominantly into the virtual space. Thus, the need for virtual collaborative work in teaching increased significantly. CE is a joint remote collaboration by two academic institutions working together in a transfer-oriented, publicly funded project. In the course, design and product engineering students learnt to cope with today's complex problems. They acquire skills to think beyond subject and system boundaries and are equipped with these job-related qualities already during university education by solving a crowd-sourced real-world task. Students worked with various tools to arrive at an initial design proposal that is supposed to be implemented in a future physical prototype. This paper describes the collaboration context of both university partners, concept development and implementation of the laboratory course and lessons learned from the collaboration.

Keywords: Collaborative user experience design, crowd engineering, collaborative virtual product engineering, interface design and development

1 INTRODUCTION

Designers and engineers must cope with adaptability by the very nature of their activities: The development of new products and services is changing rapidly, e.g., products are becoming more and more complex, digitized, and interconnected [1]. Both, designers, and engineers increasingly need to cooperate in physically distributed and cross-disciplinary teams [2]. Higher education of prospective designers and engineers must address these requirements by developing innovative course formats. Only such teaching from undergraduate level onwards prepares students adequately to meet today's complex challenges. Students need to learn how to think beyond subject silos and system boundaries already during university education, for instance by understanding potentially interdependent economic and social aspects of the respective innovation contexts. Our paper exemplifies this approach with the case study of a problem-based laboratory course called "Crowd Engineering (CE)". CE is a joint remote collaboration of the Institute for Virtual Product Engineering (VPE) at TU Kaiserslautern and Human-Computer Interaction Research Group Zweibrücken (HCI2B) at Hochschule Kaiserslautern – University of Applied Sciences. CE addresses students from two distinctive but complementary backgrounds, in particular higher term bachelor students from the field of User Experience Design (UX) and master's students of product engineering theory. In doing so, CE pairs mechanical and systems engineering with the digital media - and information technology-heavy UX profession – eminently important for today's smart product development. Section 2 describes the context of the participating university partners and gives an outline of the related work. Section 3 focuses on the real-world task definition of designing and prototypically implementing features of a touch screen-based ordering system for meal self-service in a university canteen/cafeteria ("MENSA Live"). This overall course goal was crowd-sourced to student groups that were assigned to specific tasks. Section 4 discusses lessons learnt and provides an outlook on potential future work.

2 RELATED WORK AND BACKGROUND OF COURSE PARTNERS

The term crowd engineering is borrowed from crowd sourcing: Howe [3] defines crowd sourcing as a composition of 'crowd' and 'outsourcing', i.e., the task of distributing a function previously assigned internally to employees to a heterogeneous network. In our context, crowd sourcing does not equal outsourcing a function to an undefined network, but to a network of acknowledged participants — an important practice in today's design and engineering contexts [4], [5]. The concept of crowd engineering was implemented by VPE for the first time in 2016 [1]. Based on this earlier experience of a joined engineering course with another university and a German automotive OEM, a new version of the course was launched in 2020 with HCI2B as a new partner (see Sec. 3).

We followed a seven-stage digital engineering lifecycle in our work of model-driven digital product and service engineering (Fig. 1): The outlined digital engineering lifecycle supports the transformation of traditional products and services toward networked (smart) products and innovative services as shown in Figure 1.

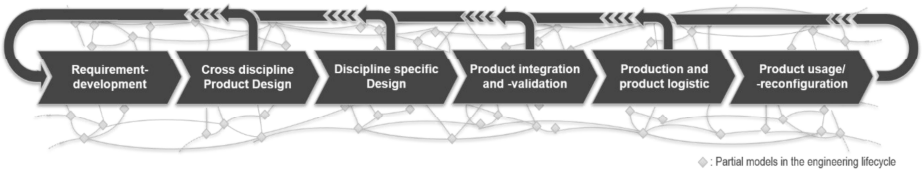

Figure 1. The Digital Engineering 4.0 Lifecyle

This concept of digital engineering lifecycle is a core concept in the works of the Institute of Virtual Product Development (VPE): The activities of the Institute of Virtual Product Development (VPE) focus on topics from Smart System Lifecycle Management and Smart Systems Engineering (e.g., Closed-Loop Systems Engineering [6]). In research and teaching, VPE deals with processes, methods, and IT tools for digital development ("Digitized Engineering") and the management of smart, networked products and product service systems (PSS). VPE uses a holistic learning concept for product engineering. The teaching offered in this area extends from the second bachelor's semester through to the master's degree. The lectures and laboratories offered thematically build on each other. Core concepts of the second partner of the lab course, HCI2B, are as follows: a focus on lightweight Usability and User Experience (UUX) methods and respective (quantitative) UUX metrics [2], [7]. This approach is tightly coupled with the dissemination of usability concepts and practices centring around Collaborative User Experience Design (CUXD) as a model for integrating lean UUX methods and disseminating them in operational processes [8]. VPE and HCI2B are partners in the interdisciplinary transfer project Open Digitalization Alliance Palatinate. In this project, a consortium of different research institutions and transfer partners joined forces to develop a culture of transfer-orientation in different innovation fields of digitalization. For instance, VPE and HCI2B investigate applications and implications of innovative methods in design and product development in industrial production engineering.

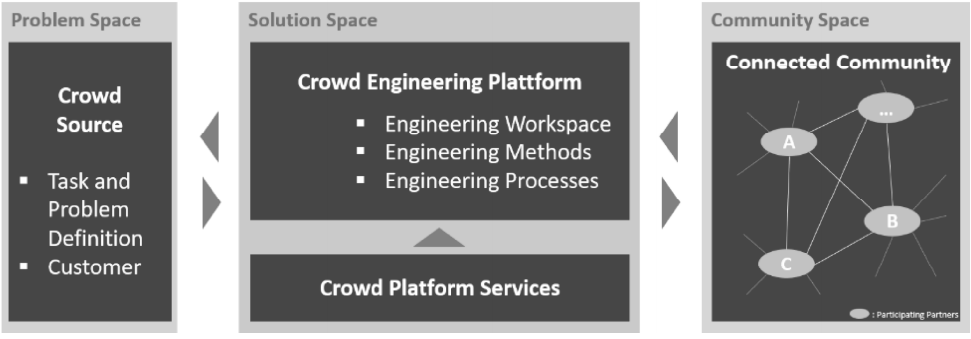

Figure 2. Crowd Engineering (CE) Lecture Framework HCI2B & VPE

3 COURSE CONCEPT AND USE CASE

The real-world task of the laboratory course focuses on the design and (partial) implementation of the automated ordering system MENSA Live. In the future, the system should enable contactless ordering in the university cafeterias. This task follows the subsequent CE lecture framework (Fig. 2 and 3): First, students need to empathize with the context that manifests our problem space. The cafeteria operator struggles with Covid-19 regulations and strives for contactless ordering and queuing minimization in the facilities. Second, to achieve this goal, students draw on methods and practices of smart digitized engineering and user experience design to tackle the solution space. Third, the tasks of designing, prototyping, and validating link students in small groups through sub-processes (community space). Overall, the students are encouraged and enabled to work collaboratively and to link knowledge and skills in an interdisciplinary way through three iteratively linked project groups: requirements development, UX and Computer-Aided Design (CAD) design and modelling.

The requirements development project group initiates the process by scoping characteristics through guided interviews with stakeholders from the university canteen operator. The analysis of the interview contents is a decisive step for creating a first specification summary that serves as a basis to support further iteration loops between the different project groups throughout the project course. This project group also takes on the overall coordinating task of inviting to necessary iteration rounds that help the students to get hands-on involvement with agile project management methods and respective software tools. Tasks of the UX project group focus on the human-centred design of interactive input/output devices (UI design and development) and their prototypical implementation. The group's work promotes the usability and positive user experience of the interface and serves as crucial input for the CAD modelling. The creation of individual components in CAD software fosters coordination and data availability to the other project groups, so that different components can be created by different participants and installed in assemblies by a group coordinator. Finally, this helps students to learn about the importance of ensuring consistent data management by supporting PLM software to ensure regular consultation and correct implementation.

The lab course enables students to work collaboratively and to link knowledge and skills in an interdisciplinary manner. Enrolled were 28 students, 16 from VPE and 12 from HCI2B. Students' work in the lab was centred around the winter term 2020-2021 in the timeframe of mid-December 2020 to early February 2021. Due to the short time span of approx. eight weeks, focus was placed on the conceptual design of the system, as a physical realization was not feasible in this time.

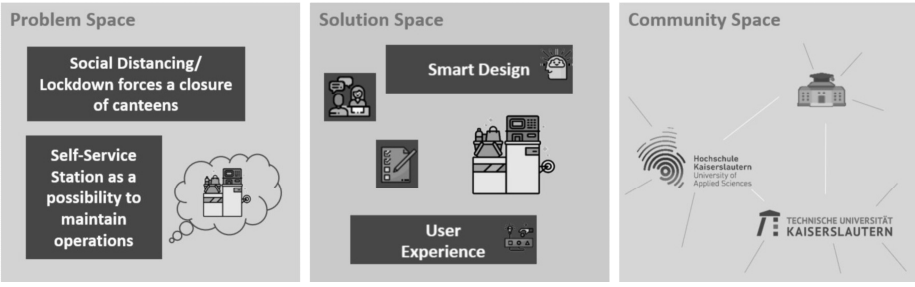

Figure 3. Actual Task in CE Lecture Framework

The approach followed lean principles [2] and was constantly accompanied by consulting and support between students, professors, and teaching staff, also during ideation and evaluation sessions. During implementation, emphasis was placed not only on content transfer but also on communication, exchange of knowledge and collaborative learning within and between the student working groups and university locations.

To summarise, the focus was set on establishing an understanding of the advantages of such an approach and the iterative stages of digitized engineering and design lifecycle in our concrete project. The project work iteratively passed through different stages: the definition of strategic aspects, the first creative prototyping approaches, design ideas, lean implementation, and iterative evaluation of the product (up to roll-out). The findings from the student project (Fig. 4) were documented and processed in such a way that a successful knowledge transfer can take place for subsequent student seminar groups and lab courses.

Figure 4. CE Result: MENSA Live System
(A) Stakeholder Review and Requirement Refining
(B) UI/UX Design of the Men's Alive Application
(C) MENSA Live Hardware Design (e.g., CAD)
(D) MENSA Live System Overview

The implementation of crowd engineering depends on the right choice of tools. An important factor in the implementation is the access to new information and communication technologies that have changed higher education in recent years [9]. The outsourcing of functions to a crowd is only possible through collaboratively usable tools for communication, requirements creation or design. To provide students with suitable collaborative tools, different platforms for different tasks were provided. As a general collaborative platform for data exchange and communication, teaching staff created a course on the Online Learning and Training (OLAT) [10] platform. OLAT is a web application providing closed rooms for collaborative work while integrating additional tools that include web conferencing systems. Using OLAT, course materials were made available to all students. At the same time, interim results in file format were shared in OLAT and discussed with supervisors. To give all students access to CAD software and, at the same time, to promote collaborative work on a model, the software must be accessible by different user systems. In addition, distributed work must be possible, as in a PLM system. Therefore, a cloud-based solution was preferred as CAD tool to combine both requirements. Thus, PTC Onshape [11] was made available as a student tool. In Onshape, it is possible to work on CAD models simultaneously in a browser-based manner.

Design work followed the collaborative UX design approach and made use of prototyping tools such as Figma, Axure and Adobe XD. To implement programming, a small group of two students with extensive programming experience was split off from the other groups. In this group, software requirements were created to map the ordering process and to create a smartphone connection. A low-code-based development platform was made available as a tool. Due to the relatively short development time of only four weeks, an easy familiarization with the development environment was crucial. The low-code platform Siemens Mendix [12] allowed to create applications on a relatively intuitive and simple basis. For (mobile-first) web application development, the current Angular (version 10/11, [13]) and Bootstrap [14] frameworks were used.
The course was completed with a group-based written performance on the one hand and a presentation on the other. The written work was submitted in folders containing, e.g., a morphological box, a list of requirements, problem statement and customer journey maps, a black box, a hierarchical functional structure, price lists of purchased parts, labour hours, operating instructions, a parts list as well as technical drawings and "design the box" marketing conceptualizations. The aim of the presentation was to explain the product to the customer and thus also to promote and market the product directly.

4 LESSONS LEARNED

At the end of semester, the laboratory course was evaluated using a questionnaire that reviewed students' experiences and impressions by 25 items with five-level bipolar scaling (from strongly disagree to strongly agree). Questionnaire items were divided into three parts: Teamwork, task/objective/time allocation and personal experiences. Overall response rate was 78% completely answered questionnaires. Since the project partners VPE and HCI2B want to hold the course again in next year's winter term, this form of evaluation is important to gain legitimacy from the students' side. Overall, the students' impressions can be summarized as very positive with some hints for further improvement: All students were very open to an inter-university event with potential transfer partners (such as service/industry domains) and would like to see more formats following this direction.
Teamwork was perceived as somewhat difficult. Slight deficits in the formation of competencies in the individual groups were identified. Due to the different disciplines of the students, there were many sources of competencies and formal as well as informal knowledge to rely on. But active transfer of such knowledge and competencies within community spaces is not a self-establishing and self-reinforcing process. According to our current experience, it needs external triggers that were stimulated by teaching staff via direct feedback and through the collaboration tools described above. Other feedback was linked to the way in which teams worked together. Although the communication tools provided by the university were used, information was not always shared as fast and comprehensive as it was required. The performance of the respective student team leaders, who interacted not only within but also between the groups, was highlighted as very positive. The time frame of approx. eight weeks for task completion was generally considered to be sufficient.

5 CONCLUSION AND OUTLOOK

To summarise, students' assessment of the project was positive. The approach in its present form has not only confirmed its relevance — regarding restrictions in the Corona crisis — but has also provided an outlook on possible perspectives of expanded forms of teaching and working in the future. This next crowd engineering course will again be a joint project between VPE and HCI2B and an industrial partner. The limitations of the teaching concept outlined in Sec. 4 will be addressed. Our goal is to achieve a long-term cooperation between the teaching institutions and to keep this unique perspective attractive for subsequent students. In future courses, an even closer collaboration of students from both universities will be attempted. To this end, a task will be created by an industrial partner which conveys a high industrial value. The tools used so far require only minor adjustments, since the weaknesses that have occurred are not due to the use of the respective tools. Overall, formats such as crowd engineering show possibilities for enabling collaborative work, especially in times of difficult physical presence. For this reason, this format will continue to be part of the lecture concept of the two respective educational institutes and will be further developed and implemented in the subsequent semesters.

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APOCALYPTICAL AND UTOPIAN MOTIVATION FOR CHANGE IN SOCIETY

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ABSTRACT
Actions executed in the name of sustainable development by corporations capable of changing society in a fundamental way often have similar goals, but sometimes conflicting motivations. This is often reflected in the language they use to justify change. The sometimes apocalyptic motivation for change stems from sources capable of changing society's mindset, such as contemporary media. Some organisations working on fundamental societal change, such as the United Nations, will express their justifications using language supportive of a utopian goal. An action that is taken with the motive of creating a utopia can look quite different from an action that is executed to avoid an apocalypse. There seems to be a need for reflection in design education on big change and motivation, as this paper will discuss. Therefore, the research question is: *Can design thinking be used to create motivation for sustainable development to aid global actors reach their expected or improved outcomes?* Although this paper has a traditional structure, it's goal is to promote discussion rather than promoting new insight and answers in this specific field. The findings are derived from two case studies of the Norwegian climate lawsuit and Equinor's justification for its carbon capture and storage project.

Keywords: Climate change, sustainability, utopia, apocalypse, motivation

1 MOTIVATION

This paper discusses the motivation behind actions taken in the name of sustainable development. One action performed twice with conflicting motivations might not have similar results. Tear a piece of paper with anger, then tear a piece of paper with accuracy, and you will see the difference. This paper will not focus on the results, but on the motivation behind actions. The actions discussed in this paper are big actions, taken by corporations with the ability to change society in tangible ways. The motivation behind these types of actions is shaped by common mindsets in society, and society's mindset is shaped to a considerable extent by contemporary media [1, 2]. Contemporary media tend to focus on issues of a dramatic nature which will be a part of the decision process of big actions [3]. Design thinking has a big part to play in this arena, as design thinking makes a broader understanding of a problem available. This paper encourages broad thinking, as it states that motivation should be analysed in the two extremes, apocalyptic and utopian.

2 BACKGROUNDS: APOCALYPTIC AND UTOPIAN MOTIVATION

2.1 Education

Basic design education often focuses on form aesthetics and production, which is vital when working on consumption. Yet trends in the field of design show that designers often embark on societal issues which relate to politics and legislation more than to aesthetics. Provided that designers get a more direct role in changemaking, design education can pose a threat to positive change unless the educational institutions provide more basic teaching on societal issues.

... educators are confident that designers can create benign solutions for indigenous people, malnourishment, for example, in social, cultural, psychological and biological contexts, among others, by acquiring what is believed to represent basic skills and knowledge, such as manufacturing, design methodology, and form giving.(Gulden & Skjøvoll, 2015)

2.2 Reasoning

An action is a derivative of reasoning, and reasoning is categorized in two main ways: normative and motivating. When speaking of normative reasoning the focus is on whether a reason is good or not according to norms. The term motivating reason simply issues a reminder that the focus is on matters of motivation.

2.3 Apocalyptic motivation

Many scholars see apocalyptic films not only as a symptom, but also as a constitutive of existential angst. This anxiety is often a driving force in the justification of certain projects [3]. The apocalyptical narrative is strengthened not only in film, but also in the news media landscape. Evolutionary psychology tells us this is a natural phenomenon [4]. But does this also affect the minds of those creating societal change? What consequences does this yield?

Eco-anxiety is a consequence of our beneficial relationship with nature, combined with nature deteriorating, resulting in a sort of eco-grief [5]. Existential threats should incite anxiety, it is an evolutionary trait in humans that aids our survival.

The task of fixing the problem of climate change on an individual level might be too big of a task, and therefore an irrational fear that is undeserved to the individual [5]. This global threat is too big of a problem for an individual to fix and has negative mental health consequences on the individual.

2.4 Critical utopian action research

Critical utopian action research (CUAR) is a research method whereby researchers participate in the process of contemplating futures in a research project, typically a workshop. The group enters a space of imagination, where they form a utopian scenario in their chosen topic. Their task is then to leave this space to reify their utopia.

The Future-Creating Workshop has three phases: (1) a critique phase, where participants express their concerns about the existing system through a brainstorming session; (2) the utopia phase, in which participants express their dreams through a second brainstorming session followed by periods of group work where utopian ideas are developed by focusing specifically on dreams and wishes and putting a pause on reality; and (3) the realization phase, which is a twofold process in which the utopia groups first continue to develop the utopian ideas and then the work towards the realization of the different plans begins. [6]

CUAR is the counterpart of change motivated by avoiding apocalypse and is therefore a relevant tool to use in this context.

2.5 System thinking

The problem of climate change is a systemic issue, and the system of society is a contributor of climate change [7]. The societal system is driven by strong flows: political order, self-interest, the rule of law, the state [8]. The foresight landscape is equipped to consider what the system might look like in the future. System thinking will also have a part to play in the process. Effective system thinking will be a big advantage in the problem locating process [7].

3 METHODS: CASE STUDY

This paper analyses two cases of action and their motivation, based on the language used in their justifications. The purpose of this is to laterally understand two different actions and compare them. The cases include different sustainability-driven actions taken by Equinor, the United Nations, and non-governmental organizations. The information saturating this paper was collected through analyses of documents and websites.

4 RESULTS

4.1 Case study 1: Carbon capture and storage

'[Carbon capture and storage] CCS is one of the measures that the UN Intergovernmental Panel on Climate Change recommends keeping global warming to 1.5 degrees Celsius. The International Energy Agency states that we will need to store billions of tonnes of CO_2 every year if we are to reduce global warming.' [9]

This is Equinor's justification to why they want to implement carbon capture as part of their portfolio. They justify their decision by saying that the International Energy Agency encourages carbon storage in order to reduce global warming. The language hints towards an apocalyptic motivation. Equinor is capturing carbon so that a situation which will lead to the consequences of climate change does not happen. This action is happening due to apocalyptic fear. Fear of internal economic decline may also be an incentive for an action such as this.
The company might face sanctions or consequences for its reputation if it does not confine itself to the Paris Agreement restrictions. Equinor is a company that deals with the substance that is contributing the most to greenhouse gas emissions, which is an activity that is regulated by the Paris Agreement [10].
The motivation for CCS lies on different levels, but when observing Equinor's wording, it looks like they are doing this for sustainable development. But we can also observe the government and the United Nations very directly affecting the possible behaviour which corporations such as Equinor can engage in with regard to sustainability. One of the UN's main priorities is to improve people's well-being [10]. The UN has imposed CCS on Equinor through the Paris Agreement, which was organized to improve people's well-being. In this sense, the motivation behind carbon storage is utopian from the UN's perspective. On the contrary, the language used by Equinor signifies apocalyptic motivation. The different mindsets here can contribute to an unclear goal. Literature on project leadership says that all parts of a project need to see the goal and their own motivation with the same eyes [11].

4.2 Case study 2: The climate lawsuit

Non-governmental organisations have decided to sue the government of Norway because they think the government is undermining the constitution by giving permission to extract oil from the lithosphere [13].
The climate lawsuit is another example of a solution grounded in apocalyptic motivation. The NGOs are concerned that the government's decision to grant oil drilling licenses will hinder the UN's goal of not exceeding a global average temperature of 1.5 degrees Celsius. Again, the motivation is to stop development that might lead to an apocalyptic world.
The case of the climate lawsuit is similar to the case of CCS, which is an action taken to reduce the level of greenhouse gas emissions. While the climate lawsuit has the same goal, the motivation is causally related to the existential threat of the oil industry and its emissions.
The climate lawsuit is an agent, in this case multiple NGOs and a legal team, trying to hinder another agent in its negative contribution to the greenhouse gas economy. This action is clearly motivated by the fear of an apocalyptic future.
The justification for the lawsuit is that the government is undermining Norway's constitution by handing out licenses to extract oil in the Arctic Ocean. The specific article they are referring to is Article 112 if the Norwegian constitution, which states that everybody has the right to a liveable climate. The agent suing the government states that the amount of oil discovered, if used, is greater than society can consume if we want to uphold the Paris Agreement's goal of not exceeding a global average temperature of 1.5 degrees. The constitution is not upheld because handing out superfluous licenses contradicts Article 112 by contributing to exceeding a global average temperature of 1.5 degrees.
The action of filing a lawsuit against the Norwegian government seems to be grounded in a fear of an apocalyptic future. The action is made possible by the intention of the constitution's Article 112, the wording of which seems to be founded on a utopian motivation. The Article reads as follows:
Every person has the right to an environment that is conducive to health and to a natural environment whose productivity and diversity are maintained. Natural resources shall be managed based on comprehensive long-term considerations which will safeguard this right for future generations as well. To safeguard their right in accordance with the foregoing paragraph, citizens are entitled to information on the state of the natural environment and on the effects of any encroachment on nature that is planned or carried out.
The authorities of the state shall take measures for the implementation of these principles. [2]
The constitution's Article 112 states very clearly in its first paragraph that it exists to ensure the right of maintaining a natural, productive and diverse environment. The agent suing the government has apocalyptic motivation for the lawsuit. This suggests that the agent has a certain misunderstanding of what the constitution is intended for. The agent is pursuing an anti-apocalyptical goal which is rooted in apocalyptical motivation, but part of their reasoning is an action with utopian intentions.

5 DISCUSSIONS OF THE FINDINGS

This project has examined the presence of apocalyptic or utopian motivation in different environmental actions. The aim of the paper is to enhance the understanding of justifications regarding action with consequences to society.

The paper strengthens the hypothesis that justifying a project with utopian motivation might yield positive outcomes, but there is no guarantee for this. Such is also the case for apocalyptically inspired cases. Being mindful of these concepts can steer projects in more prosperous directions. When deciding what projects are important or whether a company should go through with it, the results in themselves might be good motivation, but the effect of the project can be defined before the project starts. If a project aims to better the world, the underlying motivation may steer the project towards failure [3].

6 CONCLUSIONS

I have tried to understand motivation as a duality, on either end of the spectrum of positive and negative, both anchor points of change which can yield results both good and bad. The mindfulness and clarity of the base motivation of any change is something I advise considering when in the planning phase of any project. Starting a project by defining motivation might cause the execution of the project to grow into something infinitely different than a project where motivation was not considered. What would Equinor's reaction to the Paris Agreement be if they too sought to improve the well-being of people? CCS is an action that is meant to secure well-being, it is not meant to improve wellbeing, as the Paris Agreement is.

The findings of this paper suggest that designers and changemakers can benefit from thinking in both an apocalyptic and a utopian manner when deciding the goal of a project. The project's goal can be put into the extreme scenarios. Does the project aim to better the world, or to protect it? Both are possible motivations for the same project. but choosing a direction can be beneficial to the participants of a project. We want to protect children in a kindergarten, so we build a fence around it. We do not want to worry about children, so we build a fence around this kindergarten. The difference in motivation may affect the result aesthetically, ethically, practically, and in many other ways. The UN tackles the problem of sustainable development by wanting to make positive change and securing well-being, and Equinor has the same problem, but they want to store carbon so that the temperature does not rise. Comparing problems, solutions and motivation is not easy, not always in good faith, but it can contribute to better solutions when making change. Differentiating between 'bettering the world' and 'not worsening the world' can be a key turning point in any project.

An action which is made possible and carried out by different agents, where one or some agents have apocalyptic reasons for inciting that action, and the other(s) have utopian reasons for carrying out that action, might benefit our environment in similar respects, but the outcome the different parties seek might not end up as intended.

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DEVELOPMENT OF COMPETENCIES IN A TRANSDISCIPLINARY ENVIRONMENT THROUGH CHALLENGE-BASED LEARNING

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ABSTRACT
Over a course of 5 weeks, undergraduate students of the "Creative Studies" entry, developed a research based on discovering insights focusing on cultural and social aspects on a previously selected community into the city of Querétaro, México. The students are enrolled in a new educational model in which they study their first year with an exploration academic core and then they select their major field in order to eventually graduate with a minor specialization.
In the 5 week course, the students developed a secondary investigation to contextualize themselves before beginning the collection of data on site. Work in the field and in the classroom was alternated to guarantee experiential and immersive learning based on theoretical content taught in the classroom and then applied on field.
This paper describes the process to discover the main findings in the implementation of this new academic structure called Block, in which there are content modules, a research challenge and the evaluation of research and transversal competencies.

Keywords: Competencies-based learning, challenge-based learning, transdisciplinary ambient, educational innovation

1 INTRODUCTION

Tecnologico de Monterrey is a private multi-campus university with headquarters in Monterrey, Nuevo León, Mexico. Since 2015, a new educational model has been implemented at the Tecnologico de Monterrey, called Tec21 Model. This new educational model into the institution is designed in a particular way in the youth of the new century. As of August 2019, a new academic structure called Block was implemented: a multidisciplinary project consisting of learning modules and the resolution of a challenge. This paper will describe the methodology and implementation into the Block structure on the course "Research Methods and Human Factors". This Block was carried out in two of the most traditional neighbourhoods of the city of Querétaro and with the participation of freshmen from the entrance of Creative Studies, the disciplines of Industrial Design, Architecture, Digital Art, among others. This paper is a descriptive approach to the design and implementation process of the course through the exercises and activities developed by the students.

2 METHODOLOGY

For the realization of the Blocks, as it happened at the time with "Semester i" [1], it was required to break with educational paradigms at the professional level. Each of the aspects of the Block methodology are described below.
The Block is divided in three complimentary modules in which each student will learn the theoretical knowledge that will help them to accomplish the Challenge activities, in order to build their evidence that will be the tool to grade the competencies declared in the course.
At the August-December 2019 semester 4 groups were programmed in the campus, each one with different mixtures depending on type of students, number of teachers, type of activities and the community visited to do the field research.

The interdisciplinary environment was given by the diversity in the teacher's background and student's profile. The teachers were selected by their disciplinary approach to the topics of the course and the students were mixed randomly by their registration with no particular election criteria.
The diversity of these variables allowed each group to work with different styles, mainly determined by the community to visit but the teachers were the principal factor to guide the way in which the activities were to be implemented directly on the field. It happened due to the teacher´s profile and their experience with the research methods that they apply in their profession. A general description of the Block can be seen in figure 1.

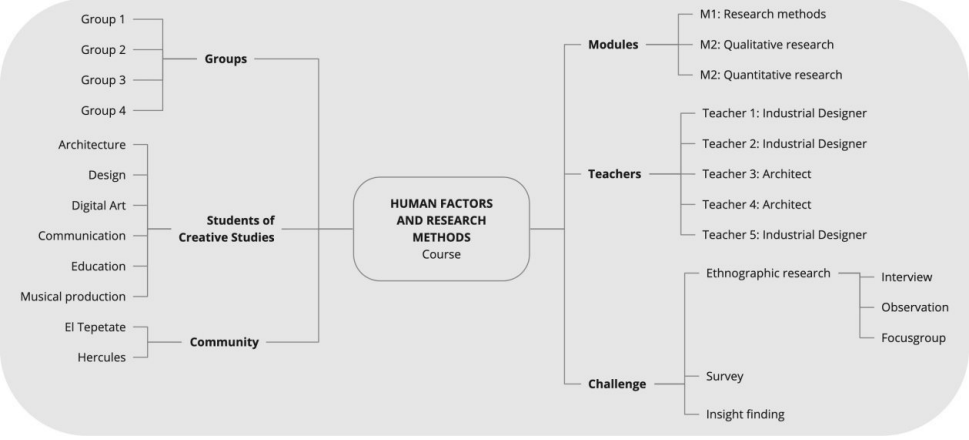

Figure 1. Course structure

2.1 Context

"Creative Studies" is one of the lines from the undergraduate introductory programmes that the institution offers to their new students.
The entry into Creative Studies has a duration of two semesters and the main objective is to learn to handle various languages and technologies related to the conceptualization and creative creation, to design and produce projects and multidisciplinary solutions for various professional fields: architectural, digital art, design, communication and journalism, education, literature, and musical production [2].
Along this year the students explore all the creative possibilities of creative knowledge and give them the tools to generate creative thinking approaching holistic solutions to wicked problems from a lateral perspective. After these two semesters, the students have to decide in which major programme they will decide to study.
The Tec21 model has the "Challenge" as the centre of the learning process. Something important to consider is the problematization of a current situation for defining a complex challenge, which needs to be relevant not only for students but also for society, providing a unique opportunity to explore the role that universities must have in the value creation beyond academic purposes. To this extent, a design brief was defined in order to provide a shared perspective upon the research approach during the course. The Block of Research Methods and Human Factors is structured to contribute with the critical thinking of the students developing curiosity for knowledge and empathy to the others.

2.2 Course

The new educational model demands the "Challenge" as the centre of all the efforts from students and teachers. In the Block of Research Methods and Human Factors the aim is to focus on the activities and all the topics in the approach to work in teams that collect information and relevant data to find insights by researching in the community.
The Challenge represents an opportunity to learn something new and strengthen what the student already knows by solving a given problem. Is mandatory to bond with educational partners that are not specifically educational institutions but companies, organizations and/or communities that allow the students to learn in different environments, not only at school.

The challenge was named as: **Recognizing the elements that define the identity of the traditional neighbourhoods of the city of Querétaro** and the aim of this exercise was to allow the students to understand the elements that define the neighbourhood identity not only as an activity that contributes to the remanence of cultural diversity in the communities but as a protection strategy for the neighbours themselves against interests that are seldom aligned with political needs, a strategy that makes visible what is valued in the communities and that largely defines the quality of life of the neighbours. The trigger question given to the students was: **How could we generate new parameters that allow us to communicate the neighbourhood identity?**

The main objective of this challenge is to develop in the students their capacities to develop specific competencies thus, applying procedures for the study of local groups and communities, demonstrating commitment to the priorities for community development.

The competencies developed were:

- Identify needs, desires and behavioural patterns, preferences, and public's consumption, applying qualitative and quantitative methods.
- Solve problems and questions of reality, based on valid and reliable methodologies.

The three modules are taught one per week by different teachers, but the Challenge runs in a transversal way covering all the activities performed by the students in order to collect all the evidence that confirms that the competencies were acquired along the five weeks. A teacher is required to supervise the Challenge and guide the students to cover all the aspects of the Brief in order to assemble their evidence to achieve the competencies as seen on Figure 2.

Figure 2. Challenge structure

In the Block of Research Methods and Human Factors the core theme consisted in approaching insight finding the identity of the community beyond what the state identifies as cultural and social value. Gentrification and touristification were two topics discussed among students, as well as how the cultural heritage of the community are assets constantly threatened by the tourism market. The research opportunity emerged by understanding the diverse elements that are part of a community identity, which defines as well, the quality of life for its residents.

Therefore, the challenge for students consisted in identifying and recognizing the daily practices that are part of the identity of the community, looking to generate new parameters enabling to communicate what is valued in the territory by people of these places, beyond infrastructure, investment, or access to services.

As part of the methodology, students were asked to visit and explore the territory. During the first visit, students were constantly encouraged to think and question how identity is represented in the different elements of the community: from the local traditions, economic and social activities, as well as cultural expressions.

The Block is divided by Modules that structure the theoretical knowledge and allows the student to scaffold their approach into the Challenge. The Research Methods and Human Factors will be described as follows.

2.3 Module Distribution

2.3.1 M1 Research Method

The main focus of this module is to introduce the students into the importance of applying research methods in the creative activities in which they eventually are enrolled.

The first part is aimed to provide theoretical knowledge about the research methods, the students start the course with a lecture of history that frames the context of the discipline and enforces the cognitive abilities into the classroom and provides a strong concept of a research project applied into a real context.

The second part is focused on the analysis and synthesis of the information gathered during the Qualitative and Quantitative research methods into the approach to discover powerful insights that determine the identity traits of the specific community that had been studied by the group of students.

As evidence, each team delivers an executive document in which they attach all the information obtained during the primary and secondary research complimented by the discovery of results and findings and the future recommendations. At the end of the module every team presents the information to the teachers and the community and delivers infographic material to spread the insights to the rest of the inhabitants.

2.3.2 M2 Qualitative research

The qualitative module aimed to go into detail to the students' research question and through different research methods such as interviews and observations, provide answers to it [3]. The aim is to bring students to know and design some tools that they could apply in the field to inquire about the sense of identity and belonging perceived by the community. It was important, therefore, that the abstract knowledge be complemented with exercises that facilitate the understanding and use of the instruments (mainly observation guides and guides to direct focus groups and interviews) that would be applied in the field.

For this reason, the teaching of the module has been based on two moments: one of explanation of the techniques by the teacher, another of design of the guides and put into practice in an experimental way, in the classroom, under the supervision of the teacher.

Besides the interviews, students needed to develop a guide for observation in the territory. Based on the Gehl method, each team needed to select two tools which they considered necessary to capture the elements of the local barrio and for providing answers to their research question.

2.3.3 M3 Quantitative research

The quantitative module aimed to introduce the students to the research methodology as well as to the territory as a place to develop research. The use of quantitative research methods in the development of design projects might not be entirely clear for students in the social sciences, the humanities, or other creative disciplines. In fact, it is fairly common that students choose these professions precisely because they are not confident in their knowledge or ability to use quantitative methods [4]. The Quantitative Methods module was therefore planned with these preconceptions in mind – fully expecting students to be sceptical about how design can be analysed through quantitative methodologies, or possibly anxious about the use of statistics in research.

Given the short time frame of the course, the goal of this module focus was that the students developed solid criteria for identifying, choosing, and further investigating the quantitative methods best suited to answer a given research question. Indeed, scholars teaching in the social sciences have come to the conclusion that it is more effective for students to be able to understand key ideas presented in quantitative research, than to master the use of statistics software packages [5].

Based on the first visit students were asked to develop their research question, aiming to frame their own research interests after the first field study visit. They also established the population group that needed to approach in order to respond to their research question.

After this first deliverable, students were asked to develop a questionnaire with a minimum of six questions and a maximum of ten. This tool extremely helped students to understand much better how in practice researchers define the concepts, variables, and indicators. Also, it was crucial for students to start with the research as well as to find topics to be further research during the qualitative module.

2.4 Competencies

The sub competencies to be developed in this Block, at a basic level of mastery, are the following:

Identify needs, desires and behaviour patterns and preferences of users, applying qualitative and

quantitative methods (disciplinary sub competency).
Scientific thinking: Solve problems and questions of reality based on objective, valid methodologies and reliable (transversal sub competency).

2.5 Evaluation

The students were evaluated by the delivery of an evidence which was formulated as a Research Report where the students framed within the acquaintance of knowledge related with Human Factors Research, whose main objective is to develop their abilities to identify needs, behaviour patterns and preferences of the public in their immediate environment, applying basic methods qualitative and quantitative; through knowledge and application of basic techniques and procedures of qualitative and quantitative research; thus applying procedures for the study of local groups and communities, demonstrating commitment to community development priorities. Such evaluation is based on the observation of the competencies developed during the course and the numerical grading of the quality of the research report.
Besides the Research Report, the students developed infographic material and introduced the results as a keynote in a conference to all the interested in accomplishment to present the relevant insights and findings to the audience.

3 RESULTS AND FINDINGS

The modules within the course look to emphasize the importance of developing a new attitude towards people through the acknowledgement that their experiences and stories are the best assets for any creative process. The activities designed for the course, developed students' capacities in finding and setting opportunities for creative intervention through research, rather than simply seeking solutions to needs expressed [6].
This became evident in the students' projects. Below we present images of the presentation to the community and two examples of deliverables.

Figures 3-5. Presentation to the community and examples of deliverables

The research methods employed by the student should be chosen according to the research question, and not based on the student's chosen profession, ideological preference, or preconceived ideas about their difficulty [7]. Likewise, instructors of this module should have ample experience not only in utilizing both quantitative and qualitative methods, but in knowing how to mix them for the purpose of strengthening the quality of social research.

3.1 Students opinions

The comments of the students have revealed three successful aspects of the course; while they have judged negatively only the temporal factor: "Time too short to complete the work fully". It is possible that students tend to express their satisfaction and complacency in a somewhat conformist and uncritical way, since they think they should please the teacher.
However, it can be rescued with some authentic testimonies about the importance of undertaking research prior to the realization of a project: "I had the opportunity to know people that live in different situations than me, I could empathize with them".

These have focused on the appreciation of the experience of immersion in the field, the listening and recognition of the other as a bearer of knowledge. Some students have clearly noticed the pleasure and surprise at the discovery; and this has gone hand by hand with self-appreciation, the awareness of acquiring new skills.

4 CONCLUSIONS

The physical approach to the object of study favours empathy with the same and with the other subjects involved in the process. It was useful and proficient to be able to apply the revised procedures in the classroom in concrete realities and close to the students, so that they could feel a greater commitment to the research topic.

But the difficulties in planning and executing a successful module on quantitative and qualitative methods were compounded with the time constraints baked into this course. As noticed before, the goal of the modules was to familiarize students with this family of methods while giving them a chance to explore them on their own through a practical challenge. However, instructors should be careful of mistaking expedited learning with poorly executed quantitative research. While students gain valuable experience in formulating and conducting structured questionnaires, for example, they should also be made aware of the constraints of sample size and statistical significance when presenting their conclusions.

The mixture of students and teacher profiles and the community selected for the group gave an interesting variation on the format of the final deliverables and the focus in which the research method was taught. In one community the people were very participative with the group but in the other it was an organization linked with the inhabitants and their everyday activities because it was harder to obtain the information, the people were reluctant to share with the students. It gave teachers the opportunity to approach from a different perspective to the phenomena. The students' vision was determined by the ethnographic tools used in the research, changed the way in which they prepared their final conclusions. Although those fluctuations variate the final perspective on the approach to the Challenge and the way in that the students developed empathy and respect for the diversity was homogeneous in the core due to the sensibilization on critical topics like the decolonization, gentrification, and human factors in general.

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WHEN TERMS OF SERVICE ARE LONGER THAN A SHAKESPEARE PLAY: EASING THE UNDERSTANDING OF LEGAL DOCUMENTS THROUGH A USER EXPERIENCE DESIGN METHOD

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ABSTRACT
Whenever users use an internet service, they agree to its terms of service and privacy policy describing how their personal data will be managed. The complexity of managing this process is often overlooked, and users rarely read the whole document. Agreeing to terms of service and privacy policies is not a straightforward matter, and there is a need to highlight this in design education. A new approach is needed in design education that connects responsibility, user experience, products, and services together. This study uses a user-oriented design approach to explore how to address the issue of informing users about how their data is managed. The study uses a qualitative approach and includes in-depth interviews with people in different demographics and in different user groups. The findings reveal how coupling icons with easily understandable texts can improve user awareness of how their data is managed, leading to a more mindful approach to these services.

Keywords: User experience, terms of service, digital rights, consent, contracts, informed consumers

1 INTRODUCTION: LEGAL CONTRACTS IN THE DIGITAL AGE

This paper will discuss how understandability of terms of service for internet services can be improved using symbols and text. With the large-scale diffusion of online services such as social media, streaming platforms, online stores and the like, users must sign digital legally binding contracts stating how those services will use their users' data. Such information – which includes demographic and behavioural data and personal preferences – will then be used to provide users with the services they request. However, it could also be shared with third parties such as advertisers to target them with tailored advertising [1]. This practice of collecting data could be used for good purposes, such as helping people to buy items they need, but it could also have adverse consequences, as shown by the Cambridge Analytica scandal, when targeted political ads were used to influence election results in various countries around the world [2]. Such incidents highlight the need to regulate the collection and use of personal data. Different actors should be involved in this process, from regulators and service providers to users. However, this research paper will focus on the terms of service presented to the user during the sign-up flow, since encouraging responsible behaviour while reading and signing such agreements can have an enormous impact on what data is uploaded and how it is used.

2 BACKGROUNDS: A MATTER OF UNDERSTANDING

Terms of service agreements are mandatory for companies that offer their services to the public, but they are not required to be easily readable. Research conducted on the top 500 most visited websites showed how those contracts would not perform well in the most popular readability tests [3]. This is reinforced by the fact that such contracts usually make use of broad and vague statements such as 'We may share your location information', semantically including but hiding sentences such as 'We share your ZIP code for marketing purposes' and thereby lowering the risk perception of the reader [4]. Given the fact that those contracts are incredibly vague and difficult to comprehend, Jonathan A. Obar and Anne Oeldorf-Hirsch conducted an experimental survey on more than 500 adults, asking them to join a fictitious social media website. A total of 74 per cent of the test subjects decided to ignore the privacy policy and the terms of service, selecting instead the 'Quick Join' option without reading the contracts, while 97 per cent of the remaining test subjects agreed after spending from 30 to 90 seconds reading

documents which normally would take around 30 minutes to read in full [5]. These findings brought to light the information overload created by terms of service, disincentivising the users, who perceived the contracts as a nuisance, preventing them from using the services they were interested in. To address the issues users must face during this process, European regulators considered including a section regarding the use of icons in the GDPR as a means for helping users understand the meaning of those documents, but this idea was discarded in the final version of the regulation. The discussion regarding pictograms and iconography in terms and conditions has created polarised positions. On the one hand, it is argued that the use of such devices may impede understanding of the documents because the nuances of the legal language may be lost [6]. On the other hand, it is argued that the icons are intended merely to complement and clarify the legal language, not replace it [7]. Multiple sets of icons have been developed to answer this need, such as DaPIS, machine-readable icons based on the GDPR [8] and the Mozilla privacy icons, made to give users a guarantee about what companies will do with their data [9].

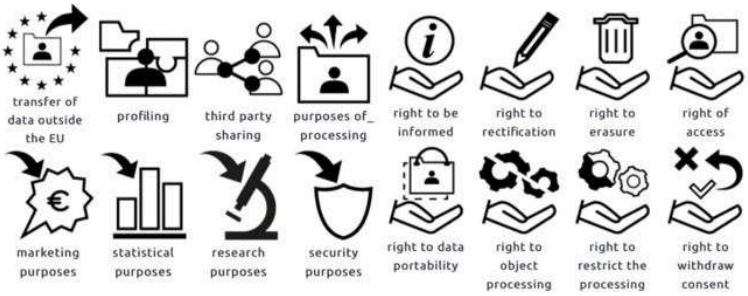

Figure 1. Rossi A. and Palmirani M. DaPIS icon set

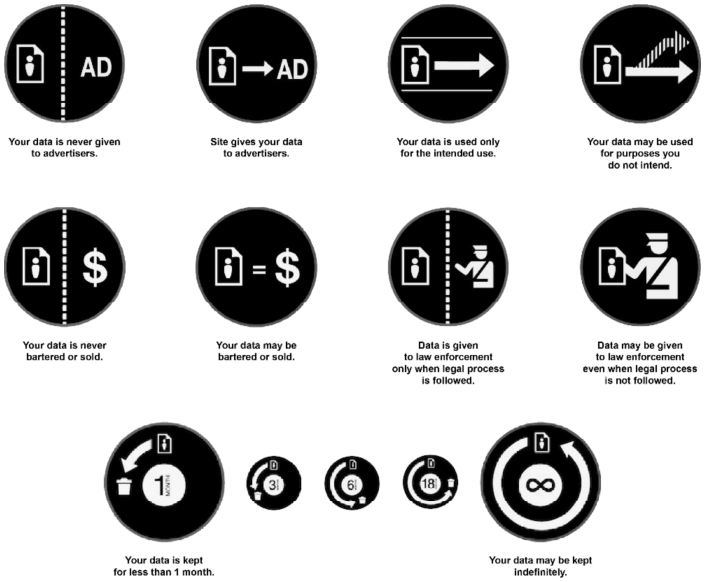

Figure 2. Raskin A., Mozilla privacy icons

Research has also been conducted on plain-language contracts, a term that refers to contracts that are made 'as clear and as simple as possible' to quote former president of the United States Jimmy Carter.

Such contracts are usually shorter and more understandable, reduce the signing time by 60 per cent and positively impacted the customer's perception of the company [10]. The research discussed in this paper will compare these different methods in order to understand how best to communicate important information to users. The research question is: How can design help users understand how companies will manage their data without reading the full terms of service agreement? The focus is the system design, trying to define the characteristics needed for this system to work.

3 METHODS: IN-DEPTH INTERVIEWS, LITERATURE REVIEW

The methods chosen for this study are digital in-depth interviews and a literature review, in order to obtain methodological triangulation [11]. In-depth interviews were used to obtain the views of different target groups on a given phenomenon [12]. The aim of the interviews was to gain insight into the frequency of their interactions with online terms of service agreements and their usual behaviour regarding those documents. Later on in the interviews, the subjects were presented with a series of tests based on the DaPIS icon set and the Mozilla privacy icons for plain-language contracts and judicial-language contracts to understand their preferences in terms of understanding and engagement. After being introduced with an icon set, they were asked to interpret an excerpt of a terms of service document regarding the treatment of user data. The text was preceded by the icons and a corresponding plain-language contract. They would then repeat the test with a different excerpt and set of icons and a plain-language contract. This allowed for understanding methodologies and preferences in different demographics.

4 METHODS: IN-DEPTH INTERVIEWS, LITERATURE REVIEW

The subjects for these in-depth digital interviews were chosen based on user-oriented methods in product design education for obtaining insights from different demographics: a 25 year old IT engineer, a 52 year old office worker and a 75 year old retired lawyer. A brief summary of the interview subjects is presented below.

4.1 In-depth Digital Interview 1: IT engineer, 25 years old

During the interview, the subject disclosed that he normally encounters terms of service contracts multiple times per month, and that the recent lockdown caused a surge in these encounters – this is due to the increase in the use of online services, especially streaming platforms. When faced with those documents, he quickly skims through them, searching for parts that catch his attention and accepting the conditions soon after. When confronted with the excerpt, he understood its general meaning while still having some doubts regarding the vaguer parts. Once the tests were completed, he reported that the Mozilla privacy icons were his favourite, as he believed they conveyed more clearly the message of the text, while the other icons gave him only a hint of the topic. The plain language contract was appreciated although he did not deem it necessary.

4.2 In-depth Digital Interview 2: Office worker, 52 years old

The subject reported that he rarely encounters terms of service agreements because he mostly uses the same online services. When faced with those kinds of documents, he reports that he usually accepts the conditions without even checking the contracts, as he considers them a nuisance and a waste of time. When asked for his opinions about private data management, he stated that he had nothing to hide. When tested, he had a hard time getting the excerpt's meaning right in its entirety, mainly because of the presence of a specialised judicial lexicon. When asked about the icon sets, he stated that he preferred the Mozilla privacy icons because they were clearer and more straightforward. He also strongly emphasised the usefulness of the plain-language contract, reporting an improved reading and understanding experience.

4.3 In-depth Digital Interview 3: Retired lawyer, 75 years old

Given the subject's very moderate use of technology, he rarely encounters terms of service agreements, apart from when he created an email account. When confronted with the test, he had no problems understanding the excerpt's contents, pointing out specific passages that were vague and admitting that understanding these kinds of documents did not come easy to people who were unaccustomed to legal jargon. While he could understand their purpose, his opinion of the icons remained negative, because the legal document, exposed in such a way, resulted oversimplified. He considered the DaPIS icon set

as the most useful, as it provided information on the topic of the document without conveying a message that could be misinterpreted. He commented positively on the plain-language contract, but he raised concerns about its implementation by the companies, stating that more customers would refuse to sign up once they fully understand how their data will be used.

5 DATA INTERPRETATION

The results of the in-depth interviews showed a striking resemblance to the behavioural model researched by A. Obar. Most users will either try to read the terms of service and give up soon after or directly skip them to pursue their objective [5] - signing up to the app or accepting a website privacy policy and terms of service because they are overly complicated [3] and vague [4]. This presents a growth opportunity for plain language contracts, to which we will come back to later. The widespread preference for the Mozilla privacy icons may be attributed to the unusual mix of images and text to convey complex messages in a comprehensible manner. This approach, however, may fail to transmit precise information due to the fact that the icons have been designed in an effort to be as comprehensive as possible. The DaPIS icon set proved less useful by itself, as it does not directly transmit the document's information. However, it can be employed to inform users about the topics covered in the terms of service agreement, provided that the meaning of the symbols is widely known and recognisable, as the use of abstract symbols can pose a threat to understandability. The inverse correlation between age group and icon set appreciation could also be linked to differences in the shared visual dictionary. In fact, the older section of the demographic is not familiar with these symbols, and this leads them to experience issues in the interpretation. In conclusion, all the interview subjects appreciated the plain-language contract, praising it for its brevity and understandability without compromising on the content. This also helps corroborate the hypothesis made by Obar and Oeldorf-Hirsch regarding the information overload that discourages people from reading the document independently [5].

6 CONSIDERATIONS

The use of icons has been proved useful to convey essential content to users and as a tool to integrate and clarify pre-existing terms of service written in judicial jargon, as supposed by Arianna Rossi and Monica Palmirani [7]. The user preference was mostly for icons that allowed them to understand the document's content more than the topic itself, as it could allow them to verify the kind of data they are going to surrender with a mere glance. Every interview subject has acclaimed the use of simple sentences in an effort to explain the contract, usually coupled with icons, to have a better overview of the terms of service before signing. Linking descriptive icons to brief and easy-to-understand descriptions could enhance awareness among users, who will have access to the information they need without the issues created by jargon-filled terms of service agreements. This study, however, has been limited by its sample size, which provided useful but only partial results; it can be developed further through ethnographic research, in an effort to understand the preferences of a more extensive sample of people. Their feedback will then be used to improve the icon designs. [11].

7 CONCLUSIONS

In this study, a user-oriented design method was used to shed light on a complex phenomenon. Online users from different demographics were interviewed to understand their behaviour regarding online terms of service agreements; they were proposed an array of different simplification methods, using icons and explanatory texts, and their reactions were taken into account. Our findings, matching with previous research done in this field, are a good first step in the raising of awareness of the customers regarding privacy issues and the wider world of online data sharing. The findings strengthen the designers' position in the public debate regarding the inclusivity of legal documents and data security, showing how they can enhance user experience by informing users in an easy-to-understand way about how the companies will use their data. The need to control personal data is becoming increasingly important, and this research shows a possible solution that, if implemented, could raise user consciousness on the subject and contribute to progress in the field of designing for legal and data awareness.

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EMBEDDING CHANGEMAKER SKILLS AND SOCIAL INNOVATION INTO DESIGN STUDENT LEARNING

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ABSTRACT
Building on entrepreneurship education and the United Kingdom (UK) government review on creativity in business, this paper discusses a case study of a funded project to develop design students' future skills by collaborating on transitioning student projects into start-up venture and commercialisation for the common good. Undergraduate students are shown to gain insights from different faculties and each other's subject expertise using a variety of set activities throughout the academic year to challenge and support them. The learning for students included scheduled workshops with the possibility of new venture creation based on the new product development (NPD) methodology, student networking and applying their soft skills in a new context. Four workshop tasks (Enterprise, innovation and you, enterprise development, prototyping and venture articulation) were developed for this project and visualised in a route map. The collaboration of product design students with entrepreneurship students has been observed at the commencement stage, during and after the experience to understand their personal development and identify key learnings captured through opinion polls, focus groups and observation. Triangulation resulted through focus group and feedback from wider project team and academics reflecting on learning models in design/engineering versus entrepreneurship/business. This project is timely due to its year-long inter-faculty student experience during a pandemic using and developing 'changemaker' competencies and social innovation.

Keywords: Changemaker, co-creation, collaboration, social innovation, student researcher

1 INTRODUCTION

In the showcased project, design and entrepreneurship students took part in a series of scheduled activities throughout the academic year 2020-21 that have challenged and supported them. They gained insights from different faculties, through collaboration and the subject expertise across Design and Business Entrepreneurship studies. This showcase demonstrates the enhancement of the Changemaker Certificate, which is an employability initiative developed by the University of Northampton, itself a UK based partner institution of an international collaboration around social innovation, called Ashoka Universities [1].

The learning for students included four facilitated workshops with the possibility of new venture creation based on the new product development (NPD) methodology, student networking and applying their soft skills in a new context.

In the discussion, the suitability of workshops and visual guidelines for university use will be highlighted and the evaluation of student engagement and entrepreneurial activity shared. Students become potential siloed in their faculty or school of thought – this cross-faculty cooperation supports their development towards T shaped learners, with deep understanding and breadth of collaborative expertise [2].

This project changes practice at an UK university, developing an iterative model and toolkit for cross collaboration, aided by a visual road map of journey and start-up facilitation. This model builds on the Design Council's Double Diamond Design Process [2] and St Galler Start-up Navigator [3]. Upon completion of the workshop activities, the authors conclude that the inquiry forms a clear argument for the implementation of such initiatives for the benefit of all stakeholders involved.

2 METHODS

The paper aims to present and discuss the methods used to work collaboratively across disciplines and the methods used to embed social innovation skills into cross-faculty student learning. The project

delivery has been built around the support from two undergraduate student researchers, which were recruited to act as 'Academic Brokers' and collected data throughout. Students as researchers is an innovative pedagogy aimed at influencing undergraduates to become submersed in their academics by inheriting research skills through co-creating within their future field of work. A partnership is formed between teacher and student to investigate issues often found within the academic workplace.

2.1 Entrepreneurship methods overview

Entrepreneurship teaching focusses on the entrepreneurial mindset, Business Model, Strategy and Business Formation. Predominant learning styles provided in entrepreneurship teaching are the taught delivery of subject knowledge in textbook format and live case study, delivered through discussions in workshop format, fostering critical thinking and presentation skills. The project added to the programmes problem-based learning approach and ensured the 'live' aspect despite the pandemic.

2.2 Design methods overview

In this project, the Design Thinking methods of visual concepts [2], co-creation [4], and rough prototyping with sketch, 3D doodles and wireframes have been provided to the participating students, through set activities in a prototyping workshop format and communicated, as follows: "This time the focus is on Prototyping. How well do you know your user experience UX from your user interface UI? We will (virtually) take you to the design workshops and Makerspace in the Creative Hub, demonstrating rapid prototyping technologies including laser cutting and 3D printing. Followed by an introduction to top app prototyping tools and a taste of Adobe XD".

2.3 Collaborative methods of working together

The project has deployed new collaborative innovation toolkits with students, namely problem tree exercise, exploring the causes and effects of a problem, Gamestorming [5], Visual Thinking [6], and an introduction to prototyping of screen-based applications using 'wireframes' and user experience design tools for mobile apps, developed by Adobe Systems.

Whilst challenged by the global pandemic, the project workshops have all been delivered online. Virtual Learning Environment (VLE) by Blackboard and the Online Canvas for Visual Collaboration by Miro have been used to conduct the workshops and other student interactions. Both design students and entrepreneurship students were working towards new venture articulation, learning aspects of New Product Development and they had the opportunity to use the project as evidence to gain an optional extracurricular qualification, called 'Changemaker Certificate', with three levels of attainment which were classified as Bronze, Silver or Gold. The university defines Changemaker as "spotting a social or environmental problem and having the skills and determination do something about it" and are defined as to "live responsibly, work collaboratively, be resourceful, practice empathy, remain true to your personal values" [1]. The changemaker values were at the heart of the project, the projects aims and the project team.

3 PROJECT, PROCESS AND WORKSHOPS

The aim of the workshop series was to support students to develop their employability skills whilst embracing social innovation. This has been facilitated through engaging the students in social innovation in the context of learning, fostering student's abilities in terms of communication, networking, presentation, and team-building skills. In addition, the workshop series provided the possibility for start-up ventures [3] and of gaining insightful experience by means of collaborating with staff and students with different sets of expertise and visualised in the roadmap diagram in Figure 1. Together, in five cross-faculty teams the students practiced social innovation, co-creation, and prototyping, by creating design proposals, storyboards, and wireframes - resulting in apps, products and services that are going to address the big social and economic issues [4].

The project team included 18 BA Business Entrepreneurship students, matched by 18 BSc Product Design students, two student researchers and two senior academics involved in the workshop facilitation. Activities and dissemination were supported by the project team that consisted of student researchers, Learning Technologist, Librarian, Employability Department staff and a Graphic Designer. 'Students as researchers' was an innovative pedagogy aimed at influencing undergraduates to become submersed in their academic environment by cultivating research skills through co-creating within their future field of work. A partnership was formed between teacher and student to investigate issues

concerned. The project team had met in online planning meetings ahead of workshops and in a subsequent debrief where reflections were gathered. Student researchers were mentored for the delivery of workshops, presentation styles and project management. Evaluation was undertaken through focus group and feedback from the project team and academics, reflecting on learning models in design engineering versus entrepreneurship/business models.

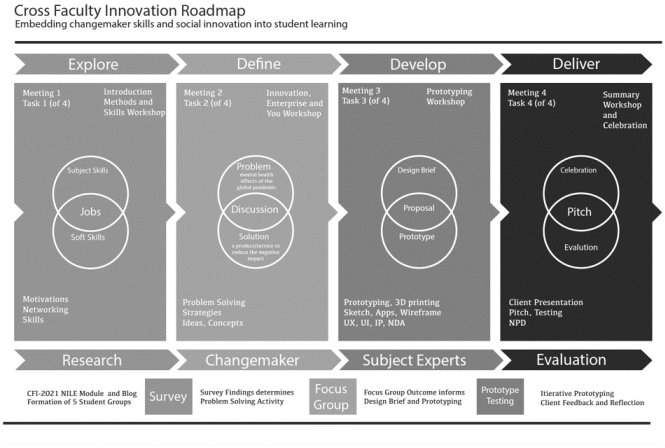


Figure 1. Student groups from two faculties attend four virtual workshops. Process visualised in a roadmap diagram

Embedded in the cross-collaboration activities, students learnt to jointly address a social issue: the decline of mental health of university students during lockdown. Projects resulted in a number of outputs, such as the joint creation of a design brief, 4 of which defined apps for mental health and 1 service. These have subsequently been prototyped to proof-of-concept stage, for testing and evaluation. The students were tasked to "Create a) a brief (Outline Design Proposal) in bullet point format and b) visualise the app/service through a Mindmaps / storyboard / wireframe model. The brief and the visual was handed over to UX Designers, for execution or refinement of app/service idea." As briefed by the student team, prototypes were then developed in a suitable software package (Adobe XD) to be ready for demonstration in workshop four and examples shown in Figure 2.

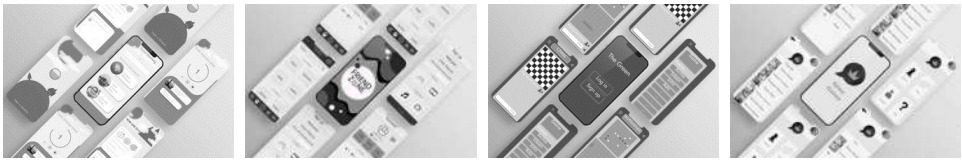
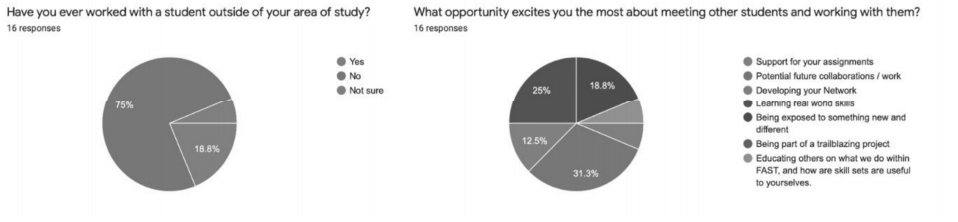


Figure 2. Prototyping workshop outcomes. Four Mental Health Apps, created in Adobe XD

4 FINDINGS

Quantitative and qualitative forms of student evaluation were collected via opinion polls (survey) across all 4 workshops, see Graph 1. In addition, students' remarks were collated during the virtual classrooms, discussion in breakout rooms as well as focus groups. Different aspects have been looked at including innovation, teamwork, collaboration, leadership, visual thinking, application of changemaker skills as well as students' experiences whilst working with clients and the mechanism of project management. It was evident how such feedback allowed the designers to fully understand artistic/display communication i.e., how they can make it easier for everyone to understand and interact with, as well as helping students express themselves in giving a brief. The findings demonstrate the excitement of mixing theoretical information and knowledge with creative skills and expression.



Graph 1. Visualisation of collaborative experiences and expectations from the initial survey

4.1 Findings from survey and workshop sessions

This paper focuses on the key areas including collaborations, soft skills (time management and networking) and self-improvement/self-development. The second workshop survey (a key question) asked - What are three things that you take away from today? From the responses, the networking was seen as very important, Examples of students' voice include:

Student	Comment
1	"*Multidisciplinary team building skills, Time management & Networking*"
7	"*Good to teamwork and collaborate*"
5	"*Friends, ideas, skills*"

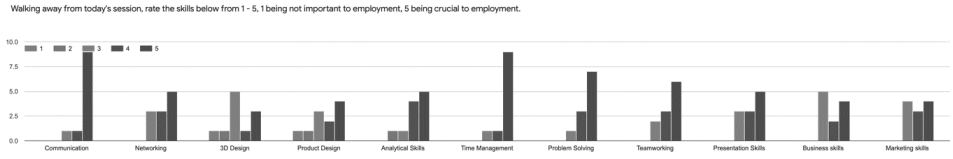
Students had wide ranging opinions, which appeared on both ends of the spectrum with some identifying similarities and differences between themselves. Students commented:

Student	Comment
3	"*Perspectives are different, Collective thinking is interesting...*"
4	"*Working with people that think differently to me allows me to be more creative interacting with others, different perspectives, design insight...*"
6	"*A wider knowledge of what both faculties have in common, as oppose of how different they both are...*"

Students also identified hesitations and 'worry' about being involved in something so new, which felt daunting and outside of the 'norm' and their discipline.

Student	Comment
2	"*Leaving with less nervousness, greater clarity on why we are doing this collaboration and the opportunity it brings through a different pathway of thinking and executing tasks...*"

The responses highlighted the importance of networking, new connections, knowledge of processes in another faculty, ranking the key skills seen important to employment, as drawn up in Graph 2. Contrary to expectations the soft skills of communication and time management have been substantially higher valued than the subject expertise in Product Design or Entrepreneurship being important to employment.



Graph 2. Ranking of employability skills from the second workshop survey

During session 3, the student researchers joined-in the VLE's breakout rooms, probing disciplinary expertise. Students discussed different ways of pitching – selling yourself, not just the product. They considered how to promote themselves and their app service, using personality and storytelling. This highlighted to the students the alternative perspectives outside of their discipline. For the 'design students' it had been about the design aspect. The focus on being able to demonstrate the skills, while

for the entrepreneurship students the focus had been on the market opportunity. Further, business students wanted more research to ensure they knew all aspects (the more research/ info the better), while design students highlighted that did not want to do too much research for fear of jeopardizing their creation and influencing their own creativity. This showcased an important disciplinary difference and enhanced the discussions. Further, BSc Product Design students commented on improved business acumen while BA Business Entrepreneurship students increased their understanding of NPD, briefing and physical development of product. By the fourth workshop, tensions and groupwork issues started, developed and have been resolved with self-development and growth identified by students. They explained how their collaboration skills improved:

S2 "They improved definitely! Since it was hard to communicate with others over [the VLE], it has improved since then."	*S4 "Better communication with new acquaintances, taking on natural leadership role".*
S5 "Facing challenges in Multidisciplinary team. Being able to support others in their projects."	*S6 "providing me the chance to network with the students [from the other faculty]."*

While other students highlighted the initial challenges of communication and how they improved how they worked together towards a mutual goal, many suggested their favourite part of the workshops was the identifying and working together initially on the creative side and experiencing different ways of working.

S1 "...where we got to breakout into our groups to discuss our project."	*S9 "... where we came together to brainstorm an idea to work on going forward"*
	S 7 "... provided the chance to engage with students from the other faculty."

4.2 Findings from Focus Groups

The focus group led by a student researcher, for pedagogical and research reasons, used 11 questions to ask each of the groups about their overall experience of working together. Two key areas of results were identified: employability skills linked to communication and collaboration.

Students identified how much the experience had helped them grow and develop skills which they would later use. Quotes included:

FG1: *"Communication is key for finding a job. This has made me more comfortable working with others."*	FG5: "*I don't think I would have talk to someone outside my faculty to learn about their course or faculty*
FG5: *"Solving a problem or solving an issue I am trying to move out from my angle and see it from another person's perspective."*	FG2: "*Presentation of things forced me to think a bit more creative in the way I do my work - how would I place things to make them more attractive"*

Further, students reflected on how important working together had been and how giving them time and a reason to talk had strengthened tentative relationship and showed how future working practices had been positively influenced. Quotes included:

FG2: "*I had met her before as we are both students' reps and had met before, but this gave us a chance to talk more"*	FG2: "...m*ade me less scared about collaborating outside of product design"*

Initial reflection of the feedback received was positive, with support of cross-faculty development within the university. Upon completion of the focus groups, students who attended were offered the opportunity to develop an online profile linked to the external facing blog. This is used to showcase the ongoing work with the intention of uncovering potential employment opportunities.

5 DISCUSSION

As drawn out from the survey and questionnaires, students become potential siloed in their faculty or school of thought – this cross-faculty cooperation support students' development towards T shaped learners which is characterised by deep understanding and also a breadth of collaborative expertise [2]. Students might have developed 'habits' of working in their siloes – for example, in future,

entrepreneurship students might need to work with product designers. This collaboration was good practice and very much replicates real- life that they could encounter [4]. Further, Design students have taught using non-siloed language entrepreneurship students how to use a 3D printer thereby acquiring new future-proof skill sets [7]. Soft skills and employability skills - Varied business acumen and design knowledge exist across learners – peer to peer learning enhances students understanding as well as the ability to work and learn together [8]. Presenting, networking, and building rapport has been practiced in online sessions to which exposed students to different environments.

This cross-faculty experience led to different learning for each part of the team which led to rich data and future research opportunities which are explored in further papers. The findings showed that social innovation is a topic of interest for students and relevant to students lives. This paper identifies that more resources are needed to support students to develop the space and skills to embed further knowledge and practice in the safety of a university setting. Cross-faculty, while not a new concept, relies in addition to the Changemaker values, on trust and communication between faculties, which themselves are siloed. To date, only limited guidelines are available on working together across faculties in a university setting; this research aims to fill this gap and progress criteria for sustained collaboration by developing an iterative model as visualised in Figure 1, exploring Changemaker methodology [1].

Finally, this paper demonstrates learning typologies, kinaesthetic approaches (i.e., prototyping and learning by doing, exemplified in Figure 2) and synergies with other pedagogic research across faculties by creating a model to help other learners and academics to embed social innovation and Changemaker.

6 CONCLUSIONS

In conclusion, the relevance of joint Entrepreneurship and Product Design students' learning from an institutionally funded project has been highlighted. The findings demonstrate the experiences, results, and skills improvements from across the projects. Throughout the project a series of structured activities has been used to support employability skills, including networking across the faculties, problem solving and new product development (NPD), devising a design brief and undertaking App development in an industry standard prototyping tool (Adobe XD).

The activities resulted in a dedicated VLE Organisation Module, the co-creation of app prototypes that address the decline of mental health in students during lockdown and student's recognition of their own personal growth and development of working with other disciplines. The paper explores the enterprise and innovation facilitation, informs 'Changemaker' competencies and proposes an iterative model of collaboration for other faculties and universities to consider.

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ADAPTING COURSE DESIGN TO FOSTER THE DEVELOPMENT OF SPATIAL ABILITIES IN ENGINEERING EDUCATION – A CASE STUDY

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ABSTRACT
Spatial skills are crucial for engineering designers, particularly when interpreting views of an object represented by drawings, visualising parts, or manipulating geometry in CAD. Spatial skills can be improved through instruction, teaching, and training. Several interventions are described in the literature. Established approaches in engineering education are, for example, sketching exercises and technical drawing tasks. Emerging visualisation possibilities such as Virtual Reality, Augmented Reality or Mixed Reality is the subject of current studies in the field. However, their effect on the development of spatial skills needs further studies.
In a previous study, the authors have investigated which visualisation techniques can positively influence the development of student's spatial skills. Here we want to take a more detailed look at the following question: How can we adapt an introductory engineering design course to match these findings?
In this paper, we report on our experiences from using various training to develop spatial skills. First, we will show the interventions that have already been considered in the teaching concept. The use of technical sketching and CAD will be explained in detail. The findings of our previous study, which informed the modification of the course, will be summarised. This includes specific interventions and training, covering machine elements and sketching exercises and interactive e-learning content.

Keywords: Spatial ability, engineering education, spatial training, engineering graphics

1 INTRODUCTION

The role of spatial abilities, especially in engineering and engineering education, has been investigated over the last decades. In general, spatial ability is understood to be the ability of the human brain to produce, retain, retrieve, and transform 3D models as well as virtual images and objects [1]. Typically, "spatial ability" denotes the innate ability a person has, and "spatial skill" is learned or acquired through training. In this paper, the term mental skill is used because of the lack of knowledge regarding prior cognitive skill training.
Spatial skills are fundamental for novice engineers and often needed in engineering design where interpreting views of an object represented by drawings, visualising parts, or manipulating geometry in CAD are important activities. So, a lack of spatial abilities is not only resulting in particular problems during the introductory engineering design course, but it may also affect the professional career of students.
As a central component of multi-factorial spatial concepts, the capability to imagine and transform spatial information (mental rotation) is mostly used as a marker for spatial abilities. Mental rotation performance, in general, can be improved due to a variety of measures [2] which are described in the literature. The measures range from special spatial materials and tests to playing video action games [3], use of Augmented or Virtual Reality [4], interactive animation, and virtual objects [5] and also the use of rapid prototyping [6], [7]. An interesting finding of a meta-analysis regarding the development of spatial skills [2] is that basic engineering tasks such as sketching 3-dimensional objects [8] and technical drawing [9]–[11] can greatly improve mental rotation skills and also had a positive effect on students learning [12]. Furthermore, studies revealed that interacting with three-dimensional displays [5], [6] and actively manipulating these displays is more beneficial for the development of spatial skills [13].

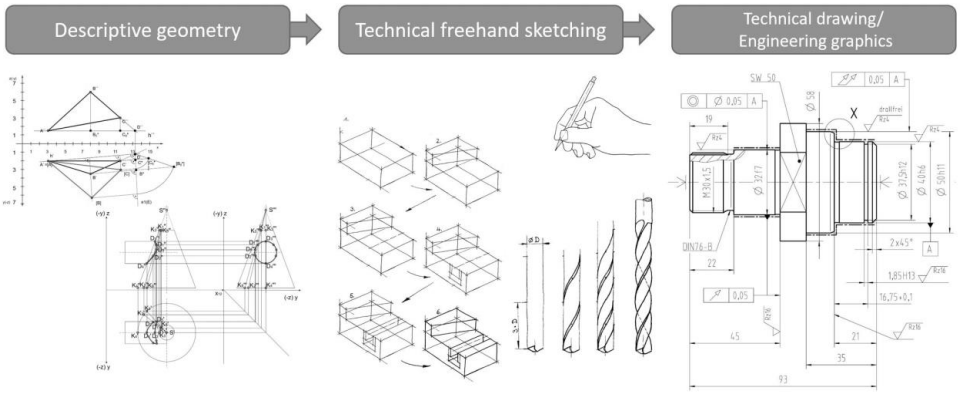
The studies examined in the meta-analysis indicate various training options, which are, however, for the most part, considered and examined in isolation.
This led to the following questions for the design of the engineering design course:

- Which measures described in the literature are most appropriate for the engineering design course?
- How can the effectiveness of the implemented measures be assessed?
- How do the studies, in turn, inform the design of the course?

The paper is structured as follows. First, we shortly describe the original course design and addressing research question 1. Afterwards, the paper addresses the second research question by reporting an empirical study conducted previously by the authors [14]. The paper concludes by explaining the adaptation of the course.

2 ORIGINAL COURSE DESIGN

The introductory engineering design course which lasts 14 weeks is offered during the student's first semester. The total number of course participants averages around 200 students enrolled in different study programmes including mechanical engineering, biomedical engineering, industrial engineering but also mechatronics and prospective teachers.
This course is focused on teaching theoretical content regarding construction theory and technical representation and also developing individual skills. During the course, the students learn the basics of descriptive geometry, technical freehand-sketching, engineering graphics, and technical drawings' conventions (Figure 1). Of the measures to foster spatial imagination mentioned in the introduction, technical sketching was thus already implemented in the course design.



- Fundamentals of projections
- Orthogonal Multiview projection
- Geometrical construction of cuttings and intersection between multiple bodies (2D in orthogonal projection)

- sketching techniques
- Sketching elementary elements and objects
- Procedures for sketching more complex structures

- Conventions of technical drawing including line types, representation of technical objects, entry of dimensions, sectional views
- CAD Training (Constructing the parts and deriving technical drawings)

Figure 1. Main topics of the course

In addition to the lectures and exercises in the individual subject areas, the acquired knowledge is tested with the help of test exercises. These tests also serve as a prerequisite for the examination and have to be completed by all course participants. The tests covered basic elements in orthogonal projection (digital multiple-choice test) and the geometric construction of three-dimensional intersection between two bodies (manually on paper). Furthermore, there was a three-staged task covering all topics. The first part was the making of a scale freehand sketch of a previously unknown technical object. This sketch should contain an isometric view in addition to the three main views. Subsequently, in section two, the

sketch was to be converted into a 3D component using a CAD tool and afterwards into a two-dimensional technical CAD drawing in the third section.

3 A STUDY OF VISUALIZATION MEDIA AND ITS INFLUENCE ON THE DEVELOPMENT OF SPATIAL ABILITIES IN ENGINEERING EDUCATION

The second research question has been addressed in the study, previously conducted by the authors that aimed to evaluate the effectiveness of the effect of the different visualisation media in developing students' cognitive skills. To assess the students' spatial abilities, imagined spatial transformations of objects, so-called mental rotation, were studied. Simultaneously, it was investigated which visualisation tools can positively influence students' spatial skills development. The study design and two of the main findings are briefly described below. A detailed description of the study and complete results can be found in [14].

3.1 Study design and test procedure

In order to measure the degree of improvement, a mixed study design approach was used, with a pre- and post-test for the control- and the treatment groups. The pre-test took place at the start of the semester. The second (identical) post-test was performed at the end of the semester after everyone finished the three-staged task.

A redrawn version [15] of the paper-pencil Mental Rotation Test (henceforth referred to as "MRT") developed by Vandenberg and Kuse [16] was used to evaluate the mental rotation performance. The test is composed of various stimuli that are consistent with the cube figures created by Shepard and Metzler [17]. Peters and Battista [18] provide different redrawn versions of these 3D cube figures. Stimuli with alternating black and white cubes against a white background were chosen from their library, for better distinction.

The MRT is composed of two sets of twelve items each. As shown in the figure below (see Figure 2), each item consists of five stimuli with the target stimulus on the left side and four sample stimuli on the right side. The participants have to determine which two stimuli on the right side are rotated versions of the target stimulus. Incorrect choices are either mirror reflections of the target or structurally different.

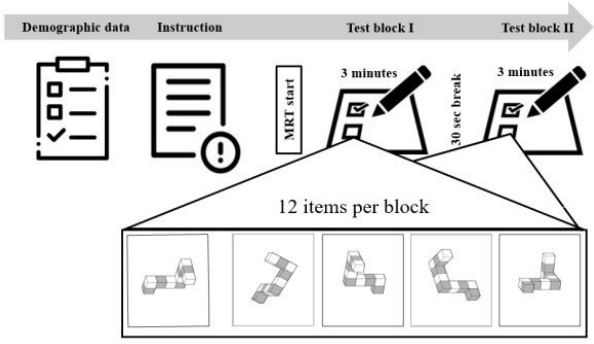


Figure 2. Schematic representation of the Mental Rotation Test setup and procedure

Following the standard scoring developed by Peters [15], one point was given if both items were identified and marked correctly. A maximum number of 24 points were achievable.

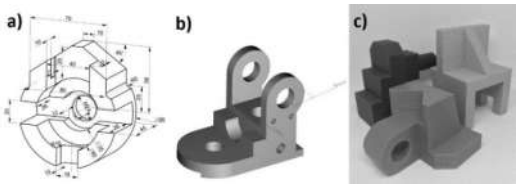


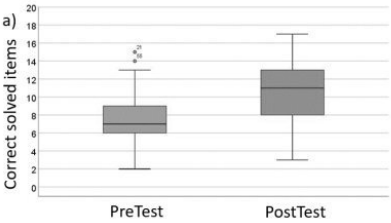
Figure 3. Intervention in the tree-staged task: a) 2D dimetric drawing, b) digital measurement in a 3D-Pdf c) 3D-printed model

For the intervention, the participants were randomly assigned to three groups. These groups differed with regard to the media used to visualise the technical objects (start point of the three-staged task) and the interaction possibilities provided by the media (Figure 3). The first group (Group1) served as a reference-group and started with a two-dimensional representation of a dimensioned dimetric component view. This is the usual way of displaying components and machine elements in engineering design. The first treatment group (Group 2) received a virtual object in the form of a 3D-pdf file in which they had to measure the dimensions digitally. The second treatment group (Group 3) received objects physically in the form of 3D-printed components, which they had to measure independently on a specific date.

3.2 Main Findings

Out of 135 students (112 males, 23 females), 79 students participated in the second test. Nine participants did not follow the test procedure correctly and were excluded from the test analysis. The final group of participants consisted of 59 males and 11 females.

The first main findings were that the training during the fundamental design engineering course resulted in a significant improvement of mental rotation performance with a large effect size (Figure 4). The mean performance of the participants improved substantially during the semester, regardless of the respective treatment (see Figure 4). The overall mean value (M) increased during this period from $M_{PreTest}$=7.37, with a standard deviation of SD=2.89, to $M_{PostTest}$=10.83, SD=3.58 correct solved items.



b)		N	Min	Max	Mean	SD	95% Confidence Interval for Mean		Variance
							Lower Bound	Upper Bound	
PreTest	All	70	2	15	7.37	2.89	6.68	8.06	8.32
	male	59	2	15	7.61	2.91	6.85	8.37	8.48
	female	11	3	10	6.09	2.47	4.43	7.75	6.09
PostTest	All	70	3	17	10.83	3.58	9.98	11.68	12.81
	male	59	3	17	11.00	3.61	10.06	11.95	13.03
	female	11	4	16	9.91	3.42	7.61	12.21	11.69

Figure 4. a) Point distribution and b) descriptive statistics for Pre-and Post-Test

Furthermore, the impact of the media used for the task definition was investigated. Therefore, the improvement (I) in mental rotation performance, as the difference between the initial mean score and the Post-Test score, was determined for each participant. Figure 5 shows the mental rotation performance of every group (M = mean number of points, SD =standard deviation). The secondary axis indicates the mean improvement in relation to the initial performance (relative mean improvement MI_r).

	M	SD	MI_r [%]
PreTest	7,61	3,16	38
PostTest	10,52	3,22	
PreTest	7,43	2,96	45
PostTest	10,76	3,45	
PreTest	7,5	2,96	36
PostTest	10,2	4,33	
	M	SD	MI_r [%]

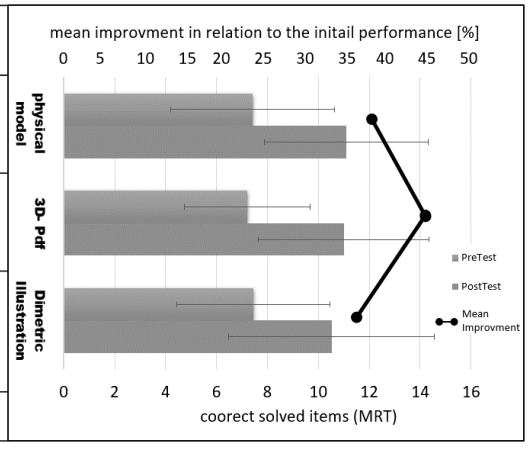


Figure 5. Development of the average score depending on the group

The second main finding was that, although an independent samples t-test did not reveal significant differences in the improvement of mental rotation performance, a trend was observed (Figure 5).

Visualisation media which offer some interaction with an object help students to capture the object's spatial reality, thus lead to a considerable improvement of mental rotation performance. The most considerable improvement with a value of MI_r=45% (MIt1=3.33) was observed in the group with the target object presented as 3D-pdf. This media allowed the user direct manipulations of the object so that the student can see the intermediate steps. For example, to complete the given task, the students had to rotate the object into the respective view to take the measurements. The live feedback about the direction of rotation and the resulting views is exactly what is examined in the MRT. Furthermore, 3D-pdf offers the opportunity to show arbitrary sections. The second-highest performance increase at a value of MI_r= 38% (MIt2=2.91) was in the group with the hand-held physical model of the target object. Although rotation was equally possible with this model, it is assumed that it is carried out unconsciously. On top of that, no section can be illustrated with this media. In the reference group with the dimetric illustration, the lowest mental rotation performance increase at a value of MIr= 36% (MIC=2.7) was detected. The two-dimensional representation does not offer any kind of interaction to support the participants' understanding of the object's spatial reality.

4 ADAPTED COURSE DESIGN

Based on these findings, the course design was adapted. First of all, sketching technical objects (the literature is unanimous on this) promotes the development of spatial skills. A new finding of the study was that media that offer interaction possibilities are conducive to the development of spatial perception. Based on these findings, various interventions were implemented. The distribution of the media used and the proportions in the individual subject areas are shown in Figure 6.

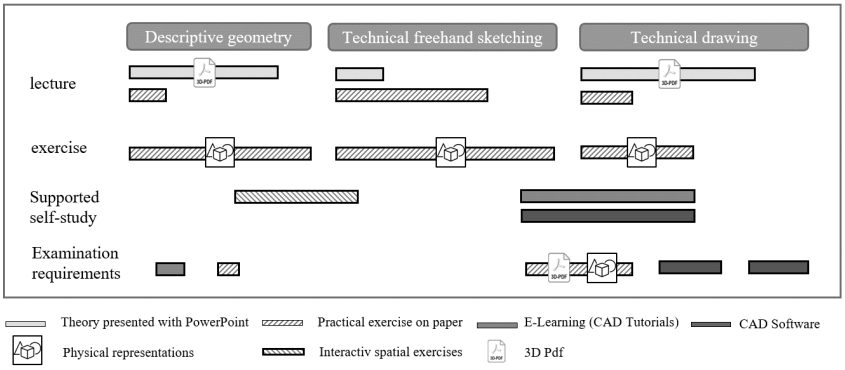


Figure 6. Overview of the use of media in the subject areas of the design course

On the one hand, 3D-Pdf is now used as a basic visualization tool to accompany the presentation of tasks in exercises. On the other hand, it is used as an additional visualisation in teaching theoretical lecture content (Figure 6). Furthermore, physical models are now increasingly used in the exercises of all subject areas. Mainly we use 3D printed objects.

Regardless of the new media available, two-dimensional representations of technical objects are still widely used in engineering. For this reason, we have created an interactive e-learning module that aims to train the recognition and mapping of figures and their projections.

Another modification is the support of teaching by a team of tutors. Implementing all measures is very time-consuming and cannot be completed only during the regular course hours. Therefore, an additional exercise is offered via tutored hours. The tutors are MSc students that have successfully completed the supported courses. However, at the time of the study, these were not yet included in the learning concept and therefore not shown in the figure. The content of the tutored courses is working with physical objects. Here, for example, gears are assembled, and dissembled, and various objects are measured and sketched. Furthermore, tutors support the handling of the CAD system.

5 CONCLUSION AND OUTLOOK

The study has shown that the course design created, in the sum of all the measures taken, promotes the development of spatial imagination. Proven influencing factors are sketching and also the creation of

technical drawings. Furthermore, the presented study revealed a trend that modern visualization media, which offer the possibility to interact with the object, can foster the development of spatial skills. Based on these findings, it is concluded to that a combination of proven classical forms of representation and modern visualisation media is beneficial for the development of spatial skills of engineering design students. The influence of these and other media will be investigated in future studies.

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GIGA-MAPPING AND KNOWLEDGE OF BOUNDARY OBJECT THEORY IN SUSTAINABLE PRODUCT DEVELOPMENT

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ABSTRACT
New combinations of disciplines allow a better understanding of interconnected modern problems like sustainability. Expanding design education curriculum may improve a designer's ability to deal with complex subject matters where expertise and perspectives from other fields are needed.
Through the theoretic lens of 'Boundary objects', one can describe how GIGA-mapping employs certain collaborative characteristics and can provide a better overview of decisions in complex subject matters. GIGA-mapping is a method in system-oriented design, a growing area of interest in the field of design. The process of GIGA-mapping can also be used in product development, especially for understanding the context of a new product, its environmental impact, production processes or alternative value chains. *What makes a GIGA-map serve as a boundary object, and why are GIGA-mapping and boundary object theory useful in product development processes?* The paper builds on perspectives and learnings from a master's student, discussing topics that could be valuable in design education. The theory of boundary objects provides interesting perspectives on the characteristics of objects or tools that enable communication across knowledge boundaries. Such perspectives are useful in design education because of the increasing need for collaborative work and the high number of considerations involved when developing more sustainable solutions. Incorporating awareness of boundary objects in design education may improve processes that require collaboration across disciplinary boundaries.

Keywords: Boundary object, GIGA-map, product development, complexity, collaboration

1 INTRODUCTION

In this fast-paced globalised world, big environmental issues and social challenges create opportunities for using design methods in complex modern challenges. So called 21st century problems are hard to solve for many reasons, due partly to their interconnectedness with other problems. Such problems have been described as 'mess' [1] or 'wicked problems' [2, 3]. When levels of complexity and uncertainty rise, finding the actual root cause is difficult. Curtis et al. [4] quote a statement from a system engineer: '*Writing code isn't the problem; understanding the problem is the problem'* [4]. Product developers face complex considerations such as sustainability choices, production technologies and diverging interests in a product´s value chain. Product development projects are, therefore, often dependent on collaboration across knowledge fields. In a real-world project setting, organisational silo structures and differences in language or practice might also cause communication difficulties, and common ground is needed for good collaboration and progress [6]. Building on Bourdieu's forms of knowledge, Carlile [7] highlights how a pragmatic approach to knowledge recognizes that knowledge is 'localized, embedded, and invested in practice', explaining why it is both a barrier to and a source of innovation in a product development setting. In light of the increasingly interdisciplinary problems designers and product developers face, new methods of combining knowledge should emerge. GIGA-mapping [5] is a promising approach that utilises visual communication to portray and handle complexity.

2 BACKGROUNDS

With systems theory [8] and systems thinking, one can better describe and understand the behaviour and patterns of the complexity around us. Natural living phenomena, or even businesses and interactive products, can be seen as interconnected 'wholes' integrated with their environment. Paying attention to this, the designer can better analyse the context of an existing or potential new solution to reach a better

implementation fit. System-oriented design (SOD) [5] is based on systems thinking and systems practice, design thinking and design practice, and visual thinking and visual practice. SOD is tailored for designers, and central to SOD is the GIGA-mapping technique [5].

2.1 GIGA-mapping

A GIGA-map can contain multiple layers and levels of detail and can also incorporate several types of maps in one. It can serve as a 'desktop' of thoughts and ideas put into context. A GIGA-map focuses on relations and links between various elements put on the map. It is a way of seeing everything at once, while still being able to zoom into and investigate or elaborate details. The constant and ongoing process of sense-making [9] is central to GIGA-mapping. We 'structure the unknown' [10] and try to make sense of something that is at first hard to grasp, interpret or understand, in order to construct meaning. One way to do this is to take a preferably large piece of paper, jot down ideas, words and sketches, map out relations between contexts and situations, and try to understand and improve behaviour or phenomena. We then see a bigger picture and can compare and envision possibilities for action. Sensemaking is about an activity or a process, it is about creation as well as discovery [11]. GIGA-mapping can thus be considered as the activity of investigating and understanding the complex context of the 'upcoming change to be'. Changes are seldom applied in isolation because a new product or technological solution will impact something else: the environment, human behaviour or industrial efficiency. Although GIGA-mapping as an activity can be done completely alone, it is intended as a collaborative tool that can collect and negotiate the perspectives and input from the group or stakeholders and from interviews or research conducted by others.

	Research	Learning	Generative	Management	Event mapping	Planning	Innovation	Implementation
Mind maps	X	X						
Concept maps	X	X				X	X	
Gantt diagrams				X	X	X		X
Timelines		X		X	X	X	X	X
Key frames		X	X		X			X
Flowcharts						X		X
Animations			X		X			X
Story boards			X	X	X		X	X
Image maps	X	X	X				X	
Spatial maps	X		X		X	X		X
Intensity maps	X		X		X		X	
Mixed maps	X	X	X	X	X	X	X	X

Figure 1. A table by Sevaldson [5] shows a non-exhaustive list of suggestions for matching map types and activities.

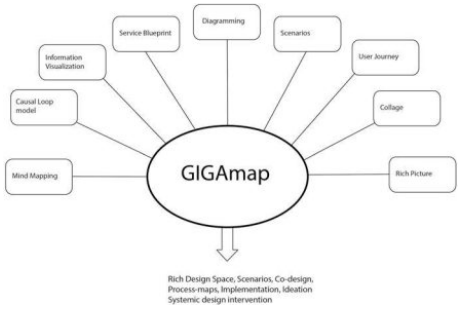

Figure 2. The GIGA-map earns its name not only from the number of elements that it should contain but also from the numerous representative modes and models it might integrate. Retrieved from [12]

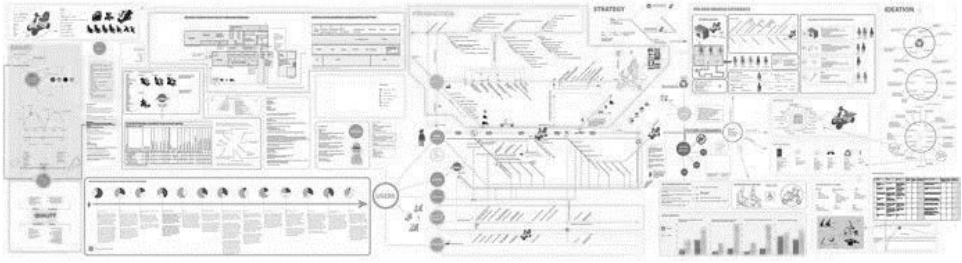

Figure 3. A GIGA-map of a Norwegian manufacturing company (Medema). The GIGA-map can express models of relations and interconnectedness to timelines, floor plans, statistics, and illustrations. by Julian Guribye and Christian von Hanno, AHO 2011, retrieved from [12]

Knowledge transfer and utilisation increase in complexity when actors from different backgrounds, sectors and disciplines come together to solve these kinds of problems in what [13] calls a 'boundary-spanning group'. Even departments within the same organisation can have 'knowledge boundaries' that cause communication difficulties, like in interactions between designers and engineers or other specialised functions [7]. According to [7], using a 'boundary object' can be a means of 'representing, learning about, and transforming knowledge' across boundaries of knowledge that separates organization departments or disciplines. Star & Griesemer [14] were the creators of the term 'boundary object'. They extended the Latour-Callon model of interessement to highlight two main activities central to translate between viewpoints. They saw that the standardisation of methods and the development of 'boundary objects' enabled groups of divergent visions and practices to collaborate without letting go of their own agenda. Despite the different definitions, boundary objects have some common aspects: (a) may be an abstract or concrete object, (b) must be 'plastic enough to adapt to local needs', (c) must be 'robust enough to maintain a common identity across sites' [14], (d) must be temporal, (e) must be based in action, meaning its materiality must derive from actor's action; and (f) must be subject to reflection or interpretive flexibility [15]. GIGA-maps have been described as bridging artefacts [12], but from what I could find, not through the term boundary object. GIGA-mapping encourages cross-disciplinary collaboration that 'entertains' input from different perspectives. This can be done through methods such as interviews, where data is collected and put into the map by the designer or by workshop participants and can later be a part of or feed into the 'main map' worked on by the designers or facilitator group. Based on the collaborative nature of the GIGA-mapping process and its tendency to cause negotiation and discussion, I will look further into the boundary-spanning and boundary-object properties in GIGA-maps. Therefore, this paper will bring additional perspectives to the lively discussion on boundary objects through comparison with GIGA-mapping processes and characteristics of GIGA-maps. It will also discuss the value of increasing awareness of these concepts through design education.

3 RESEARCH QUESTION

This paper will discuss GIGA-mapping through the concept of boundary objects. I have not found any other paper comparing these concepts. The research question is: *What makes a GIGA-map serve as a boundary object, and why are GIGA-mapping and boundary object theory useful in product development processes?*

4 METHODS

This paper will draw on existing research on GIGA-mapping and boundary objects, together with relevant topics found through a literature search. Contributions to the discussion also stem from being in the field of design/engineering and from being student using GIGA-mapping in design projects.

5 BOUNDARY OBJECTS AND GIGA-MAPS

Since design and product development are much about the creation of change, the process of GIGA-mapping requires inquiry and negotiation and involves frequent decision-making on the next pathways. The processes of sensemaking and framing contribute to refining the contours of both the problem space and the solution space [13, 16]. GIGA-mapping can create great synergies caused by the ability to

understand the status quo better and envision the changes of how things 'ought to be'. The GIGA-map format is deliberately left open [12] to avoid losing sight of potentially crucial details and make its format flexible enough to be used in different worlds. Having close collaboration with relevant actors and stakeholders reduces the risk of not being on the same page later when the costs of turning back are higher. The dynamics of the design process can be described as layers and iterations of interactions initiated by the designer. These processes may take various forms, with different degrees of stakeholder involvement, external participation or co-design. The way the GIGA-mapping process is carried out is a crucial factor in discussing how the 'unfinished' Giga-map may successfully employ boundary object characteristics.

5.1 Boundary object characteristics

The concept of boundary objects arose from observing how different actors with different self-interests at the Museum of Vertebrate Zoology worked together. A boundary object facilitates communication between social worlds and is plastic enough to be used in all of them. Often the 'local' use or elaboration of the boundary object might be more detailed or adapted to specific local needs. When used in group settings, one can discuss and share perspectives because the object is still recognisable to others. The object can be further developed by the team members separately or together. Nicolini et al. [17] described these behaviours from their experiments and mentioned how the 'unfinished nature' of a prototype caused a kind of motivation for the group to work towards finalisation, similar to what Knorr Cetina described in epistemic objects [18]. Through this drive to move forward, the attachment to the object increased as they could embed their own ideas and visions into it.

From my perspective, collaborative mapping processes can be seen as a boundary-spanning activity, where the designer or facilitator aims to gather, interweave and consolidate different and multiple perspectives and areas of knowledge. When actors can actively put their own ideas into the 'unfinished' GIGA-map, it could lead to an improved sense of involvement or motivation similar to what is described in the examples of [17] and [18] above. The rest of the group may thereafter update themselves and discuss the meaning of the perspectives added.

Lee [19] observed how designers were using artefacts and surrounding practices to coordinate perspectives and to align diverse groups of people. Often this process was temporary and, in iterations, a means of solving specific design problems in a large design project. In the design field, this can be sketches, 2D or 3D models, probes, prototypes, mock-ups, mood boards, different kinds of maps and more. Even Gantt charts may cause discussion and negotiation [20]. Studies of boundary objects and those using them have identified diverse types of boundary objects and highlighted some of the properties [21], such as modularity, abstraction, accommodation and standardisation. According to Levina and Vaast [21], researchers have also investigated what makes these objects effective. Such objects are described as tangible, concrete, accessible and up to date [21]. Listing these properties may be useful for recognising future potential boundary objects. According to Wenger [22], the design of artefacts such as documents, systems or tools is actually often about the design of boundary objects.

5.2 Earning the status as a boundary object

Susan Star [15] tried in 2010 to add clarity to the confusion that had built up around boundary objects after the introduction of the concept in 1989 [14]. Susan Star emphasised that one of the least discussed aspects of their original study [14] was that boundary objects 'are a sort of arrangement that allows different groups to work together without consensus' [15]. The same is said about the GIGA-mapping process [12]. In both situations, people seem to be able to work side by side with both overlapping interests and diverging ones.

An object's status as a boundary object may change and vary over time [19]. This means that even though a 'work in progress' GIGA-map might be a promising boundary object; it does not automatically claim this status if it does not provide the collaborative or boundary-spanning effects. Levina and Vaast [21] highlight that objects alone may not have a successful boundary object effect. It is the adoption, incorporation and 'ongoing use' of these artefacts that embed them in the situated practices of those using them. A teacher in design, commented a slight scepticism towards the notion that boundary objects themselves facilitate discussion if only 'put on a table with people around'. There is often a need for some kind of facilitation or communication linked to the objects.

5.3 Critical perspectives and limitations

As the artefacts are defined by the way they are used and not solely by their intrinsic 'metrics', Lee [19] argues that the term 'boundary object' seems too broad, explaining that other artefacts also 'live' in the space between different areas of practice. This point of view is also reported elsewhere [17, 24]. How the taxonomy of these kinds of objects should be is an ongoing discussion that needs further synthesis work [24]. Anyhow, it is the characteristics of the effects and dynamics around these boundary objects which in my opinion are of interest, and which have been the main topic in this paper. It is also important to mention that the different names and meanings of such objects can confuse transdisciplinary research.

Even though the term boundary object might seem imprecise and over-used to some, the insights of the phenomena it describes are, in my opinion, still valuable. The concept of boundary objects in collaboration relates closely to the way designers use 2D and 3D artefacts in interactive and iterative dialogue or conversation [23] with recipients, particularly in the design process. Once the artefact or boundary object is 'finished', there is no longer any gap of 'unfinishedness' to fill and continuing the dialogue for further ideas makes less sense. At this stage, it seems like the object changes status when there is no longer a need for collaborative input. It is then, at best, a piece of work to be admired and valued in other ways.

The effects described by Star and Griesemer, which led to the concept of boundary objects, show many similarities with effects observed in GIGA-mapping processes. These qualities could be investigated further. The divergent terminology in the description of such objects or phenomena is still up for debate, and not all varieties have been included in this paper. More work is needed to achieve a full overview.

6 CONCLUSIONS

A designer's work revolves around problem-solving and change-envisioning. Designers use maps, objects and prototypes as means of translating ideas, forms and visions into tangible or abstract and discussable platforms for change. Systemic design methods such as GIGA-mapping may be useful for different product development processes. GIGA-mapping could in fact be used when mapping out everything from business models, production floor activities, life cycle assessments, and more. GIGA-maps can be especially helpful when contextualising the environment of a new product before implementation, and when involving different knowledge perspectives in a project. The new product is, in fact, entering a system of relations, monetary flows, webs of organisations, and the natural and socio-technical ecosystem. Product developers should therefore to a greater extent evaluate the effects of new products brought to the markets, the environment and the society, and know the following consequences.

Having an overview of the field in which you are navigating can improve decision-making on complex subject matters, and GIGA-mapping is one way of obtaining that overview. When serving as an input for decision-making, the knowledge revealed through the GIGA-mapping process is crucial, especially when major decisions are taken based on the information in it. A comprehensive mapping process with external expert input can serve as a better basis for strategic decision-making and for envisioning of future scenarios.

Cross-boundary collaboration often faces challenges of silo structures, different terminologies, cultures and practices that cause misunderstandings or barriers that can be hard to overcome. Building on the theory of boundary objects, increased awareness of collaboration dynamics in design education can enable better collaboration across diverse fields. When one knows the characteristics of boundary objects, one might more easily employ these in various tools and templates to facilitate discussion and successful knowledge exchange in collaborative projects or product development work.

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NEVER TAKE TEAMWORK FOR GRANTED! A TUTORSHIP EXPERIENCE ON SOFT-SKILLS

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ABSTRACT
Collaborative design-based learning is widely employed within academic design education, being recognised as a valuable pedagogical approach historically rooted and yet well-established within the design studio pedagogy. However, this great learning potential may not consolidate if it is not well integrated into the didactics. From this initial observation in the context of the MSc Design & Engineering course at Politecnico di Milano the researchers developed a tutorship path implemented for a group of students along their entire master's programme, both in presence and remotely. The paper presents this action research which was conducted through the intervention and support of students in different key moments of their training. The tutorship on teamwork has been focused on providing activities to effectively perform initial team agreement, mid-term, and final evaluations (i.e., self, peer, and team assessments), along with constant support and coaching on team management. All these activities have been designed and provided in parallel to the design studios of the master's, meaning that each of them was related to real situations occurring during students' collaborative work. Qualitative data has been collected through a focus group organised with a group of 6 students at the end of the programme to evaluate the proposed path on teamwork. Four relevant themes emerged from data interpretation, which could inform teachers in the design of formalised paths on teamwork and soft skills. Additionally, the research contributes to wider discussion on soft skills development, with particular regards to teamwork.

Keywords: Culturally plural teams, design education, design-based learning, tutorship on teamwork

1 INTRODUCTION

Collaborative design-based learning is widely employed within academic design education, being recognised as a valuable pedagogical approach historically rooted and yet well-established within the design studio pedagogy. In numerous design schools, students - working in small groups - learn to design by designing together. With this setting, didactics provide a space for students to develop both hard skills related to design and soft skills related to more transversal domains such as collaboration, communication, work organisation just to mention a few. However, this great learning potential may not consolidate if it is not well integrated into the didactics. According to Savin-Baden and Howell (p.78) "few students come to higher education with well-developed team skills and to function in teams, they will need a range of skills and abilities that include interpersonal skills, active learning, team building and management, inquiry skills, conflict skills and presentation skills" [1]. Indeed, if it is assumed that students are already trained or prepared to work in teams, it could happen that they will work in teams without having the right set of skills and proper tools. In our context of Politecnico di Milano we observed that from the second year of bachelor until the final year of master's students are engaged with teamwork in the majority of design-based learning courses which are minimum one per semester. Despite the massive employment of collaborative learning a structured training on teamwork and collaborative skills is missing. As a result, students have to deal with the uneasy sides of collaboration by themselves (e.g., diversity, disagreements, different backgrounds, different abilities), getting frustrated and overcoming the issues not always in the most effective, sustainable, or inclusive ways. In this regard the role of what we defined as tutor could play a crucial role, creating a space of dialogue and reflection on the collaborations. Using facilitation [2] or coaching [3] [4], staff members could contribute to supporting raising awareness on effective approaches to teamwork. In the context of the Master's of Science in Design & Engineering (D&E), an interdisciplinary and highly international course, the researchers developed a dedicated path, called Tutorship for Teams (T4T). Even if the path was initially conceived to dedicate time to raise students' awareness on the importance of cultural

sensitivity in plural teams, it became more of a basic training and tutorship on teamwork, since the majority of students never received a formal training before. T4T is the first iteration of a path lasting the whole duration of the master's programme and entirely dedicated to teamwork. The paper presents the way T4T was implemented and evaluated. Qualitative data collected through a focus group with students are reported and interpreted to disclose the recurring themes emerging from participants' conversation.

2 METHOD

2.1 Tutorship for Teams (T4T): a transversal path dedicated to teamwork

As part of the teaching staff, the researchers structured a tutorship path in the context of D&E at Politecnico di Milano for a group of students along their entire master's programme between 2019 and 2021. T4T included activities addressed to different groups of students of D&E design-based learning courses. 51 students participated in all the activities proposed in the path. The fundamental idea underpinning the T4T design was to provide tutorship for students engaged in teamwork in the Design Studios, that were planned during the first three semester of the two-years master's. These semesters are dedicated to courses, while in the fourth semester students must carry out their internship and work on their thesis project. The activities proposed in the T4T were divided into two semesters (i.e., the first and the third) and developed in parallel to the Design Studio of those semesters (i.e., Product Development Design Studio 1 and the Final Project Work).

2.1.1 T4T first part: Seminar on Teamwork in the Product Development Design Studio 1

A seminar on teamwork was proposed to the students during the first semester of D&E, going from September 2019 to January 2020. This first activity was optative and opened to all the students enrolled in the Product Development Design Studio 1, that were divided in three parallel courses with different teachers. The professors of the sections presented the seminar on teamwork as an optative activity and one section decided to push student's participation by considering it in their final assessment. The initial activity was organised in October, after teams were formed, and there was a general presentation with the students (around 100) of the tutorship path for the first semester. The presentation, organised and done by the tutor (Author 1) was aimed at presenting the reasons and the objectives behind the whole path and introducing the scheduled activities. Then the second half of the meeting was dedicated to two activities 1) self-evaluation using the CATME scale [5] [6] and 2) the creation of a team agreement done collectively by each team and containing rules, roles, individual expectations, and contributions of all team members. During the first meeting the email contact of the tutor was shared with students, as the person to be contacted if a support on teamwork was needed. The second optative activity consisted in a private group review about teamwork with the tutor; teams of students had to autonomously contact her and set an appointment between November and December. Not being part of the teaching staff of the courses the tutor support was intended as external viewpoint and support. It was several times clarified by both teachers and the tutor that discussions during the teamwork reviews would remain private between the tutor and the group and would in no way be communicated to the course staff. This decision was driven by the context since the local education system is quite strongly hierarchal and therefore teachers decided not to directly interfere with teams' dynamics. During the 1-hour review, three main activities were proposed 1) individual self-evaluation using the CATME scale, 2) sharing of individual perceptions on teamwork and 3) the discussion and adjustment of the team agreement done collectively by all team members and the tutor. The participation to this second activity was modest.

2.1.2 T4T second part: Teamwork Module in the Final Project Work

The second part of the T4T was proposed only to the students in one of the sections during their third semester of D&E, approximately from September 2020 to January 2021. In this case the activities were proposed in the form of a mandatory Teamwork Module in the Final Project Work course, a design-based learning course where the tutor is part of the teaching staff. Due to the pandemic emergency, the course was blended until mid-October when, due to local restrictions, it became completely remote together with teamwork. The Module on Teamwork consisted of three main steps; the first was organised in September 2020 after the teams' formation. After a brief presentation of the module each team was required to create its team agreement. Then the second step was organised after the mid-term presentation in early November and in this occasion, students performed a self-, peer and group evaluation using the Teamwork Colour Matrix tool [7] and presented it to the rest of the team. The aim

of the activity was guaranteeing a moment of reflection for all the students and for each team to discuss and improve its organisation. After this step all the team had a review with the tutor which was completely dedicated to teamwork. The last step took place during the Christmas break, immediately before the final presentation, and it was nearly identical to the second step. The only difference was that students were required to deliver a final one-page report on teamwork. Based on the whole module, the tutor assessed the learning trajectory of each team and the soft skills acquisition demonstrated by the team throughout the course. This assessment was composed of a formative assessment, that was sent to each team in the form of a feedback, and a summative assessment, which was incorporated into the average of the grades of all teaching staff.

2.2 Evaluating the experience: a focus group with students

Qualitative data has been collected through a focus group organised with students at the end of the tutorship. The main objective behind the data collection was to highlight positive elements and critical points in regard to the tutorship proposed, to collect suggestions and, most importantly, to collect their impressions, perceptions and point of views on the activities proposed. At the end of the Final Project Work the researchers sent an open call to the 51 students that experienced the whole tutorship path, asking for volunteers willing to discuss their experience by participating in the focus group. People willing to participate had to fill an online form declaring their interest: 11 students answered the form and 6 were selected for the focus group. The participants were both males (n = 4) and females (n = 2), coming from 5 different groups of the Final Project Work course, all Italians and with a bachelor degree in industrial design awarded in an Italian University, which was Politecnico di Milano for the majority of them (n = 4). Focus group was based on methods described by Cardano [8] and organised online. A significant modification was to have only one moderator conducting the focus group, being also the principal proponent and the T4T tutor. The choice of having only one moderator was determined by the need to ensure students freedom of expression while telling their experiences and comments about the T4T path. Due to the trustful and direct relationship built between the students and the tutor throughout the T4T, the decision was to avoid any possible uncomfortable situation for the students such as having a professor or an unknown person listening to the discussion.

Table 1. Focus group discussion guide

Items to be discussed	Questions
1. Individual overall impression	Which is an image that represents the proposed tutorship path on teamwork?
2. Positive elements	What were the three most positive elements?
3. Critical elements	What have been the main critical points?
4. Expectations	What you would have liked but did not receive?
5. Suggestions	Do you have any suggestions for improving the path?

The focus group was composed by three main parts 1) an introduction by the moderator presenting the research and recapping the steps of the T4T path; 2) a guided discussion of around two and a half hours and 3) a conclusion by the moderator. The guided discussion, where the data collection took place, was organised as follow:

- the moderator posed the first question following the discussion guide (tab.1).
- left some minutes for the student to reflect and formulate their own answers.
- each participant was invited to respond to the question when she felt like it.
- after each person answered some more minutes were provided for all to add further comments emerged by listening to others.
- the moderator posed the next question and so on and so forth.

The whole discussion was monitored, and video recorded; the moderator took notes during the focus group and transcribed the records afterwards. The transcripts were then systematically reviewed; each segment of conversation was labelled in accordance with its emerging themes [9] and all labels analysed and clustered into four most recurring themes, described in the following section.

3 RESULTS: EMERGING THEMES

3.1 Generalised lack of formalised culture around teamwork

A theme that strongly emerged from the dialogue is the recognition of a lack of formalised culture around teamwork. Indeed, students are very much accustomed to teamwork from the first years of bachelor, but they had never been formally trained to it.

> *...we should be used to talking about groups, it should be almost natural. In the sense that certain dynamics should have been dealt with even before the master's degree because we did two design studios a year, so there was no lack of opportunities. When I got to the fourth year, I personally realised how naive I was, because the project came out of the group, and to have never spoken, except in some very critical situation perhaps when everything was almost in shambles and you had to talk, is almost absurd.*

The acknowledgement of this lack of culture, is also pointed as one of the main causes of the initial mistrust, low engagement, low participation to the T4T path. From the conversation emerges that students initially participated only because they wanted to please the teachers, especially when they understood that this activity would have been positively evaluated by professors.

> *It's better if we do it because apparently this will be considered positively by the teachers and it doesn't cost us too much, let's do it but if it were up to us, we wouldn't have done it.*

Despite having work in teams for years, it emerges that students in their final years perceive themselves as “highly experienced on teamwork” and therefore initially underestimated the T4T path as a fruitful learning experience.

> *We treated it more as a "fill in a questionnaire" activity as if we were in junior high or high school, only later we took it a bit more seriously.*

Interestingly, by participating in T4T students realised they were not used to talking about teamwork and saw it as something that can be discussed, questioned, and improved. In their view the activity proposed supported the teambuilding because making rules and roles explicit (i.e., team agreement) guaranteed higher accountability of teammates. On the other hand, the structured moments for sharing their individual perceptions about teamwork and teammates were considered awareness-rising, contributing to achieve better team results, to improve teams’ dynamics and communication.

> *I connect directly to this last thing that GL said, the awareness was one of my positive points [ndr in evaluating the path]. To start talking about teamwork, I think it is the most important part of the path.*

3.2 Collaborative skills as a basic knowledge

Despite the lack of formalised culture and knowledge around teamwork, students referred to collaborative skills as basic knowledge for designers and, most of all, for design students.

> *As designers, as people who work in groups all the time, the group world should be open to us, it should be something extremely natural, which it is not at the moment. We will probably talk about groups in a mature way in a few more years, because we are late.*

The excerpt opens another sub-theme strictly related to the concept of teamwork as basic knowledge, namely the fact that T4T path should have been present within bachelor’s programme in design. Throughout the conversation, participants repeatedly mentioned the need to train students and provide basic tools for teamwork starting from the bachelor’s programme.

> *Going back to a point we discussed earlier, I know that [ndr in D&E] it was done for the master's degree because it is more international, but I would have already introduced this method of team working at the bachelor's degree.*

All the participants suggested to propose some type of structured activities on teamwork starting from the first years of designers training, because the current situation is that students learn to manage teams without guidance and therefore not necessarily in the most adequate way.

> *Even though we had been working in a group for five years now, it was always our own thing within the group, and everyone developed their own ways of managing it. In this way [ndr with T4T], just by talking about it, by the fact that teamwork emerges as a situation, as a discussion, it just gives you awareness and makes you say "ok, maybe there are more structured and functional methods to work in groups" [...] So just having done a course like this opens your mind for many aspects, for sure.*

Another interesting element identified by students is that, in their experience, teamwork and collaborative skills were considered fundamental knowledges in other contexts such as in the work field

(e.g., companies, career service of Politecnico di Milano) or in their extracurricular activities (e.g., theatre courses, circus school).

> *I wanted to comment on the fact, as FF already said, that in our university courses there were none on teamwork before. And I totally agree! I've already had experience in doing activities of this kind when I took part in workshops with companies [...] Not having done courses of this kind before at university is paradoxical, it's strange, at least in our course, since in any case in design we will always work in teams.*

3.3 Engage students: mandatory vs optative activities

On several occasions, students have questioned and expressed opinions on the most appropriate way to deliver teamwork courses or paths: a recurring theme concerns the comparison between compulsory or optative activities. The group did not agree on a single opinion, but their experience in T4T provides an understanding of advantages and disadvantages of both modalities. For the first optional part of T4T, students demonstrated lower engagement with the proposed activities because they saw them as "another thing to add to the list of things to do". They really did not understand the support they could have gained from the path, but rather participated, as previously mentioned, to "please the teachers" in the hope their participation would have considered as a plus in the final assessment of the design studio.
In this regard, what we labelled as "cornering" from teachers' side (i.e., rising the final grade for those that participated in the T4T) emerged as a controversial aspect in students' experience. From one side students criticised when the teachers applied gimmicks.

> *The professors had told us "this activity will then be considered in the final assessment" and I remember [...] my group didn't really like that.*

On the other side because of this "cornering" students decided to participate in the T4T activities, demonstrating that in an assessment-driven model of education this could be an effective.

> *The first year our group did it under pressure from the teacher because she said she would give us an extra grade if we did it. The only reason, honestly, the only reason why we did it.*

Indeed, in the second part of T4T, when the activity was integrated in the course and mandatory for all, the students participated and appreciated the majority of activity proposed.

> *I really liked this activity because of the clarity it gave me and the group, especially in the second year, where it was no longer optional, but part of the course.*
> *Paradoxically I preferred this year where it was a part of the course, it was a compulsory part, but we didn't even feel it too much because it had to be done.*

After several contribution on this theme, one insightful idea emerged.

> *The fact that it's optional gives you a bit of an impression that it's not key to the project, to the group, and so on. Utopianly, it should be optional in my opinion. The willingness to participate should be something that comes from the group itself. And again, here I come back to the fact that this is totally our fault […] If at our age we need an activity to be compulsory in order to do it, then something is wrong. Obviously from a practical point of view [ndr a mandatory activity] is the only thing possible, because if it was only optional, we wouldn't have participated and therefore we wouldn't even be here talking about it probably.*

3.4 The role of the tutor

The role of the tutor and the students-tutor relationship appear to be a crucial factor in the success of T4T. From students' perspectives, a key turning point for the path was the moment when they understood they could trust the tutor, as a person willing to listen to them, to help them in solving their team issues and to support them in improving teamwork.

> *It's good to have an impartial person, who can listen to you, ask you questions, let you open up. We understood the fact that you were impartial, but after a while... it took us a while... I have to tell you, in the first year first semester we still thought you were a bit of a professor, your role wasn't very clear [...] then I opened up a lot more and I think my group mates were a lot more relaxed to talk.*

Another interesting fact is that students appreciated the tutor being an "external-internal" person. In their view the tutor should be seen as a person not involved in the assessment but knowledgeable about their projects and course dynamics.

> *In my opinion it is fundamental that this role is covered by someone internal-external, someone who knows what happens in the course, who is present in the course, who knows for example what happens in your relationship with the professors but who is not a professor, someone who does not evaluate you.*

Moreover, to build this trust, it was crucial that the tutor had a direct experience in the course as a student.

> *The thing you said at the beginning when you introduced yourself is "I come from your experience, I've been through what you've been through, I'm like you with a bit more experience, I'm a person who seeks*

dialogue with you, I know what you're going through and what you're going to face". So, you became an authoritative figure as a result of the experience you had [...]

All the students denied the possibility to be evaluated on the teamwork and soft skills component of their learning experiences in design studio. This is particularly interesting because no one considered that this already happened in the Final Project Work, where the tutor explicitly evaluated teams on this component.

4 DISCUSSION

The engagement with the focus group discussion was very high and all the participants contributed to it, also building their reflection on the contributions of others. The existing trustful relationship between the moderator (i.e., tutor of T4T) and the participants contributed to a calm, sincere and constructive atmosphere. The main contribution of this paper is to provide students' viewpoint on teamwork in design education at the end of their academic career and to address their perception on the implementation of tutorship path for teams within design-based courses. The overall evaluation of path was positive, even though students' engagement within T4T was initially low due to unclear understanding of the general aim behind the proposed activities. After the initial distrust, the activities acted as an awareness-raising factor, since it was the first time for all that a formal training path on teamwork was offered within an academic context. The four relevant themes emerged, revealed that much more could be done to improve formal training on teamwork. The main limit of the research is that the emerging themes should be extended and validated through further focus groups and in-depth interviews with students, possibly with reference to multiple institutional contexts. Beyond that, the described themes should be considered as a starting point to open some relevant debates that future research should address to foster the formalisation of training paths dedicated to teamwork in design institution that employ the collaborative learning approach. In our view, one of the most important results of this research is that the role of teamwork tutor emerges as a key figure within the path: further studies could provide deeper understanding of the characteristics and possible training for this role.

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TEACHING DESIGNERS' ENTREPRENEURSHIP: MAPPING STUDENT DESIGN PROCESS OF LEAN START-UP AND EFFECTUATION

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ABSTRACT
Recent studies show entrepreneurs tend to prioritize either the business or the design side of their start-up, as combining design and entrepreneurship may represent a dual focus and tension in the development process. However, it is commonly recognized that both needs to be developed to become a proficient design-based entrepreneur.
In the following paper we examine an exemplary case of design-based entrepreneurship. We study a case of how industrial design master's students from Aalborg University, may develop an integrated design and entrepreneurial approach to solve a dual design and business challenge. By using theories and a mindset of effectual reasoning combined with the lean start-up approach, a design based entrepreneurial approach was mapped out.
We use this case not only to study similarities and differences between the design approach and the entrepreneurial approach, but also to understand key elements in how to integrate on one another in an educational setup.

Keywords: Design education, effectuation, lean start-up, design processes

1 INTRODUCTION

Within the last decades entrepreneurship has received an increasing focus and interest in practice as well as in the university curriculum. Research shows many creatives and designers are more likely to become entrepreneurs at one point in their career [1]. However, as Tötterman mentions, *there is evident that there are many design entrepreneurs who lacks the needed business competencies in relation to administration, marketing and operations* [2]. This provides a challenge of how to integrate the trades of the entrepreneurial discipline in the design education.
In design education, there is a long practical tradition for immersing in design projects that evolve around physical, emotional and social aspects. Aspects such as user research, materials, form and production are fundamental pillars of many industrial design educations. However, to become a skilled designer today, it is also important to consider the business context, which a design is to emerge in. However, studies show combining design and entrepreneurship may represent a dual focus and tension in the development process. Entrepreneurs tend to priorities' either the business or the product side, despite it is commonly recognized that both needs to be developed to a matured degree to become proficient design-based entrepreneurs [3].
This study builds upon a recent educational course [4], which emphasizes the execution and action aspects of the design process. The students are given a challenge to design, produce and promote 20 units of any product in 15 workdays and at the end sell it at a fair. From this layout we deploy an information-oriented selection strategy, to identify and examine an exemplary case of an integrated design and entrepreneurial development process. We deploy such purposeful sampling, in which we select an information-rich case, to enlighten the question of interest, rather than representing a broader population [alike 5]. Our aim is to select an exemplary case of design-based entrepreneurship to map out activities and processes, that may help integrate entrepreneurial elements into design education. Hence our study aims to understand how to integrate entrepreneurial elements in a design process.
This paper show that Industrial Design Engineer master's students can act as entrepreneurs and utilize both an entrepreneurial and design-based process by applying simple principles and methods from the effectuation approach [6] and lean start-up [7]. By doing so, we force designers away from a primary

user and desirability focus (expressed as thought representations e.g., sketches, renderings, posters), and instead focus on *doing* realisable design, thus giving designers a feeling of ownership of all aspects of their product including design, production, business, market and resource issues. To succeed in this course, the students have to integrate elements from both Design Thinking with elements from Effectuation and lean start-up. The study shows they may be able to operate confidently within design execution phases, by doing and shaping the future instead of trying to predict it (Effectuation); as well as making quick market research checks and pivots (lean start-up). Effectuation is a direct contrast to causal logic, where you in the beginning already set a goal and the process to achieve this goal is carefully organised in accordance with a set of given resources, but this cannot be applied in Effectuation processes, since it is inherently characterized by uncertainties and risks [6].
In the following we will layout the educational setup, then provide an overview of the students' design based entrepreneurial process overview.

2 THE EDUCATIONAL SETUP

On the 2nd year master's of Industrial Design Engineering the students attend this course, where the learning goal is to further accelerate product development and drive business focus, hence integrating and consider the business/entrepreneurial aspects in the design process and outcome [4]. The task is given: *"Design, produce and promote 20 units of any product in 15 workdays and at the end sell it at a fair."* [4]
The rationale behind such task was to make students consider both the design, production, business, market and resource aspects already from the beginning. The idea behind the limited time of 15 days, was students were required to develop these aspects in parallel and or rapidly iterate between them. In the following we first give an overview of the process, to discuss and later reflect upon how it may contribute.

3 DESIGNS BASED ENTREPRNEURIAL PROCESS OVERVIEW

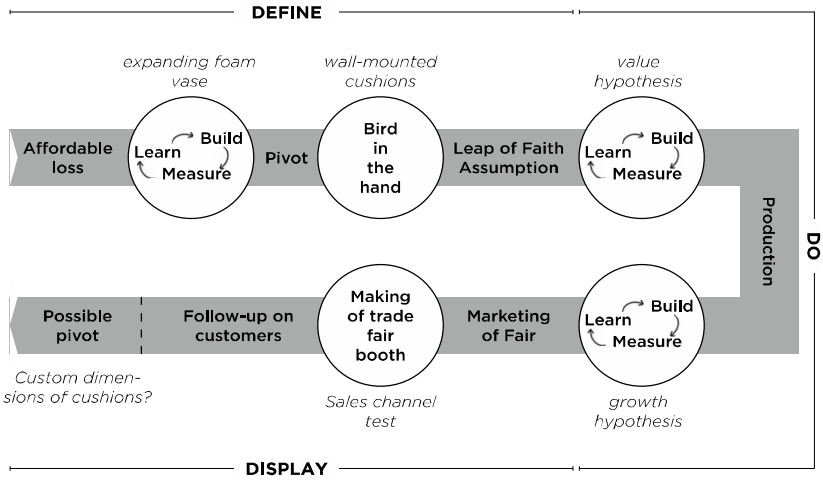

Figure 1. Define-Do-Display process overview

The above figure illustrates the overall process overview, of which it is clear that the build-measure-learn feedback loop [7] is frequently used, but in three different scenarios and purposes. This, together with the rest of the development process, will be addressed with exemplary dives in the following sections.

4 HOW A NATURAL DESIGN ENTREPRENEUR APPLIES METHODS FROM EFFECTUATION AND LEAN START-UP

4.1 Fail early, fail often, fail forward

In the beginning of the project of making 20 units of a product that was supposed to be sold on a fair within 15 workdays, it was clear that the team had to commit to an Effectuation approach [6] and develop an actual MVP (Minimal Viable Product) [7] as fast as possible. An MVP is a core component of lean start-up and is part of how to figure out the problem that needs to be solved to begin learning in the early phases.

By quickly and early on in the process committing to the build-measure-learn feedback loop [7], the team only ideated shortly on possible products to be build. Build-measure-learn is one of the central principles of lean start-up and is in short *"a framework for establishing – and continuously improving – the effectiveness of new products, services and ideas quickly and cost-effectively"* [7]. In practice it revolves around building something small for potential customers to try and test followed by measuring the feedback and their critique to finally learn from it and then continuously repeat the process to ultimately deliver precisely what your customer wants and needs. Instead of endlessly generating one idea after another, the team chose an idea in which was cheapest, easiest and fastest to make an MVP of. The team wanted to tap into the DIY-trend at that moment and quickly went on Pinterest to find pictures of a PU-foam vase which met the criteria of being a 'designer-product'. The goal was to be able to produce a product fairly cheap and fast while in the end possibly being sold at a higher price. A quick and dirty prototype was made. Unlike in e.g., the Design Thinking process presented by Stanford d.school where stages like *emphasize, define* and *ideate* comes before *prototyping* - which is typically not until in this stage that user involvement is considered in the product development. Of course, in design you also evolve the product development through various iterations, and it is recognized that 'prototyping' is also applied early on in the design process, but language wise it is called something else – for instance sketches, mock-up's, wireframes and for another purpose.

Producing an MVP in the early phase made it possible to move quickly onto validating the value hypothesis [7], which was performed by using both a digital platform (Instagram Stories) and an analogue multiple-choice test to get as much data as fast as possible. The first mentioned was made by three so-called 'Stories' (a feature that lets users post photos and videos that vanish after 24 hours). The first two Stories presented the vase in its intended context with a short description (key-selling-points), the third and last one invited the viewer to make a decision on the Story – the viewer was asked to vote either 'yes' or 'no' on whether he/she could imagine owning a vase like that. 140 people saw the Stories and 92% voted 'no'.

Figure 2. Screenshots of the foam vase used to probe the customers

The team learned from the data collected, which clearly did not show an immediate interest in the product but gave the team an idea of what kind of people the analogue multiple-choice test should target. When students post educational work on social platforms. They are confronted with 'real world'

feedback, which may of course create both positive effects of students *feel* ownership of their design, being held personally accountable, however this may also negatively affect the safe learning environment.
The multiple-choice test verified and supported the same data from the digital test but gave the team additional statements about why the majority of people voted 'no'. Considering the time available at the moment, it was clear that the expanding foam vase was not worth doing further developments on, and the team chose to make a pivot [7], but with the 'failures' from the first build-measure-learn feedback loop in mind. Making a pivot is a *"...structured course correction designed to test a new fundamental hypothesis about the product, strategy and engine of growth"* [7]. From the first feedback loop, the team learned about how important an MVP is and that the answers received can never be better than the quality of the MVP.
Within three days, the team already went on to try and make another product from scratch, unlike in Design Thinking [8] where the potential reframing-process typically takes much longer time and the creation of a Design Thinker's correspondent to an MVP, a so-called prototype, would be made much later in the process. Besides these differences, there is also the difference between what the purpose of an MVP is contrary to a prototype (as known from Design Thinking Paradigme) [8]. An MVP is mainly used for business intentions whereas a prototype is mainly used to test functions, features and proof of concept.

4.2 Validating a Leap of Faith Assumption (LOFA) by selling the product without even having it yet (call to action)

The Leap of Faith Assumption describes the riskiest assumption there is about an idea [6]. It either breaks or makes your business. There are two kinds of assumptions, which are necessary to understand: *value hypothesis* and *growth hypothesis* [7]. A value hypothesis tests whether or not if a certain product actually delivers value to the potential customer, meaning that it determines if a customer should adopt a product into their lives or not [7]. A growth hypothesis comes after you have managed to provide value to the customer with a product and is about how customers find your product and how the company behind it will grow once customers begin using the product [7]. After the team found out that the expanding foam vase did not work as intended, they used the bird in the hand principle [6], to get a grasp of what was mostly reasonable to do at that moment. The team listed the three categories of means: (1) *Who they are*, (2) *What they know* and (3) *Whom they know* – which created a lot of possible imagined ends. By forcing the team to think with an effectuation approach, the set of means listed allowed goals to emerge contingently over time from the varied imagination and diverse aspirations of the team members and the people they interact with [6].
The team suggested using one's father's workplace (a textile and foam factory) as a way to get cheap raw resources (fabric, cold foam and buttons), and this resulted in a spark in the other team member suggesting producing a wall-mounted cushion which he once had in his apartment. Instead of making a lot of assumptions of whether or not it was a good idea, the team decided quickly just to do something. And that something was to re-activate the online sales ad of which one of the group members once had and was now granted permission to start a conversation to everyone who firstly approached him and asked if the item was available. At that moment, the value hypothesis was already validated by a picture of a wall-mounted cushion that the team did not even have produced yet, since the team sealed the deal with the majority of the people who were asked, if they were still interested in buying the product. By doing this, the risk of the assumption about if there was a market for it or not was indeed removed, and the team could focus on producing the product in 20 units without worrying about the investment returning to them or not.
In retrospect, the team learned that the customers who said yes to buy the product were 'existing' customers who already showed interest in the sales ad back when that group member first put them up as his own private sales ad in the area of Aalborg, Denmark. To test how new customers would discover the wall-mounted cushion (growth hypothesis) [7] they took new pictures of the newest produced cushions and made several new sales ads on the same digital platform as before, but in different locations too. Aarhus, Odense and Copenhagen were chosen because the team members were often at those cities anyways. It was about getting out to as many people as possible to sell 20 units as fast as possible, because they knew, that they would not sell any at the fair. This was based on the assumption of that the kind of segment the online sales ad was from, would most likely not attend the fair at the fixed opening hours and location. In contrary to the effectuation approach and lean start-up, where probing early on

by involving the customer as soon as an MVP is made and trying to figure out whether or not there is a market, in Design Thinking the bird in the hand principle has some similarities, just in another matter. Designers uses their own understandings, experiences and preferences directly in the conceptualization process [9]. Furthermore, designers often reuse knowledge, solution principles and experience from previous projects as their starting point of reference for creating new and innovative solutions in a totally different industry [9]. Though there is a difference in how and when the value hypothesis is applied in Design Thinking as mentioned in section 3.1. However, there is a clear difference when it comes to growth hypothesis, which is not typically contemplated in Design Thinking, because it is more about problem solving at its core [4] than considering the business development aspects.

4.3 Finding the right market, channel, and price is crucial

Some of the reasons for not continuing the expanding foam vase project was that the team did not identify or hit the right market for it at first, and maybe also chose the wrong channel to display them and lastly, they also struggled with the RRP (recommended retail price) of the product. Most of the answers from the multiple-choice test showed that most people would not sacrifice that much money on a vase they could make themselves with even less money. By having these early experiences of a failed project in mind, the team went more strategically with their wall-mounted cushion project and hit correctly with both the right market, a promising sales channel and the RRP was neither too high nor too low. By using the bird in the hand principle (*What they know* from a former sales ad of an almost identical product as the newly produced wall-mounted cushions) together with the affordable loss principle, the right market to target was easily obtained. The bird in the hand principle was also used in terms of the first category, since one of the team members had a lot of experience and professional competencies within retail sales from his many years of seniority within the field. The understanding and experience he had, saved the team from a lot of unnecessary time spend by 'controlling the failures' and made a working business strategy fairly quickly and without a bigger investment. It was truly an effectuation approach they managed to use. Design wise it was visible on the finished product that the quality and finish of the product did not exceed what the two group members could manage and were capable of at that moment when it comes to manufacturing and production, but instead reflects the level of execution. 20 pieces were produced fairly quickly without any need of learning new production methods, since they used the competencies and know-how they had, instead of spending time on production methods they have not have any hands-on experience of before. For instance, none of the group members was an expert in sewing, so the corners of the cushions were just folded like gift wrapping and the fabric was clipped to the back of the cushion. These were well-considered choices, considering that it was not the *normal* way to upholster such a furniture accessory, because if the team chose to do so, the time and money spend on the cushion would grow exponentially and thereby also affecting the market and RRP, whereof they knew worked fine without doing so.

5 CONCLUSIONS

This paper is an example of how Industrial Design Engineer master's students can achieve a successful combination of effectual reasoning and lean start-up theories. Working with all these kinds of approaches in coherent with each other but knowing when to use what and to understand the differences and similarities was the most challenging part of the whole process from idea to finally selling the units. For instance, an Industrial Design Engineer is used to call the people that they design for as *users*, while in lean start-up they are called *customers*. They are to an extend the same person but interpreted in different ways. The word 'user' is in Design Thinking understood as someone who uses something and in the world of lean start-up, the word 'customer' is considered as someone who purchases something. This was also experienced from the beginning of the project till the end, whereas instead of seeking a problem to solve for a user, as one would typically do in Design Thinking, it was determined to seek for business potentials to target specific customers with the intention to run a feasible business.

The basic of both is innovation and looking at a methodological level they both also seem the same, in terms of first come up with an idea, then test and show it with/to others, prototype it, make sense of the feedback and finally adapt it until it solves the problem.

It is not because Design Thinking does not have business elements in it (e.g., the 6th phase 'Implementation') but the focus is more on the user and desirability aspects, making many design products a bit detached from the business reality while in Effectuation and lean start-up it is about retaining current customers' businesses and solving immediate problems by familiarising through

building, measuring, learning, repeat. Furthermore, it was also clear that one of the biggest differences of Design Thinking vs. effectuation approach and lean start-up is that the two last-mentioned are much more in the 'proof of business' stage than Design Thinking being more in the 'proof of concept' stage. But yes, there are many similarities as well, for instance the passion to understand how people use certain products or services in their specific environments, and then testing concepts through rapid prototyping and learn from it. Whether you choose to use the language given in Design Thinking, Effectuation or lean start-up they all build on the same foundation about generating revenue with an innovative new product or service that functions flawlessly and solves human problems.

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OLD WINE IN NEW BOTTLES – AN ALTERNATIVE DIDACTIC APPROACH TO TOOLS USED IN FASHION DESIGN

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ABSTRACT
Design disciplines in general are challenged to foster alternative solutions towards a green transition of the industry. This naturally effects the design educations where the majority of curriculums include various learning objectives regarding sustainability, circular economy, re-cycling, etc. However, in this paper, we argue that many of the traditional tools and skills already inherent in the curriculums have the potential to promote a green transition provided they are introduced differently. Using well-known tools and skills in alternative ways is however challenging as the way in which their use is articulated and presented by lecturers determine the way in which the student implements and makes use of the tools. This article explores whether and how an alternative use of well-known tools in a fashion design context can beneficially contribute to increased product awareness among students and thereby support a sustainable development of the fashion industry. We suggest using the professional tools "line-up" and "collection plan" as anti-poles for the creation of a space for critical reflection. The anti-poles respectively address fashion as dreams and fashion as products. Fashion is a very visible part of consumption. As a concept that involves planned obsolescence, it is a major sinner in polluting the environment. Consequently, fashion design provides a relevant case to explore whether well-known tools and skills submitted through an alternative didactic approach, predominantly through articulation, can contribute to foster design students' ability to contribute to sustainable development in design and engineering education in general.

Keywords: Critical reflection, well-known tools, green transition, didactic approach, fashion design

1 INTRODUCTION

Institutions, organizations, and researchers within the realm of fashion predominantly agree that the fashion industry faces a paradigm shift towards a green transition. Time has come to leave the fast fashion system established in the 1990s with its one-eyed focus on sending endless numbers of cheap garments to the market in a continuous stream that promotes product detachment and frequent replacement resulting in piles of products that are under-used before they are sent to landfills. The good news is that several companies have embarked on the sustainable and circular journey. Fashion design curriculums in general have an intensified focus on sustainability. Policy makers worldwide set goals for the industries to reduce or stop harmful influence on the environment. Consumers are becoming increasingly aware of acting more sustainably when it comes to garment consumption. However, there is still a long way to the full green transition of the industry. There are numerous obstacles to a green transition; the fashion industry is paradoxically rather conservative in terms of new approaches and alternative business models. It is predominantly trend-led and profit-oriented with an overall linear value chain. On top of that, the take-back and recycle systems are still in an early development phase.

Not only is the traditional mindset in fashion design exposed to necessary disruption. Product design and engineering disciplines in general are currently faced with a demand to think differently in order to contribute to a green transition of society. Thinking differently requires us to reconsider what we usually do and to change our mindsets towards alternative goals approaching them in other ways than usual.

It can be beneficial to look at the realm of fashion design as a case study Partly because the concept of fashion with the notion of impermanence, rapidity, and an interminable succession of accumulative obsolescence in the products offered to consumers permeates the consumption of products in general.

Lipovetsky [1] uses the concept of fashion and its ostensibly persistent pursuit of novelty to present his construction of a transformation from post-modern to 'hyper-modern' times. A transformation he interprets as *"a 'society of fashion' restructured [...] by the technologies of ephemerality, novelty and permanent seduction"* and continues to describe as *"a world of seduction and ceaseless movement, whose model is none other than the system of fashion"* [1: 36]. Additionally, the practice of fashion design provides a particularly interesting case as it continuously distinguishes and navigates between the intangible concept of fashion and the tangible clothing products [2].
As fashion design educators and researchers, we find it highly important to influence the industry by the way we develop the curriculum and teach the fashion design students. It may be that the chances of influencing the processes in design and product development are few. Nevertheless, we provide the future designers with skills and competencies that allow them to contribute to the transformation of the system whenever it is possible. We aim to give the future designers an expertise that can be utilized to its full potential regardless of whether they are working in companies that are preparing a systemic shift or companies that are much longer on this journey. Thus, this paper seeks to initiate a discussion about ways in which well-known fashion design tools such as "line-up" and "collection plan" can be used didactically in our efforts to prepare the students to contribute to sustainable development of the industry and thereby a green transition of society.

2 PRODUCT FOCUS IN AN EXPERIENCED REALITY

In "The Earth Logic Action Research Plan" Fletcher and Tham's objective is to radically change our mindsets towards a green transition by placing the Earth before profit, demanding a systemic change before it is too late [3]. They build their arguments on an awareness towards resistance to paradigmatic change, suggesting that we think of fashion not only as garments but as *"new relationships between people, other species, artefacts and technologies* [3: 14]. In relation to this, we emphasize that in a fashion context it is rarely the case that fashion is experienced as pure garments. Fashion is concepts, dreams, style, trends, etc. Therefore, we suggest establishing what we call a product focus in an experienced reality. Product focus is about being preoccupied with the individual product in the lived and experienced reality and critically evaluate the justification of every single product that is designed and developed.
Using a thorough consideration and reflection on the value of each product in relation to the intended use and/or user as our starting point, we aim to provide the future designers with a space for critical reflection. With this article, we want to explore and discuss the possibility of taking the well-known and often used tools and techniques "line-up" and "collection plan" from the fashion design education and industry and turn them into tools for contemplation and systems change. Drawing on Lehrdahl's framework [4] illustrating the movement from the abstract to the concrete, from intention to product focus, we suggest that a dialogue and conversation about the conceptual idea of a product (the line-up) versus the concrete and real product (the collection plan) will foster students' critical reflection and thus contribute to a systemic change of design and product development in the fashion and textile industry. Thus, the point of departure is to address and pinpoint the somehow abstract intention, creating a space for critical reflection towards the concrete garment or product with the aim of supporting sustainable and responsible consumption and production as expressed in the United Nations Sustainable Development Goal number twelve [5].
In his seminal work on experience and education, Dewey discusses traditional versus progressive education arguing that critical examination of underlying principles must form the starting point of ways in which we develop a new mindset for our teaching [6]. His work is still highly relevant since we experience a time where we are forced to change what can be understood as a traditional way of educating fashion designers into a new and still unknown territory of a greener industry of which we can only begin to grasp the contours. In our considerations, we want to acknowledge that fashion designers, as other designers, are practitioners. Many practitioners in the field of design probably perceive themselves as reflective practitioners. The process of knowledge production, which takes place in practice, is described by Schön as "a conversation with the material of a situation" where the practitioner reflects in and on practice [7]. The challenges are that the material of a situation in relation to sustainable solutions is about creating a space for dialogue between the untrodden and unknown territory and the materials. The designer is the agent reflecting in and on practice and in a context where strategies and other practitioners also play a role. This paper is speculative as we debate whether we can use well-known tools – in the specific case line-up and collection plan – to create a space for dialogue

that promotes the conversation with the material of a situation and thus contributes to creating the required new mindset through increased critical reflection by educators as well as students.
Karell and Niinimäki argue that fashion designers traditionally are seen as *"translators of creative ideas into profitable products"* but also acknowledge that *"design can influence numerous aspects in the production and consumption of products"* [8: 2]. In a Finnish study with 31 respondents, including designers from sustainable-minded clothing companies and among them a number of micro companies, the most significant barrier mentioned for contributing to 'sustainable strategic (design) decisions' is lack of knowledge [8]. While we agree that knowledge is important, we wish to point to the possibilities embedded in connecting a shift in mind-set to the traditional tools and techniques used by fashion designers. That is, the knowledge that stems from professional skills and tools. In the following sections, we introduce the line-up and the collection plan to exemplify such tools that we see bear the potential to be applied in a different way didactically.

2.1 Line-up

In fashion design education, a line-up is a communication tool consisting of an assembly of several fashion drawings illustrating the fashion concept in a visual and storytelling way. The design brief for most fashion projects at VIA Design & Business includes the line-up as part of the student's solution and presentation of the project and generally outlines a minimum number of outfits that the project and thus the line-up (solution) should consist of. As a communication tool, the line-up provides a quick-to-grasp impression of the fashion collection, the design universe, silhouettes, and aesthetics. At the same time, however, the line-up supports an implicit maintenance of a traditional view of illustrating a collection, and there is a risk that not all the products in the final collection will be considered in-depth. This may cause the designer to fail to evaluate the value and justification of the individual product in the real world and focus on the value of the overall impression instead. Thus, inadvertently creating products that do not capture a user. The maintenance of this traditional view of a collection predominantly derives from the lecturers' introduction of the methods, which thus influences and governs the students' solutions. Students are less likely to be innovative in their collection development if the lecturers maintain and communicate their traditional perception of a collection.

Figure 1. A line-up by student Louise Kristiansen, VIA Design & Business, 2020

2.2 Collection plan

A collection plan – or range plan – is a more schematic tool, which is applicable both as a business tool, as a strategic tool, and as a structuring tool to support the design universe and the aesthetic concept. The collection plan illustrates and communicates each product in detail in terms of form, shape, materials, colours, etc., making it possible to address each product individually and evaluate the characteristics and environmental implications of each product. At the same time, it can be used to evaluate the value for the intended user, not only as part of a concept, but the relevance and applicability of each product in itself. The collection plan can support a critical reflection of the justification and necessity of a single product. Is it just there to 'glue the collection together', or is it actually relevant and value-creating in itself?

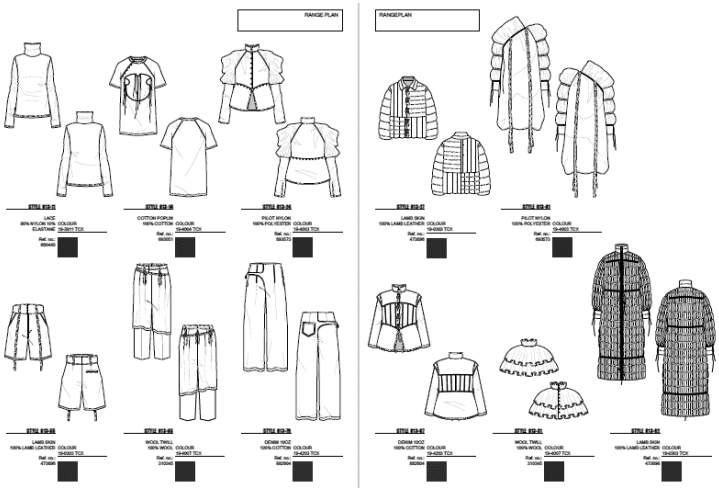

Figure 2. A collection plan by student Louise Kristiansen, VIA Design & Business, 2020

Articulating the space between line-up and collection plan as a space for dialogue between the dream world of the fashion industry and the real world of the users' interaction with the actual clothing products is an attempt to create a space for critical reflection. Addressing each products' life cycle and ensuring that each product both enters and leaves the world in a responsible and sustainable way will inevitably contribute to sustainable development of garment design. It is additionally recommendable to understand and explore use niches as a path to create product attachment, often emphasized as a contribution to a more responsible and sustainable fashion product consumption.

3 EXEMPLIFYING CRITICAL REFLECTION

In this section, we will exemplify the space for critical reflection between two companies' use of narratives and the actual product range. We have selected two companies that both work with alternative approaches to garment design compared to more traditional ways of building a fashion collection. Their mind-set and approach are not unknown but also not widespread in the fashion industry. Both companies are niche companies demonstrating alternatives to traditional collection building by having a limited product portfolio and thus an increased product focus. They have developed business models and strategies which are alternatives to the traditional and still dominant fast fashion approach to fashion design, and both companies are financially sustainable. The two companies actively use critical reflection in their design development. None of them specifically accentuates line-up as a used tool, instead they highlight a strong narrative and a conscious attitude as their strategy for how and why they make clothes, and then they use the collection plan as a tool for critical reflection and product evaluation. Though their business concepts, collection structures (plan) and thus design process are different, both Andersen-Andersen [9] and Week of Wonder [10] employ a product-focused approach. This derives from their strategic dispositions with sustainability as an anchoring point in their business models; both from an economic as well as from an environmental point of view. Both companies aim for the paradox of designing for a diversity of segments with a limited number of products and product groups. In this way, they counteract the dominating approach in the industry - and especially the fast fashion industry – of designing and developing numerous products that may or may not appeal to the users.

Andersen-Andersen works with longevity understood as durability – material, manufacturing, form, and styles that are in the collection several years, and they acknowledge that development takes time. They design and produce knitwear where they have created their own niche of traditional, sailor-inspired sweaters and blouses. Wolf, CSR Manager of Andersen-Andersen, describes how the long-term and set collection plan guides the development of new products. *"Our products are designed for longevity. We offer the same items to the customer year after year, and the development of new styles or colours are*

a time-consuming and strategic decision" (quote from interview conducted Jan 2021). This strategy has certain implications. An example is the lack of emphasizing additional sales and a careful selection of retailers that acknowledge Andersen-Andersen's values.
Week of Wonder similarly works with longevity in the form of durability in material, manufacturing, form, and aesthetics. Styles are repeated and kept in the collection for more seasons, however, in a variety of material options. All products are made-to-order to ensure that each product is produced for an intended user, thus increasing the probability of product attachment, and avoiding sale and reduced prices. Vestergaard, CEO of Week of Wonder, clearly states how the development of the collection plan governs the methodical and strategic approach to the development of the collection. *"I evaluate the applicability and achievement of needs in each product type in relation to my clientele before working with the aesthetic expression"* (quote from interview conducted Jan 2021). As Vestergaard's sustainable approach partly includes a strategic decision to develop only few styles to create a collection that will hit different types of women, she emphasizes the importance of her initial work with the collection plan. We contend that an increased preoccupation with and focus on the individual product and the interaction between product and user in the experienced reality as exemplified by the two companies contributes to designing valuable and long-lasting products and thus to more responsible and sustainable consumption and production. This approach also supports a transformation from a focus on fitting into a fashion context to a focus on products designed for real use and product attachment. Thus, the two companies exemplify the critical space for reflection, which we discuss in this paper.

4 TOWARDS A NEW DIDACTIC MINDSET

In the previous sections, we have discussed how the space for critical reflection may emerge between the perceptions of dreams of fashion to dreams of use. In this section, we sum up our discussion and arguments for an alternative didactic approach to professional and well-known tools and methods for fashion design.

4.1 The space for critical reflection

The ability to create a space for critical reflection depends largely on the educator's ability to abandon and unlearn an understanding that has been trained through many years of practice and has therefore become an inherent pre-conception of the nature of a collection and the fashion system. In order to be able to foster the shift, the starting point must be that we as educators change our mindset and do away with our own well-established notions of professions and industries in general and, in this paper, specifically fashion design. We must take it upon ourselves to articulate a new teaching paradigm replacing the traditional 'way' of designing fashion. Changing the mindset touches something deep inside us. It is a balance. Using line-up and collection plan to create a space for critical reflection intends to foster the students' awareness of and curiosity towards the alternative possibilities that may arise between the abstract and the concrete. Critical reflection thus becomes an approach to evaluate the value of each individual product but also a tool for evaluation of the justification of each product category, contributing to foster ideas for concepts consisting of mono product collections aka Andersen-Andersen or limited product category collections aka Week of Wonder.

4.2 From dreams of fashion to dreams of use

We often get the feedback from students that it can be difficult to both fulfil the needs of the companies and contribute to strategic solutions concerning sustainable development. Didactically, we provide the students with skills that make them employable and skills that enable them to act strategically and contribute to change and development. The fashion design students are faced with the dilemma of acting as responsible contributors to a new normal where sustainability and responsibility is not related to a question of if, but rather a question of how. For some students, this attitude counteracts their dream of being a player in the fashion world and create dreams. Fashion design students develop an array of skills. Thus, we have a task and a responsibility to encourage the students to establish their 'dream of use' instead of maintaining a (maybe outdated) 'dream of fashion'. As educators, we strongly believe that we have a responsibility to promote a new paradigm and system within fashion design. To do this, we need support from the political system and the industry as well as another way of using and consuming garments.

5 CONCLUDING REMARKS

The advantage of using line-up and collection plan to create the space for critical reflection is rooted in the fact that the tools are already part of the curriculum and thus well-known tools for the students and lecturers alike. Thus, introducing line-up and collection plan as dialogue tools for sustainable development does not require changes in curriculums. Students as well as educators can begin the change in mindset from a safe space, incorporating well-known tools and techniques in the processes. However, it does require a different didactic approach to the introduction and use of the tools. It is about introducing and articulating their use differently. On the basis of earlier experiences, we expect that interaction between design work and dialogue – reflection in action – will create a fruitful space for research [11]. Thus, further researching this proposed educational methodology as it takes place in the classroom will provide us with examples of initiating a critical discussion among students.

In this paper, we point to the possibility of establishing a space for critical reflection between the line-up, the intangible concept and narrative, and the collection plan, the tangible products, the concrete and real. We argue that the field of fashion design can be developed in this way, i.e., that we educate fashion designers who to a greater extent than now can be involved in strategic and sustainable decisions. We believe that other design disciplines can learn something from this because fashion is a clear and archetypal discipline although there are infinitely many directions. Similarly, other design disciplines presumably have a number of well-known tools, which can be challenged and potentially used to create the space for dialogues and conversations that promote critical reflection within their realms. Thus, the practice of critical reflection contributes to the students' ability to challenge the familiarity of the field and the situation as we know it and move towards a necessary sustainable change and a green transition.

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TRANSDISCIPLINARY BEHAVIOUR CHANGE: A BURST MODE APPROACH TO HEALTHCARE DESIGN EDUCATION

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ABSTRACT
With the future of health(care) shifting from treatment to prevention, design for behaviour change is an essential part of this movement. Although we have made significant breakthroughs in behavioural science and design for shaping behaviours, there are still some significant gaps and opportunities unexplored. Developing new transdisciplinary approaches to the education of designers for behaviour change becomes of increased importance. New practice-based models are required to facilitate the connection between understanding behavioural theories and applying these to healthcare contexts. This paper illustrates a unique burst mode blended teaching model that fuses teams of mixed healthcare, design, and other diverse backgrounds with the use of digital technologies to pre-empt unwanted behaviour and assist behaviour change. The course module combines asynchronous learning for behaviour change diagnosis with synchronous teaching of behavioural theory, collaborative concept development and rapid prototyping. Digital platforms are used to facilitate remote global teamwork alongside individual physical hands-on prototyping using sensors and electronics.

Keywords: Design for behaviour change, blended learning, design innovation, transdisciplinary education

1 INTRODUCTION

Developing new models and tools for designing out unwanted healthcare futures is of paramount importance for healthcare design education and commercial healthcare innovation. New frameworks for design are required, which include an understanding of behavioural science, the impact of the environment on behaviours and how this can be applied in the healthcare contexts through design. Well-designed products can have a sustained positive effect, e.g., the NHS hospital bed designed by Bruce Archer, which made it easier to tend to patients reducing the strain on nurse's health [1].

Detecting or pre-empting unwanted health behaviour and applying the theory and practice of 'nudging' is still an underexploited approach [2]. Imagine the scale of impact that behavioural therapeutics and preventative solutions designed with the application of new technologies, such as biofeedback and sensors, can have in providing the right healthcare prompts at the right time.

Design for Behaviour Change is one of the core modules in the curriculum of the Healthcare and Design MRes and MSc courses at the Royal College of Art (RCA) and Imperial College London (ICL) [3]. The module is co-delivered in burst mode by both institutions full time over one week and combines lectures, interactive group work and workshops. Alongside an introduction to behaviour change theories and frameworks, the module aims to equip students with hands-on skills to deliver working prototypes. By the end of the module, students are able to design, prototype and present targeted solutions, starting from precisely identifying specific target behaviour, then examining psychological, social, and environmental determinants, and applying behavioural science within the design process. Students develop skills to design interventions for changing behaviour within a specific population or group, targeting healthcare staff, patients, and the general public. Core learning also includes rapid prototyping for concepts articulation, hands-on interactive electronics prototyping, teamwork, and presentation skills.

The Behaviour Change module has been delivered in a face-to-face, highly interactive model in academic years 2018/19 and 2019/20 and as a remote teaching model in 2020/2021. The modules were co-led by two academics representing each collaborating institution, and multiple visiting lecturers

provided support to students throughout the week. The profiles of teaching staff included design, behavioural science, healthcare, business, electronics, and programming. The cohorts were comprised of students from multiple locations, including the UK, Mexico, Brazil, the US West and East coasts, India, China, Canada, the Netherlands, Greece, Spain and Romania with a variety of previous experience and backgrounds, from social sciences, anthropology, architecture, fashion, fine art, occupational health, emergency medical services, user interaction and product design.
Design for behaviour change can play a crucial role in improving the future of health and healthcare. People's behaviour is still one of the most significant contributors to premature deaths [4]. Design for prevention through shifting behavioural patterns of healthcare staff and patients is one of the largest opportunities to improve health and healthcare outcomes [5].

2 BEHAVIOURAL FRAMEWORKS AND ELECTRONICS PROTOTYPING

During the module, students were divided into multidisciplinary teams of two to three students. As a part of module pre-assignment, the RCA students conducted primary and secondary research within the selected challenge area, providing the groundwork for the in-module group work. The challenges included hand-washing in hospitals and public spaces, posture and slouching, recuperation, and recovery, improving body flexibility and gait, sleep regulation and preventing pressure ulcers. For a post-module assignment, the ICL students summarised and analysed the solutions in an essay.
At the start of the module, students received an introduction to behavioural science (including health psychology and behavioural economics approaches), followed by pre-assignment presentations, which summarised conducted research and presented three defined mini-briefs. Teams were formed around selected briefs and focused on applying behaviour change teaching to design practice and a hands-on introduction to electronics work. All groups worked with Arduino Uno boards with sensors kits. Students used Action Actor Context Target Time (AACTT) framework [6] to identify a specific behaviour to change and then understand the determinants of that behaviour, followed by designing ways to overcome barriers and harness facilitators. COM-B model was used to identify whether the target population has the Capability, Opportunity, and Motivation to perform the Behaviour [7, 8]. Behavioural Setting Canvas from Behaviour Centred Design [9] was used to examine the environmental setting and the motives driving behaviour. Students also learned the MINDSPACE framework (Messenger, Norms, Defaults, Priming, Affect, Commitment and Ego) [10] to analyse ways of changing behaviour through changing the environment. Figure 1 shows an example of a behavioural diagnosis assessing the Capability, Opportunity, and Motivation (COM-B) for the behaviour of addressing pressure ulcers in a newly disabled population.

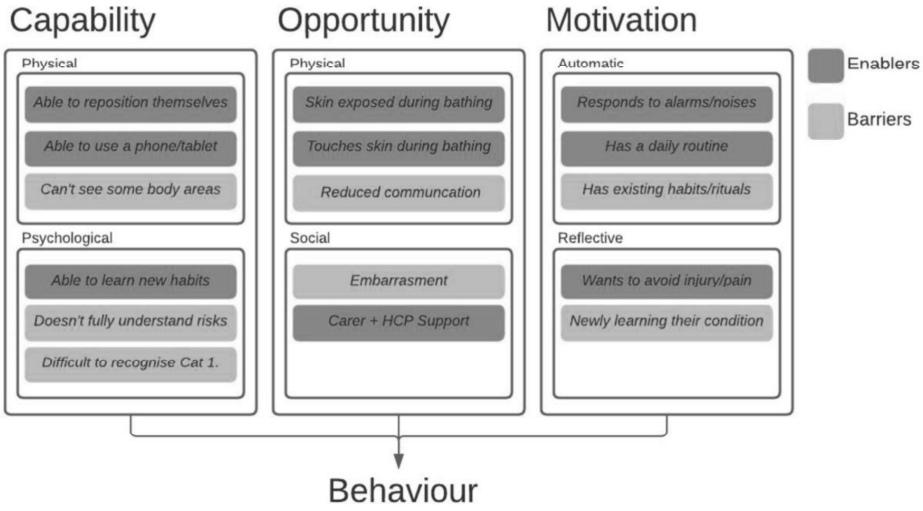

Figure 1. COM-B model analysis within a project addressing pressure ulcers prevention (Cat 1 = category 1 pressure ulcer; HCP=Healthcare professional)

Students conducted a brainstorming session with Healthcare and Design Workshop cards [11]. Day four was entirely dedicated to group work and concept development through a 'deep dive' into rapid electronics prototyping workshops. Teams were supported during concept iteration and behavioural context clinics, as well as by the assistance of electronics and programming experts to develop working prototypes (Figure 2.). Students presented the solutions through user-journey scenarios and role-play demonstrations. The practical character of the module prepares students to apply design methods and behavioural theory to promote effective behaviour change in their working lives.

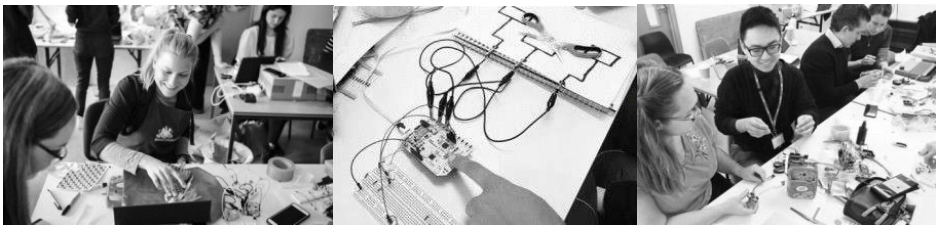

Figure 2. Hands-on electronics prototyping in teams

2.1 Module Outputs

Alongside a detailed analysis of the target behaviour, the module outputs covered a wide range of solutions, including products, systems, interactive spaces, or platforms. A selection of prototypes are presented below (Figure 3.). The smart glove dispenser that opens only after correct hand washing completion (Figure 3., left) tackles the challenge of clinical staff wearing gloves without prior hand sanitisation, addressing lack of Automatic Motivation (habit) for sanitising and Physical Opportunity for the unwanted behaviour, through changing Defaults. A car seating system with posture-detection (Figure 3., centre) adjusts to the driver to correct posture and alerts them when they might be falling asleep and need a break (using Salience and Priming). The hand-sanitising bubble dispenser offers a playful way to engage the user in hand disinfection, especially applicable within children's hospital wards and public spaces, such as doors and lift call buttons (increasing Automatic Motivation as the behaviour becomes more enjoyable, thus harnessing Affect). Post-module assignment essays provided an opportunity for critical analysis of the proposed solution and routes to evaluation.

Figure 3. Hand-washing glove dispenser (left), posture-aware correcting seating system (centre) and hand sanitising bubble dispenser (right)

3 BLENDED STRUCTURE & ADDRESSED CHALLENGES

In the academic year 2020/21, the shift to remote teaching and learning due to the global pandemic presented a series of challenges to delivery, requiring rapid module conversion while preserving the module objectives and learning outcomes. The main challenges included:

- facilitating teamwork with students and staff from multiple global locations and time zones,
- tailoring module to limit 'Zoom Fatigue', through asynchronous teaching and flipped classroom approach of strategic theory learning facilitated prior to the module, and at the student's convenience,
- sustaining applied module character through physical electronics prototyping,
- team-based opportunity to learn Arduino,
- facilitating collaboration during concept generation development in a virtual space,
- providing an ad-hoc discussion of projects and spontaneous peer-to-peer discussions,

- building in flexibility to readapt the interactive workshop sessions in real-time when required.

3.1 Implemented blended approach and structure

We redesigned the content utilising the flipped-classroom approach to prevent 'Zoom Fatigue' and allow more time for interaction, discussion, and hands-on work during the module. The content was divided into the pre-work assignment and in-module activities. The module pre-work consisted of three types of activities: group work, asynchronous mini-lectures, and electronics skills acquisition.

Twenty students were split into five teams of four participants, maintaining the diversity of backgrounds and compatibility of time zones within each group. The teams were pre-briefed with a challenge area and given the task of mapping the problem using diagramming, selecting specific behaviour and the target population. Using the pre-recorded behaviour change lectures, groups specified the target behaviour (using AACTT) and conducted an initial behavioural diagnosis (understanding the determinants of the behaviour using COM-B). Prior to the module, groups conducted primary and secondary research, including market research of currently available solutions and their success or failure. The electronics introduction was offered as individual pre-work of a series of short 'follow along' tutorials. Each student was provided with a physical Arduino Uno board, Sensors Kit, and instructions for the setup of the Autodesk Tinkercad platform. The module handbook was replaced by a web-based interactive handbook with Zoom links to different activity groups, divided into five colour-coded categories: remote conferencing, hands-on activities, student group work, mentoring timeslots, and electronics support sessions.

As an alternative to physical studio wall space, Miro.com educational whiteboard platform was set up to facilitate group work, visual synthesis, brainstorming and concept articulation. For the hands-on electronics prototyping, each team member used the Arduino physical kit, and groups collaborated on the code development using the Autodesk Tinkercad platform. Each team set up a dedicated project zoom link for the duration of the module, allowing members to virtually 'visit' each other and provide peer-to-peer feedback. The studio-walk-around tutorials were replaced with Global Virtual Studio Patrol, where lecturers joined team rooms for a review using the links provided by teams. In addition, each of the lecturers offered Virtual Open Office Hours to create an opportunity to ask impromptu questions about concept design development, behaviour change aspects, electronics prototyping and coding.

3.2 Module Outputs

The outputs were presented during the last day of the module via the Zoom platform and included:

- a posture tracker for Zoom users, which monitors body position, distance from the screen and provides real-time feedback (Salience) for improvement in sitting position [12] (Figure 3., left),
- an interactive mat rehabilitation system for post-stroke patients, which uses a gamified approach (Affect, Priming and Norms) to guide users through exercise routine (Figure 3., right),
- a smart plaster and detection mirror for pressure ulcers detection and prevention (Figure 4.),
- radiographer hand hygiene solution to reduce cross-contamination by utilising a reward system and real-time audio-visual reminders for sanitiser use upon entering a new ward (Automatic Motivation),

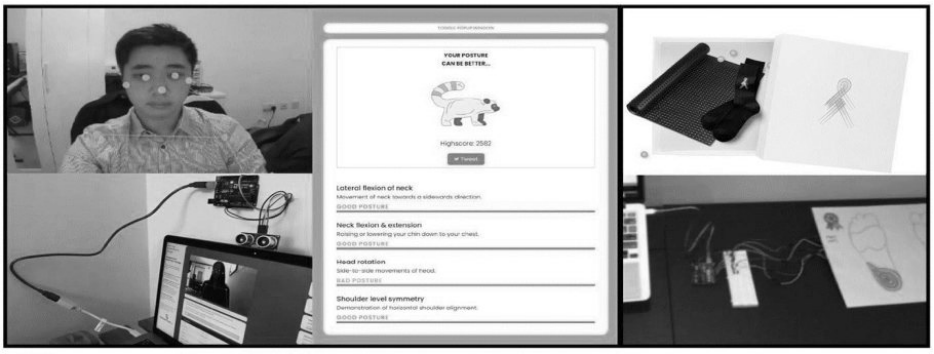

Figure 3. Pouch posture tracker, Walky wearable and smart mat for post-stroke rehabilitation

4 REFLECTIONS AND INSIGHTS

Due to the need for students to work in a highly collaborative way while being physically remote and time zone differences ranging from the US west coast to Asia, we used Zoom and the virtual Miro.com whiteboard. The use of Zoom has become a primary tool for meetings in 2020-2021. However, the Miro.com whiteboard was an extremely effective tool for supporting the creative and collaborative work required for this module. With those measures in place, students were able to work synchronously (for brainstorming and solution ideation) and asynchronously (while working individually on different aspects of the group task). It provided an easy way to collaborate and share ideas with their team members and explain their progress with the module facilitators to receive feedback and advice. Aspects produced on Miro.com were often used within student presentations and reports (Figure 5.).

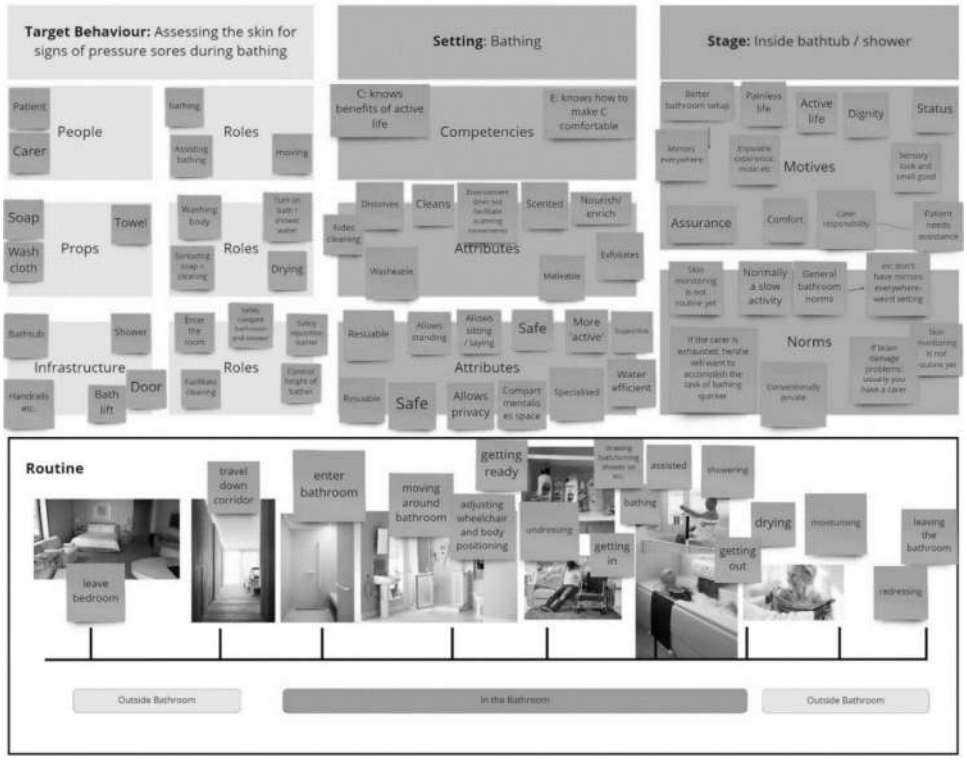

Figure 4. Synthesis - smart plaster and ulcer detection; extract from Miro.com board

The module is delivered in burst mode with an inverted classroom model, including group pre-work before the module, enabling students to "hit the ground running" with their practical group tasks. The pre-work was asynchronous to allow collaboration over different time zones and included mini-lectures (pre-recorded) on behavioural theory and electronics introduction. The RCA students also conducted background work on existing solutions for the target area. Some groups even took the opportunity to conduct interviews or formative research with their target population, based on the concepts taught in the pre-work, which was an added strength for their project. The approach of including pre-work is a realistic parallel with a workplace context, where people may be expected to have reviewed some materials prior to beginning a task. The use of pre-work enabled the best use of the week-long module in terms of collaboration with their team members and learning from one another and getting support from the teaching staff.

The decision to keep the module as a one-week synchronous module rather than convert it to a more extended, asynchronous module (as was done on some other courses) was highly beneficial, as the resulting immersion in the module content and group assignment facilitated intense focus, and

productive and creative team working. This was demonstrated by the exceptionally high standard of work produced in the final presentations, including the identification of behavioural predictors and application of behavioural theories and methods, exploration of the current solutions and the gap in the existing market, the development of creative solutions to address the identified behavioural predictors, the electronics prototyping and the considered critique of the developed solution.

5 CONCLUSIONS

The remote delivery model of the one-week-long burst mode Behaviour Change module provided an excellent opportunity to implement new tools and methods within healthcare design education and further development of the Healthcare and Design MRes and MSc courses. The tools and methods included asynchronous pre-work, synchronous lectures within the module from various experts, tools to facilitate collaborative group work (e.g., Miro.com), and coordinated time for feedback from module staff. The approach used resulted in an effective and enjoyable learning experience for students, demonstrated by positive feedback and excellent work. We were able to facilitate groups to remotely design and make complex physical sensor-based healthcare innovations by breaking the design into subunits that each student made locally in different global geographies, then demonstrated the collective product or service functions online live as a group. We developed processes for asynchronous group work across distant time zones, such as Global Virtual Studio Patrol and Virtual Open Office that mirrored campus-based studio teaching. Miro allowed us much clearer insight into the group process and decision making. Groups found it easier to show the evidence trail for their thinking. Many of those learnings have already been implemented within other modules and commercial healthcare projects and will impact our future curriculum delivery when we return to in-person teaching.

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SAFENESS BY DESIGN: A NEW DESIGN PARADIGM?

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ABSTRACT
Design has the potential to significantly improve safeness and wellbeing, and to identify and reduce risk either during the design phase or through targeted design interventions concerning product, infrastructure, systems, and services. The broad user-centred skills and technical knowledge base of designers allows for clear problem definition using ethnographic discovery processes, and creative design and innovative design resolution in a socio-technical context.
As designers' transition from product dependent (and market driven) outcomes to fewer tangible activities, increasingly the role of design as an enabler of societal wellbeing, capable of making a greater contribution to communities and lifestyles, opens up new practice foci. Whilst design has always been required to address safety from a compliance and/or product liability perspective, '*Safeness by Design'* aims to apply an explicit *safeness* lens to design practice. Aspirational in its intent, it seeks to operate outside of safety compliance frameworks; utilising human centred design, experience and interaction design, social design, and service design approaches, rather than risk management methodologies, to achieve actual or perceived safeness.
This paper suggests *Safeness by Design* as a new design paradigm, examining the contribution of early works to safer urban contexts, and proposes a safeness-led approach to design practice.

Keywords: Safeness, social innovation, design pedagogy, design intervention

1 INTRODUCTION

Design has the potential to significantly improve safeness and wellbeing, and to identify and reduce risk either during the design phase or through targeted design interventions concerning product, infrastructure, systems, and services. The Lloyd's Register Foundation's *Foresight Review of Design for Safety* [1] asks whether design for safety can be used as a strategic tool, advocating the need for safety and risk reduction to be "considered at the earliest stages of developing new products, systems and technologies instead of reacting to failures that have taken place." Developing such a culture will require a holistic approach to understanding the myriad influences that impact safety including human behaviours, cultural and environmental contexts, and complex interactions.
Many industries have of course considered safety for a considerable time, prompted by incidents and failures, and the need for regulatory compliance and risk management, and these industries are heavily regulated from a safety perspective, for example the construction industry and other hazardous workplace environments. But whilst many of these initiatives have applied an occupational health and safety approach to accident and injury prevention, e.g., through mandating the use of PPE and compliance with safe practice and procedures, it is only more recently that mental health, worker performance and behavioural aspects have been included in these narratives. Similarly, the widely used Failure Mode and Effects Analysis (FMEA), whilst a valuable risk management conducted (along with other safety integration processes) in the later phase of design process to respect safety directives, does not replace the need for a comprehensive and strategic design approach to safeness. Houssin and Coulibaly [2] identified that safety integration typically occurs retrospectively by imposing hazard reduction procedures and constraints, rather than applying a user-centred and human behavioural understanding approach during the design process. As noted by the Lloyd's Foresight Review [1] "design for safety goes beyond legislation, regulations and standards." There is a critical need for a greater understanding of the potential for a safety or safeness led approach to design practice, the formulation or identification of appropriate design methods and the integration of this approach into design education. The *Safeness by Design* initiative aims to address this through targeted engagement with industry and government agencies to integrate a *safeness* agenda throughout the design curriculum.

2 SAFENESS BY DESIGN

Safeness by Design, an initiative emerging from RMIT University's School of Design, aims to enhance health, wellbeing, and social values by using design to achieve actual and evident safeness across a broad range of environment and contexts. Rather than a design specialisation, we propose a new generalist and multidisciplinary approach to realise social impact through a safeness agenda. We advocate designers using their understanding of user behaviour and situational contexts to identify and respond to safeness concerns through targeted design interventions. It has been identified that whilst a strong focus on user-centred design has led to safer design solutions, user centred design is primarily focussed towards *satisfying* the user, instead of intrinsically creating safer designs [1]. To achieve a *safer by design* culture, it is apparent that we need to design for safer human behaviour and look beyond the mechanical and functional aspects of our products and service systems. We live in increasing complex worlds, where the risk of information and cognitive overload is a daily occurrence. Our multicultural societies require effective communication tools and a broader understanding of cultural behaviours and expectations. New technologies, whilst enabling, also pose new challenges from a safeness perspective. Designers need to understand the complexities of society, the inherent hazards within our environments and the risks to wellbeing posed by both cognisant and unconscious behaviours, regardless of intent.

2.1 What is safeness?

The pursuit of *safeness* can encompass many directions. Safeness can be defined as the state of not being exposed to danger or of protection from harm, freedom from hazards, danger, fear, risk, harm or loss, a feeling of safety and security. Whilst adverse impacts to safeness can result from either implicit or explicit risks, safeness is not purely in the physical; the perception of safeness is critical to wellbeing and confident societal behaviours. Glendon and Stanton [3] in their review of safety culture note that safety culture "is not merely empirical but rests upon a value decision." They found that improvement in safety was reflected in patterns of behaviour and working practices, as well as values, attitudes, and beliefs. Human behaviours and interactions can be unpredictable, and whilst safe practices can be embedded into workplaces, urban behaviours are more dynamic and diverse and require ethnographic research to inform the design process. *Safeness by Design* aims to employ design process and actions to remove vulnerability and insecurity and mitigate risk to achieve both perceived and actual safeness from a personal perspective across differing contexts, environments, and behaviours, through applying a holistic design approach. As noted by Sadeghi et al, it is important to assume a user behavioural model approach to safeness design, to "allow designing human activities in parallel with products, neither designing only products nor designing human activities after products [4].

2.2 Establishing a new design paradigm - initial strategies

For the initial stages of the Safeness by Design initiative, rather than take an occupational workplace or product category focus, the *Safeness* team elected to pursue a more holistic process of municipality engagement to identify and frame problems in existing urban landscapes and social contexts, and then propose a responsive design intervention. The reasons for this strategy were three-fold:

1. to identify and frame problems within a more local and accessible context,
2. to work quickly and broadly across multiple contexts with a social and community focus,
3. to evidence capability to enable early engagement in future urban planning or design cycles.

It was also felt that from an educational perspective, the opportunities for students to critically examine existing situations within their own urban environment and then propose an intervention, allowed for greater discourse on safeness (real and perceived) than would have been possible in a generative product design project. Whilst it is a long-term aim of this initiative to drive the introduction of *safeness* agendas into design cycles, it was felt that a responsive approach was more appropriate initially.

3 DEVELOPING CAPABILITIES

Addressing urban safeness in early studio collaborations with the City of Melbourne and the Ajuntament de Barcelona (city council), the initiative has resulted in design interventions that embrace holistic and multidisciplinary approaches to the issues of safeness on personal, social, spatial, and technological levels. Student project outcomes resulting from three collaborative research projects between designers at RMIT School of Design and the planners and strategists from two international cities, Barcelona and Melbourne have been exhibited in 2020/21 at both Melbourne and Barcelona Design Weeks and can be accessed through safenessbydesign.org.

3.1 Project One: Urban Safeness in Melbourne

The pilot project for Safeness by Design emerged from a collaboration between the authors and urban planners and strategists from the City of Melbourne. Masters level design students in the 2019 *Safe City Smart City* project were tasked with identifying safeness concerns within the Melbourne metropolitan area, specifically the central business district and surrounding inner city suburbs.

The project challenged designers to uncover precedents and exemplars in safe urban design, conduct ethnographic research into perceptions of safety, and to evaluate the spatial and environmental conditions that promote safe behaviour. Students were given the opportunity to develop a stronger understanding of their city, to comprehend the specific behaviours of different user and mobility groups, and to identify areas where real and perceived safeness were lacking; and then to apply design intervention on personal, social, spatial, and technological levels. Design solutions aimed to ensure a 24-hour city that is safe, inclusive, and welcoming for all users, with a specific focus on personal mobility and the safety of women transiting the city at night.

Amongst the design proposals presented to city council planners and strategists were:

- an urban redevelopment that addressed conflicts between cyclist and pedestrian mobility in a heavily congested mixed-use promenade that is both a shopping and eating precinct and a commuter cyclist thoroughfare,
- an innovative app-based cycling route planning/navigation system that utilises data on traffic and cycling movement patterns to direct cyclists away from roads with heavier vehicular traffic and/or known hazards, towards safer cycling routes,
- a public safeness system that uses personal wearable technology to connect a user in danger with fellow citizens and/or police patrols, utilising a 'flash mob' approach for a safer community. This solution is an exemplar of new approaches to crime prevention and community activation,
- the *'How to be Considerate'* educational campaign which explores the scenario of a stranger walking behind a woman at night and how this may increase fear; the outcome including a toolkit to encourage male awareness and behaviour change.

Figure 1. Safe City Smart City project design proposals (clockwise from top left: the 'How to be Considerate' campaign, Eystre wearable safeness technology, urban redesign to separate pedestrians and cyclists, new inner city cycle route planning and navigation

3.2 Project Two: e-scooters in Barcelona

The introduction of electric kick scooters (e-scooters) posed a serious issue for the historic and busy metropolis of Barcelona. Since their introduction, e-scooters have caused significant concerns for city planners as they observed considerable speed disparity between riders and pedestrians, ignorance, and lack of compliance to local regulations, reckless and irresponsible rider behaviours, and urban clutter caused by the 'dock less' hire systems offered by unregulated service providers. These safeness concerns are exacerbated in Barcelona's crowded metropolis with its narrow streets and multitude of tourists.

In collaboration with planners and strategists from the Ajuntament de Barcelona (municipal council), Undergraduate and Masters design students addressed a range of safeness and logistical issues resulting from the rapid onset of these new personal micro mobility devices, including pedestrian and rider safety, helmet usage, e-scooter docking infrastructure, education, and rider behaviour change.

In doing so they attempted to empower the city to engage with e-scooter service providers with a clear set of operational guidelines and requirements to build a collaborative, yet regulatory relationship.

The *Safe Mobility in Barcelona* (2019-20) project delivered these innovative solutions to city planners:

- an educational and reward-based system that aims to create positive user behavioural change in e-scooter riders through rider training and usage (speed and behaviour) monitoring,
- an automated e-scooter smart navigation system that enhances pedestrian and e-scooter rider safety in congested areas, whilst empowering local communities and businesses to contribute to an e-scooter networked solution,
- an e-scooter infrastructure system including lockable scooter docking and charging systems that alleviates the core urban issues created by the dock less hire system,
- a safer e-scooter design with integrated helmet and safety compliance incorporating a cognitive test system that prevents intoxicated riding and speeding in pedestrian areas.

Figure 2. Safe Mobility in Barcelona project design proposals (clockwise from top left: automated smart navigation system, educational hub and reward-based behaviour change, safer e-scooter design with integrated helmet and safety compliance systems, scooter docking/charging hub

3.3 Project three: Safe Mobility with Covid-19

The way we use and transit our cities will be significantly different for the foreseeable future. Coronavirus protective measures (especially social distancing and sanitation requirements) have resulted in unprecedented restrictions on personal mobility, generated unease and safeness concerns and a distrust of public transport and placed considerable pressure on cities and service providers. However, the impact of the global pandemic also provided an opportunity for designers to not only respond reactively to immediate community safeness needs, but to imagine safer, healthier post-pandemic cities; to consider how we can rethink our cities to shape new urban landscapes and enhance our social and professional interactions.

The 2020 *Safe Mobility with Covid-19* project responded to emerging public safeness and mobility issues in environments defined by living with, and after, the Covid-19 pandemic. This project, which was conducted during the continuing pandemic lockdowns, realised solutions for coronavirus impacted urban landscapes with a focus on safe solutions for public transport, personal mobility, sanitation and contact avoidance, smart city technologies, and local communities.

In collaboration with the City of Melbourne and the Ajuntament de Barcelona, this project challenged Master's level design students to respond to the 'new normal' with design proposals that address the psychological, physical, and technical realities needed to ensure safe mobility in urban environments, whilst showcasing the value of human centred design and focused design interventions in responding to global challenges. Amongst the design interventions proposed to the city councils were:

- restoring trust in public transport through the design of digital and physical systems and services to maintain social distancing throughout transit journeys,
- using technological (smart city) solutions including real time crowd data mapping to provide route planning and navigation to maintain social distancing on our streets and reduce urban congestion hotspots,
- responding to changing work and commuter patterns with pop-up infrastructure that facilitates local neighbourhood working and invigorates local communities.

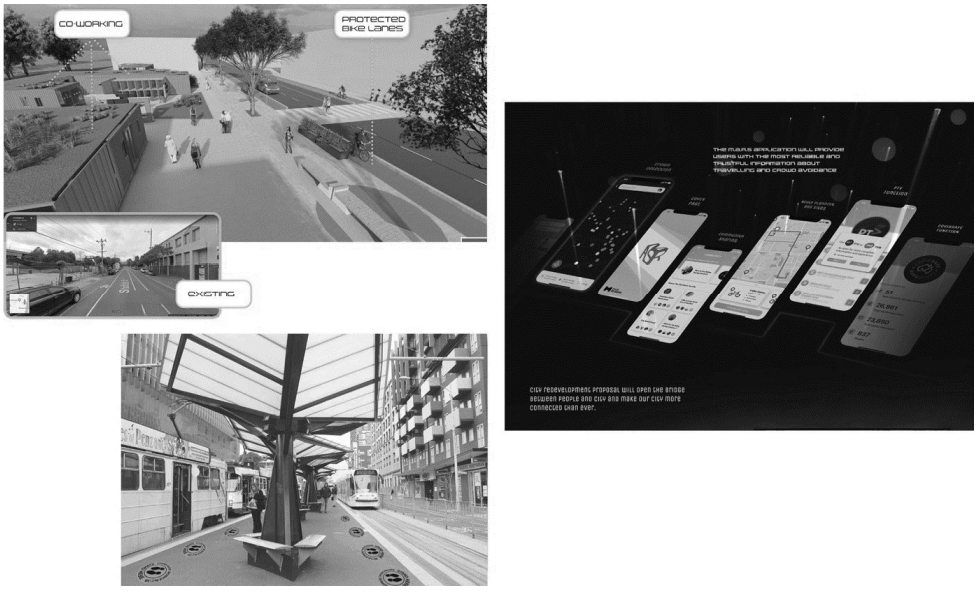

Figure 3. Safe Mobility with Covid-19 project design proposals (clockwise from top left: Co-Op community co-working hub and neighbourhood rejuvenation, M.A.R.S safe urban navigation system, public transport social distancing system

4 FUTURE DIRECTIONS

The Safeness by Design theme has proved valuable in design education. Through studio-based projects, students have had the opportunity to engage with real world issues and turn a reflective lens on urban design and examine human behaviours from a different perspective. The projects conducted so far have been successful and well received by students and external partners and have prompted new discourses. Designing with a *safeness* agenda has unlimited scope of possibilities. Even whilst avoiding the safety compliance or risk management fields of practice, all workplace and lifestyle environments have the potential for design to contribute more significantly to either actual or perceived safety. For future projects, the Safeness by Design team are moving their attention to the safeness of workers in the gig economy (notably food delivery workers) and also looking to reduce drowning and the frequency of life saving rescues of those who are unfamiliar with the dangerous surf conditions of Australia.

5 CONCLUSIONS

"Could the creation of well-being and not goods and services, be a new purpose for design?" With this question, Faud-Luke [5] proposes a model of 'design activism' in which designers are using "the power of design for the greater good." It is apparent that paradigm shifts have occurred in Industrial Design with practice moving towards discourses of practice that are societal and environmentally focused, resulting in new opportunities for both a broader contribution, and new currencies of value adding [6]. The World Design Organisation [7] states that Industrial Design is *now* "a strategic problem-solving process that…leads to a better quality of life through innovative products, systems, services, and experiences." Manzini [8] similarly sees the role of designers as facilitators who prompt new social conversations, and act as design activists proactively launching socially meaning design initiatives.

The *Safeness by Design* initiative responds to these calls with a new focus for design practice. Precedented by sustainable design, inclusive design, socially responsible design etc., which although specialisations, are now considered to be embedded within design practice, design for safeness is an important new consideration with potential for social impact. Not as a workplace risk management or compliance tool, but as a new approach to understanding, predicting, and responding to human behaviours to inform a more thorough design process.

Is Safeness a new paradigm of design intent?

ACKNOWLEDGEMENTS

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DIALOGUE FOR DESIGN TEAMS: A CASE STUDY OF GENERATIVE CONVERSATIONS FOR DEALING WITH DIVERSITY

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Keywords: Team performance, diversity, design teams, cooperation, dialogue

ABSTRACT
In the Integrated Product Design master's at Industrial Design Engineering, there is a growing diversity in students. In recent years we increasingly noticed that diversity could lead to complications within the various student teams. Examples are miscommunication, frustration, and interpersonal conflicts. This growing diversity between the team members strongly appeals to their ability to deal with these complications in a constructive way. Via a KPI tracking system we kept track of team performance and we identified four aspects affecting the team dynamics within the Advanced Embodiment Design project team [1]. This paper presents the case study of one of the student design-teams which was highly dysfunctional in design approach and conflicting cultural differences. It made this group perform at a lower level. Theory U [2] and dialogue techniques [3] were an unfamiliar approach for student design teams. Interventions using generative conversations stimulated connectedness between the team members and improved the team dynamics. The use of culture mapping [10] proofed to be a valuable tool to bridge the culture gap. Although this case study only describes one student design team, the drastic improvements resulted in the team winning the iF Design Talent Award 2020. The findings are promising, and further research is needed to investigate the generalizability of these approaches for Industrial Design Engineering education.

1 INTRODUCTION

In the master's course Advanced Embodiment Design (AED), students cooperate in design teams on a client-based design project for one semester consisting of 21 European Credits. These student design teams consist of highly diverse student members, with differences in nationality, prior education, and socio-emotional development. Each team is supervised by a teacher on a weekly basis. In previous research [1] we noticed that the diversity between the team members can lead to complications within the team. Miscommunication, frustration, and sometimes interpersonal conflicts are examples of elements that we found that lead to lower performance due to the inability of the team and the coach to dealing with these complications constructively. The design of a KPI tracking system [1] was used to monitor the student-teams' performance, which was discussed during the weekly coach meetings. We identified four aspects on the team dynamics within the AED project team affecting student-groups becoming highly functioning teams: (i) cultural differences, (ii) differences in design approach, (iii) emotional differences and (iv) differences in competencies [1]. In this case study paper, we focus on one team that addressed two out of the four aspects that frustrated the team dynamics and flow of the project: cultural differences and design approach. Within the IPD masters' programme, there has not been any previous research addressing these diversity aspects which affect the dynamics in student design teams. Students and coaches within the IDE faculty at TU Delft do not have an appropriate approach to deal and tackle these problems. The goal of this research is to describe our approach to increase the ability of the tam and their coaches to deal with these differences based on Theory U approach [2] and Dialogue techniques [3]. Dialogue techniques supported the student team shifting their conversations from politeness and/or debate to reflective inquiry-conversations which led to more generative conversations. Generative dialogues are conversations where the students listen not only from within themselves or from within others but from the whole system. Moving conversation to generating new understandings and knowledge rather than simply negotiating from current understandings and

positions. In this conversational process of dialogue, the coach helped the student team to move through the Theory U process. Shifting from habits of judgement to seeing each other with a more creative open mind. Finally, the team further progressed to sensing each other with more empathy and compassion which resulted in a healthier collaborative team, incorporating their differences as an opportunity for generating design solutions. This paper presents the case study of this student design team. We describe the theory underlying the interventions of the team dynamics expert, the composition of the group, their different design approaches, and the interventions that lead to drastic improvement and resulted in the team winning the iF Design Talent Award 2020. Although this study shows promising results, further research is needed to investigate the generalizability of the findings.

2 THEORY U, DIALOGICAL CONVERSATIONS AND CULTURE MAP

AED student design teams are multi-diverse. They are developmental, dynamic and the social processes and context of the teams often change. This is different from the context where Tuckman [4] and Smulders [5] describe teamwork. The nature of the Tuckman model (Forming, Storming, Norming, Performing and Adjourning) is hierarchical where the following step can only be reached when the previous is accomplished. Although Smulders addresses student teams he is not explicit on diversity and the iterative developmental nature of student design teams. Miller [6] on the other hand states that groups can be viewed as systems. Personal and group related processes of creativity, introspection and intuition are more prominent today [7] where many of the design challenges far exceed the knowledge and skill that any one person might possess. This context is the reality of the AED project and therefor important to understand and improve teamwork and collaboration. Hays [9] addresses how and why Theory U applies to teams: "It is a model that transfers easily from an individual to a collective context and holds great potential to spark the learning that is necessary to improve team functioning and enable greater performance".

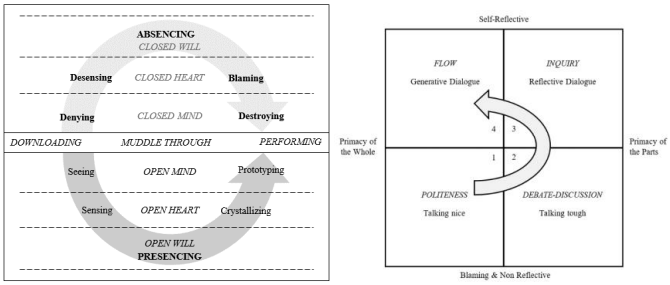

Figure 1. Theory U (left) and Four types of conversations (right), adapted from Scharmer [2]

Theory U [2] describes two opposing processes (figure 1, left): presencing and absencing. Presencing is the process where teams collaborate and embrace emerging possibilities. Absencing is the process where teams disconnect and get stuck in old habits. In each process, three elements of communication are relevant and can be either open or closed. Communication from the 'mind' is described as (non) judgmental communication of team members based on prior experiences. Communication from the 'heart' is described as the emotional (dis) connection of team members. Communication from the 'will' is described as the ability of a team to act in an instant. Scharmer also identifies a process of muddling through, where teams are in between presencing and absencing. Before teams either go into the absencing or presencing journey, they start with a phase called downloading. This is when the team is starting to get together and engage based on past patterns.

Communication within the team is central in the team process: talking and listening. Scharmer [2] describes four types of conversations (figure 1, right). (i) Talking nice, where people listen to confirm the positive aspects, the goodwill, filtering, politeness, self-censoring. (ii) Talking tough, where people listen to respond, to counter others' arguments, such as debate, discussion, and conflict. (iii) Reflective dialogue, where people listen to understand, accepting the others perspective without feeling the need to disagree with them and allow diversity of perspectives. (iv) Generative dialogue, where people listen to the human experience of the other and what resonates with their own humanity, sensing the wholeness of which we are part, unity in diversity. Talking nice and talking tough is prominent in the absencing process and reflective dialogue and generative dialogue are applied in the presencing process.

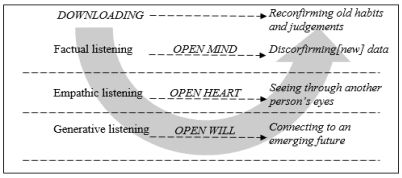

Figure 2. Four levels of listening adapted from Scharmer [2]

Within the fields of conversation, Scharmer [2] also describes four levels of listening that support the process within teams for transferring "Reflective Dialogue" to "Generative Dialogue" (figure 2): (i) Downloading: listening from habits of judgement, (ii) Factual listening: listening from outside and noticing differences, listening with an open mind,' (iii) Empathic listening: listening from within, sensing, listening with an 'open heart' and (iv) Generative listening: listening from source, from what is emerging, listening with an 'open will'.

Table 1. Eight Dimensions of The Culture Map [10].

Eight dimensions of the Culture Map		
Extreme A	**Key area**	**Extreme B**
Low-context	Communicating	High-context
Direct negative feedback	Evaluating	Indirect negative feedback
Egalitarian	Leading	Hierarchical
Consensual	Deciding	Top-down
Task-based	Trusting	Relationship-based
Confrontational	Disagreeing	Avoids confrontation
Linear-time	Scheduling	Flexible-time
Principles-first	Persuading	Application first

Besides group dynamics, cultural differences have a large effect on the team's performance. The Culture Map [10] is a model that defines eight areas where cultures vary along a spectrum between two opposing extremes (Table 1). It provides a framework for teams that face cultural differences. Team members analyse the position of their culture relative to one another. This enables them to decode how culture influences their collaboration. The space in between the extremes can be considered as a continuum. Within the range of behaviours of a given culture, individual differences occur. The goal of using the model is to support interacting between team members and improve watching more, listening more, and speaking less.

3 CASE STUDY EQUARUN

The AED project 'Equarun' is concerned with developing an assistive device to help people with deaf blindness. This device must be capable of transmitting complex instructions on road conditions, striking a good balance between freedom and safety. The team consisted of three Chinese design engineering students, a Spanish student from mechanical engineering and an Indian student educated as an electrical engineer. Both the company coach and the AED coach are Dutch. The company coach has a master's in medical research and the AED coach has a master's in Industrial Design Engineering achieved at the Delft University of Technology. Although most students in the team have different competencies, it did not play a role in team-dynamics and the team did not encounter any emotional differences. The two emerging difficulties in this group were based on differences in design approach and nationality.

A few weeks into the project, different design approaches were leading to a certain amount of incongruity. A part of the student team approached design as a process where designers decide which design is meaningful for the user. Another part of the team approached design as a process where user input should be steering the design process. Indirectly the company insisted the team should conduct more extensive tests with the deafblind runners to support all conclusions. The confusion in these approaches led to discussions and friction in communication. It also led to differences in the way the team planned the project. The cultural differences were compounding the communication gap. Certain information was received amongst the team members in a roundabout way with insufficient direct communication. The team members found it difficult to express pressing pain-points openly as the assumption was that it might offend someone. They realized it was also noticeable in nonverbal communication of their respective team members. The bonding glue to express openly in a safe space was missing. Halfway through the project, the mid-term assessment was approaching. The team assigned tasks (both as an individual and as a group) but they did not deliver on time. The team was struggling in managing the different demands of several stakeholders. The coach from the Running

Blind Foundation was giving directions which were not in sync with the academic requirements for the course.

4 APPROACH

To keep track of the team development, the coach scored the student team on 3 strategic and 4 operational Key Performance Indicators weekly [1]. Each KPI ranges from 1 (bad) up to 5 (good). The score is accompanied by textual journaling from the coach about the design team's performance. Based on these scores the coaches discuss the most dysfunctional teams on a weekly basis. The case study team discussed in this paper was pinpointed as dysfunctional in an early phase of the course. In this paper we compared the coach's journal next to that of the student team journal, which was developed in hindsight. Based on those discussions and referring to Theory U processes [2], it is decided what kind of interventions could improve the team dynamics of the student team. In this particular team, we used two experts to address the cultural differences within the team and an expert in the field of dialogue to have generative conversations with and within the team. The expert on cultural differences consulted the student team and provided the Culture Map [10] as a means to better understand each other. The team discussed the dimensions of the model and they constructed their own map using standard scores for Dutch, Chinese, Spanish and Indian culture (figure 3). The expert on dialogue mediated several meetings with the group and some sessions with individual team members. In these sessions, the expert explained Theory U, the dialogue principles and demonstrated the practice of dialogue [3]. When the interventions were successful it could be noticed in higher scoring on the KPI by the coach. To see if there is a difference in the experience of the interventions this specific team also recorded KPI's in hindsight as a reflection exercise after finishing the project.

5 RESULTS

5.1 The Culture map and KPI scores

When mapping the team's cultural backgrounds onto the Culture Map framework [10], certain points of tension became evident (figure 3). Most prominent difference is the persuasion parameter. It explains the confusion in the approach of the design process. Another parameter that caused tension corresponds to the deciding parameter. As the student team cultures were fundamentally more top-down, the project manager played a key role in steering the team towards the key milestones. Apart from this, the cultural differences between the team, coach and the client created difficulties in the parameter of 'communication' as the team was quite used to high-context communication and indirect negative feedback.

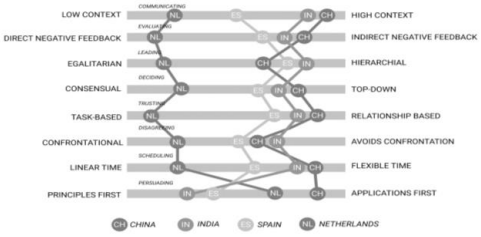

Figure 3. Team scan on The Culture Map [10]

Each week the coach scored the team on 7 KPI's [1]. The student team wrote their KPI journal in hindsight after consulting the whole team using recorded notes from team meetings and both individual and team reflections. These reflections were compulsory exercises of the course [11]. We briefly discuss how the scoring on the four operational indicators, (i) project management approach, (ii) planning, (iii) group dynamics and (iv) perceived stress level, developed during the project. In the first ten weeks the coach scored the Project Management low. The design progress was disturbed due to the lack of well-prepared coach meetings and poor communication with the coach. From week 10 on the team became more proactive and kept the coach up-to-date. In week 8, Group dynamics had a sharp downward move but improved following regular constructive feedback sessions, supportive reflective dialogue, and improved team bonding. As the team enjoyed the work in after the midterm (week 10), the perception

of stress was lower and much more manageable. The first 10 weeks the team was failing to match their target weekly goals and the KPI scores on ‘Project Management’ were low. After guided interventions on dialogue and Culture Map the team communication improved and helped them achieve the goals better. The completion of tasks, scored in ‘Planning on Time completion’ went down in week 16-17, due to the confusing mismatch in the expectations between the coach and client. The client was expecting research outcomes to be more extensive which were not manageable within the course outcomes. Higher scores on Group Dynamics were due to the expert supporting the team shifting from talking politely and discussions to factual, empathic, and generative listening. A peak stress level occurred during the mid-term in week 10. The team felt the risk of failing to match the expectations of the course. The stress gradually went down because of the reflective dialogues, which helped them become more self-aware. Finally, the team started communicating with the coach and the client more proactively.

5.2 Theory U - Open Mind, Open Heart, Open Will

After a series of events during project week 8-10, the company coach informed the course coordinators that the progress made by the team was not satisfactory. This led to the coach informing the team they might fail the course. The coach advised to restructure the design process to bring more clarity. The dialogue coach facilitated guided dialogue sessions with the AED coach and the team. In these sessions, the dialogue coach provided theory, instructions and moderated the conversations building the skills of listening and talking. To improve each of the team members individually, he also arranged 1:1 conversation. During these dialogues, questions were asked about the team’s approach to design, analysis of what went wrong, and what could be the steps which we could take. The team was given two weeks to improve, and they bonded over the crisis. The two-week notice helped them formulate their shortcomings and reflect on a better way forward, shifting from absencing to presencing [2]. As actionable steps forward, they started sharing daily updates proactively with the client, asking for the client's feedback on the design tests which they would be conducting with the deafblind and the fact that they could not conduct design tests with real deaf-blind runner groups. They planned a test within a short timeline so they could present their progress for the follow-up meeting with AED coach and dialogue coach. In the follow-up meeting, both coaches felt that the design process and planning was much more structured and coherent. They gave the team ‘the green signal', which in a way meant that the process the team had revamped was in the right direction. The restructuring helped them to connect to each other and understand their limitations.

During week 11, the team started interacting more with the deafblind runners after the first major test. They started getting more closer to them, connecting, and understanding them better. This was the onset of feeling 'empathy' for the user. To put their feet in their shoes and literally 'running' with it, they volunteered as runners for the Running Blind Foundation to guide the deafblind runners. This helped them to also understand and feel the pain points of the guides who were paired with these runners.

At this moment during week 12-13, the team felt that they were getting united by their vision - to impact the lives of the deafblind runners. When the team started meeting the runners and seeing them up close, the feeling of empathy started taking shape. It was a turning point for them as a team as the initial inhibitions and the barriers were slowly dissolving. The team connected more socially with the community of runners: they participated in the Rotterdam Marathon in association with the Running Blind Foundation and participated in the Running Blind Week as runners. All these activities helped them to integrate with the runner's community, and there was a heightened sense of belonging.

Owing to all this, the team made it a point to schedule at least one design test with the runners every week during week 14-20. The design tests were validated by the client and the coach and were conducted at the AV40 running track at Delft. These tests were conducted for design iterations. The team also conducted extensive tests with deaf-blind runners from Leiden, den Bosch and Rotterdam, and they noticed they could keep repeating the same iterative design process every week. After the completion of the embodiment of the final product, it was tested with 10 deafblind runners and their guides from various locations in the Netherlands. Although the client wanted more tests, they had to stop at a point as they also had their course requirements for completing in time. The team was not afraid to communicate these issues with their coaches. After the presentation, the team still felt a sense of inadequacy as designers as the mid-term presentation was a profound moment in this project. After a year and seeing all the deafblind runners giving strong feedback on our product and even the

organization, Running Blind Foundation wanted to take the product forward with their manufacturing partner, R2PRO. The team was encouraged by this and applied for the iF Design Talent Award 2020.

6 CONCLUSION AND DISCUSSION

In this paper we have discussed the case study of one AED student team on team dynamics. Out of our previous research [1] we identified the key issues concerning four types of diversity (cultural, design approach, emotional and competencies). In this paper we have researched the student team and the coach perspective on issues concerning differences in cultures and design approach when working in a design team. By weekly tracking seven KPI's and the accompanying qualitative journaling from students and coach, we could identify the moments and issues when team dynamics was deteriorating or improving. Although the student team generated the KPI scores and team journal in hindsight, the figures follow a similar path. Timely interventions by experts were taken to create awareness and conversational skills were used to improve the team dynamics. The Theory U [2] seems to provide a good framework for monitoring the aspects in the process. It also provides a pathway via open mind, open heart to presencing where this group of students could become a more effective design team. The focus on communication with the dialogue approach of talking and listening [3] seems to be a key element in improving the collaboration within the team and with the coaches. The culture map [10] is a valuable tool to raise awareness of cultural differences. Teams can now visualize where they differ and find improvements. With the use of dialogue, the team can shift from debate to reflection and generative conversations. After the expert mediated dialogue sessions, the KPI scores went up and without the expert the KPI scores went down again. This could indicate that the team and coach were able to cooperate when facilitated initially and in the learning process of understanding and applying dialogue themselves. The KPI scores from the student perspective in final last weeks were high. This indicated that the team was collaborating very well with hardly any discussions. The generative dialogue conversations had become a habit in the designing process. Some questions remain about the case we presented. We only described one case and we need further research to see if these findings are generalizable for other teams within the course. Should we inform all teams and coaches, for instance with a briefing or lecture about the Culture Map? Not all teams are subjected to cultural differences when cultures are close in most dimensions. The student team KPI's generated in hindsight makes the reliability of the data debatable. We therefore recommend letting student teams keep track of their own weekly KPI. Could KPI tracking by all student teams also support their self-reflection? More generally we are wondering if other design teams and coaches would also improve their team dynamics using dialogue as communication tool to overcome talking nice and talking tough in the design process? Could it be that Theory U and dialogue are overlooked perspectives in design education at the faculty of IDE at TUDelft? This research has received funding from the Comenius Teaching Fellowship funded by the NRO in the Netherlands.

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ENHANCING ABDUCTIVE REASONING IN DESIGN AND ENGINEERING EDUCATION VIA PROBABILISTIC KNOWLEDGE; A CASE STUDY IN AI

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ABSTRACT
As we are moving into a knowledge-based economy, frameworks addressing the translational processes around value and impact permeate the development of educational curriculums in the design and engineering educational spectrum. In response to this approach, this paper presents an operational framework that explores how abductive reasoning, and its embodied probabilistic knowledge can bridge the gap between the challenges of accelerating technological development and current design and engineering educational practice. This is to enable students to locate, evaluate and work creatively with knowledge to generate new and improved solutions that can tackle uncertain and future real-world challenges, while delivering impact and value for society. In the process, we introduce probabilistic knowledge as the most adequate model to translate potentialities into impact and value. This repositioning enables practitioners to move beyond proving reality to a generative space aiming to transform it. In this context we present abductive reasoning as a fundamental approach to deal with directional and transformational potentialities to tackle uncertainties.

Keywords: Abductive reasoning, prospective, probabilistic knowledge, innovation research

1 INTRODUCTION

As we are transitioning into a knowledge-based economy, frameworks addressing the translational processes around value and impact permeate the development of educational curriculums in the design and engineering educational spectrum. In response to this approach, this paper presents an operational framework that explores how abductive reasoning, and its embodied probabilistic knowledge can bridge the gap between the challenges of accelerating technological development and current design and engineering educational practice.

In the 1970s, John Chris Jones postulated that design was different from the arts, sciences, and mathematics.

> "The main point of difference is that of timing. Both artists and scientists operate on the physical world as it exists in the present (whether it is real or symbolic), while mathematicians operate on abstract relationships that are independent of historical time. Designers, on the other hand, are forever bound to treat as real that which exists only in an imagined future and have to specify ways in which the foreseen thing can be made to exist." [1]

As stated in the quote, he understood design as a future-led form of prospective thinking activity in the context of abductive reasoning in which the designer is making decisions without having all the information. Similarly, Dorst [2] and more recently Cramer-Petersen et al. [3] have concluded that design combines deductive and abductive reasoning.

This intrinsic prospective approach of design, based on abductive reasoning, planning, solution-based problem solving, problem shaping, synthesis, preparedness, readiness, and appropriateness in the built environment, determines a different model of knowing (Fig. 1). In this scenario, the designer is dealing with wicked problems by accessing areas yet-to-be or not-fully-formed [5]. Consequently, its output is based on potentialities, not certainties. We trade some degree of accuracy for access to areas that are yet-to-be or not-fully-formed. Therefore, our output is probabilistic, and research is always preliminary in its nature. Moreover, in exchange we provide guiding knowledge for prospective technological developments – as Glanville proposed, 'knowledge for' future action and possibilities rather than 'knowledge of' past actions and events [4]. Design practise is directional and transformational at its core.

In this context, we are more concerned with how things "ought to be'"[5:111-167] instead of how things actually are. These elements position design research as crucial for addressing the impact of the accelerating technological developments, based on technology complexity, black-box technologies, and wicked problems.

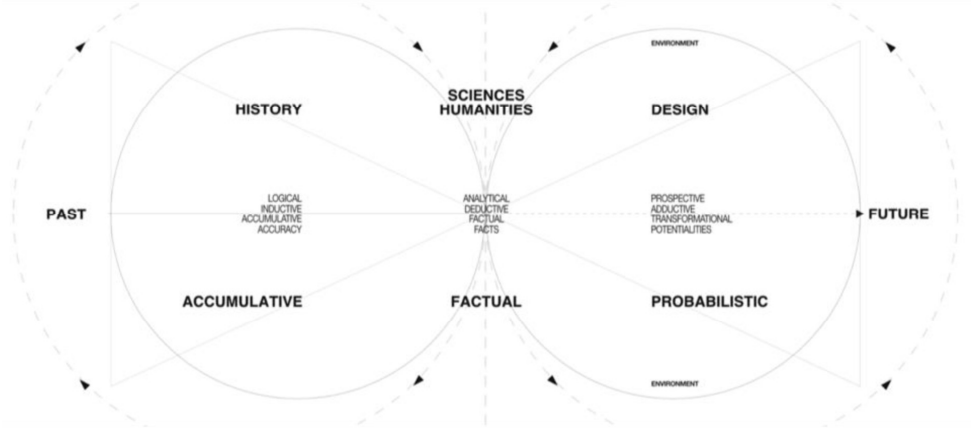


Figure 1. Prospective design research model. Fernando Galdon, 2019. [6]

2 ABDUCTION

An abduction process builds from an observation that aims for explaining an anomaly that is not possible to be addressed by an established theory. The abductive approach process moves, "from rule to result to case" [7:137]. It differs from deductive processes which move from rule to case to result. Or inductive logic which moves from case to result to rule. This approach is particularly helpful in the first stages of the research process, which is concerned with the formulation and selection process of hypotheses/propositions. In this context, abductive research helps to derive them in a way that can be tested in a final deductive phase of research. [7]

The fundamental focus of abductive reasoning is to search for a suitable theory to address a deviant/unexpected observation. This process is acknowledged by Dubois and Gadde [8] as "theory matching", or "systematic combining". In this process a learning loop is established by collecting simultaneously data and building the theory. It implies an interactive 'back and forth' directionality between theory and observation [7]. This process is similar to action research and can also be found in case study research. (Fig. 2)

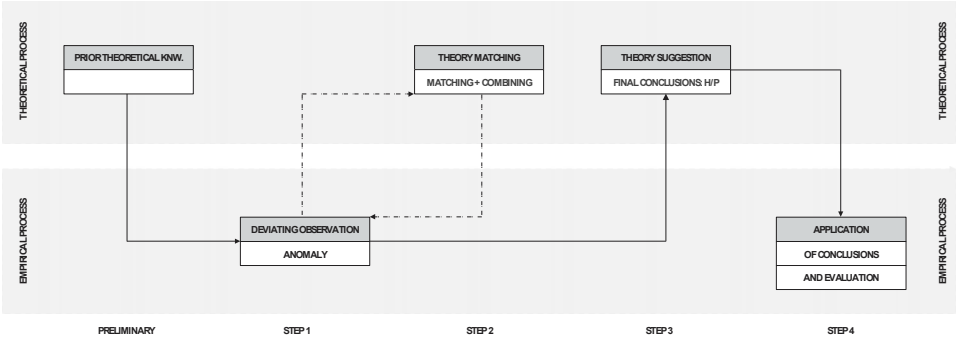


Figure 2. Abductive research framework. Galdon Building from Kovács & Spens (2005). [7]

3 PROBABILISTIC KNOWLEDGE

However, this future-led proposition presents a problem for the ontology of knowledge as currently configured. Current established practices are limited by the present, and the designer is the witness, either through measurement or observation. In this area, if we analyse what happens in economic research, we may find a suitable framework to solve this conundrum.

Economic forecasting is the process of making predictions about the economy. Economists use a statistical analysis of historical data to determine a forecast. Formal forecasts are produced yearly. However, quarterly updates or corrections are implemented to fine-tune the projection. The fundamental function of the economist is to anticipate future risks (i.e., events or conditions that can cause the result to vary from their initial estimates). These forecasts are continuously updated as the conditions of the environment evolve. These evolutions determine whether the adjustments will get tighter or looser, and how interest rates will vary, affecting a wide range of factors from loan repayments to employment levels.

This type of knowledge can be characterised as probabilistic knowledge of the future. Based on these economic forecasts, international institutions and governments infer value propositions. From this perspective, economic research enables design to access the future by legitimising probabilistic knowledge as a valid type of knowledge. This element provides a bridge to reconcile the probabilistic and abductive nature of design with established frameworks of practise that have so far been understood as factual [8]. This type of knowledge may facilitate how design and engineering students may address future challenges without fully knowing what they are.

The fundamental difference between economics and policy-making and design research is the directionality of the action. In design research we use this preliminary knowledge to co-shape the future. Design allows us to be proactive and move towards more imminent future transformations. The role of the designer is this process is to direct technological developments and reduce future risks to improve people's lives. (e.g., AI)

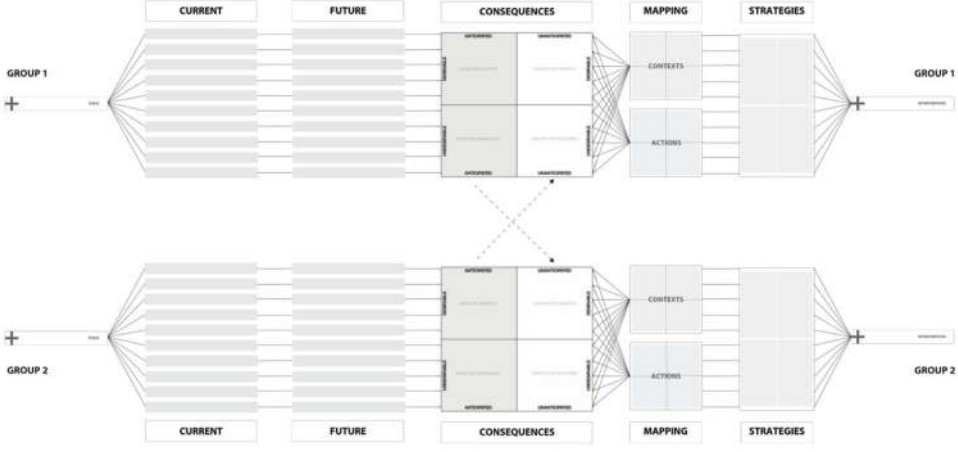
4 DISCUSSION

We tested this process through a case study investigating the changing and impactful nature of AI from a Machine Learning (ML), Deep Learning (DL), and Reinforcement Learning (RL) developments perspective via a Quasi-Experimental Non-equivalent Control Group Post-Test-Only Design. This experiment was conducted with postgraduate students from the RCA. Their diversity in terms of background, programme of study, culture and nationality, and their diverse, critical, and enabling capabilities, plus the unifying element of being designers, provided an ideal group of participants to develop the task at hand. Then, we implemented a cross-disciplinary and progressive evaluation process via peer-review academic conferences to infer transversality and robustness.

The process of abductive reasoning started when an observation in the early stages of the process did not match existing theories [9]. In the case study we conducted, this process started when we realised that the nature of AI was changing due to ML/DL/RL new development and implementations, therefore we needed a new theory to design its main elements – uncertainty and trust. Then, a creative iterative process of "theory matching" or "systematic combining" started in an attempt to find a new matching framework. The aim of this process was to understand the new phenomenon to suggest a new theory in the form of new hypotheses or propositions. This process led to figuring out a range of methods to address the nature of these emerging systems. This process constructed a theory of Prospective Design (PrD), which then was applied via a case study on Virtual Assistants (VA). The development and implementation process consisted of a combination of archival research, surveys, co-design activities, and workshops. These processes inserted consequential analyses to enable ethical directionalities in its development. (See [6] for detailed results)

In order to evaluate the output, we implemented an adaptation of the Quasi-Experimental multiple group post-test-only design, also known as Non-equivalent Control Group Post-Test-Only Design. In this type of design, the control group is non-equivalent, meaning that "participants are not assigned to either the experimental or the control group in a random manner" [10]. The pre-test was unnecessary to establish equivalence between groups, as all participants were design students from the same department and institution, and the workshops were both about the future technological development of VAs. In this context, the first workshop introduced a simplified version of the methodology (fig. 3), (control group) whereas the second workshop introduced an expanded version of model (Fig. 4).

Figure 3. Consequential analysis toolkit. [6]



The workshops aimed to understand whether prospective insights could be transformed into applied ethical interventions and grounded in the real world by applying a systematic analysis between the insight and the design activity to design trusted systems (Fig. 4). The simplified model generated reactive responses, whereas the full model created proactive responses.

In the second workshop, participants were asked to conduct the consequences quadrant used in Workshop 1, then each group mapped the anticipated desired and undesired, and by confronting both groups, the unanticipated emerged for each group (See [6] for detailed results and qualitative analysis). This element presented participants with their own limitations and enhanced self-criticality. They then mapped the prospective outcomes in terms of the impact on contexts and the impact of actions. This analytical step allowed them to understand the impact of contexts and actions on users. Finally, participants were asked to complete a design activity consisting of developing preventive strategies for the potentially harmful and power-asymmetric interactions they had mapped. They were requested to use counter-fictional principles to transform the dystopic into real-world strategies that could be applied. The results were successful, and presented strategies aiming to ground prospective insights in potential real-case interventions that aimed to reverse asymmetries to build trust. The author(s) initial research method focussed on qualitative research [6], however this research explores additional possibilities identified through a quantitative approach in order to frame future directions.

4.1 Future directions

As design and engineering education is transitioning from practise (output) to research (impact) questions of evaluation in the context of abductive reasoning emerged. How could we evaluate innovation when implementing abducting reasoning in the context of impact? In this context we present a potential framework to address this emerging reality based on work conducted as part of a PhD implementing abductivity and probabilism. In order to address the abductive process and its emerging theory and practice, a cross-disciplinary and progressive evaluation process was implemented via peer-review academic conferences (Fig. 5).

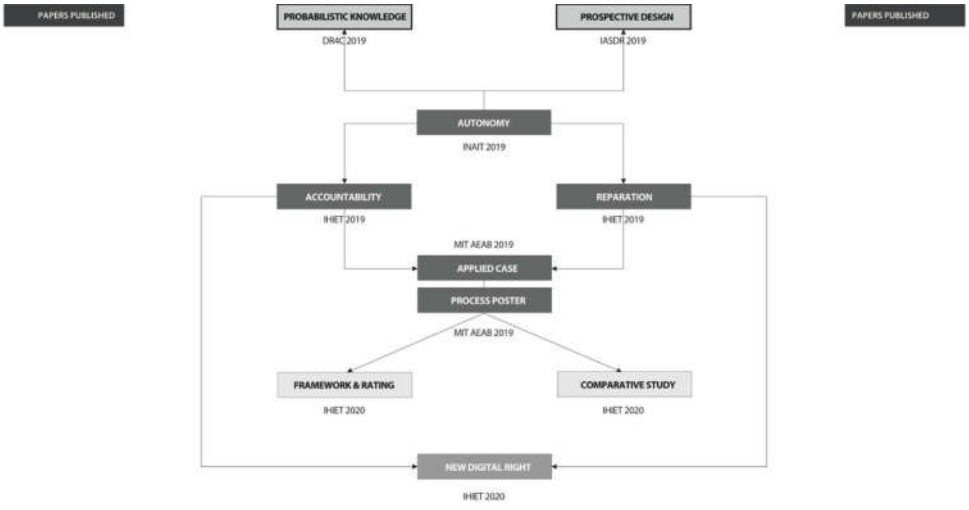


Figure 5. This table represents the progressive and cross-disciplinary publishing strategy implemented to generate robustness in the enquiry

The cross-disciplinary publishing strategy aimed to integrate diversity, transversality, impact, relevance, and responsibility in the process. As a result, we published ten papers in five different fields, ranging from Industry 4.0, human factors and design research to design futures, or applied engineering. This approach to practice aimed to support the design interventions and theoretical framework and enhance the impact of the research in terms of outputs and scrutiny by diverse audiences to maximise its transversality and therefore, its robustness. This model aims to facilitate a potential transition to impact-led practise, as well as affect and inspire educational models in design and engineering in breaking its silos and inserting more transdisciplinary in the development of their processes, curriculums, cohort formation, and/or faculty.

5 CONCLUSIONS

In this paper we introduced abductive reasoning and probabilistic knowledge as means to address notions of prospectivity and innovation via a case study on AI.

In the insights presented, the students implementing the full methodology understood, deployed, and tested both abductive thinking and the concept of prospective design and gained a process to deal with uncertainty and the ethical impact of technological developments. Consequently, we suggest the need to include prospective ethical frameworks in design to involve students in ethical issues: to go beyond what already exists, as well as beyond the positive impact of technology and design strategies to address and/or mitigate unintended consequences, as they are fundamental for the optimum development of society; to propose that things can be otherwise. In this context, probabilistic knowledge provides a bridge to reconcile the future-led and abductive nature of design. In the process, this work challenges and develops current notions in design education based on technological progress to a model based on ethical responsibility, which places equal value on the process of design and the impact of the system on society. In this context, abductive thinking becomes the primary design mindset in driving the transition from current to potential states, leading to the mediation of anticipated and non-anticipated consequences. Finally, the implementation of a Quasi-Experimental evaluation test inserted flexibility into the process, however, it also inserted preliminary. This element was addressed with a cross-disciplinary and progressive evaluation process via peer-reviewed academic conferences.

This work has been implemented in the context of sessions. Future work will be dedicated to adapting this framework to modular structures as a testbed to articulate a full academic curriculum.

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INTEGRATING DIGITISATION, MONITORING AND SELF-ORGANISATION SKILLS INTO INTEGRATED DESIGN ENGINEERING EDUCATION

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ABSTRACT
Mechanical engineering curriculums at German universities have mostly theoretical approaches to design theory. Several institutes and chairs have specialized courses regarding this topic, but these are seldomly integrated. The approach IDEE – Integrated Design Engineering Education – brings the specialized fields on design theory together in one course with a highly practical focus at the beginning of the mechanical engineering studies. This is realized by a mixture of theoretical lectures and a group project. For students, this includes their first experience of a complex group project with peers and also the first oral presentation in an engineering context. With a lack of professional and soft skills, there is often friction inside groups. There is also a need for appropriate tools to work collaboratively. Due to the Corona pandemic, lectures and the group project must be held completely online.
This paper describes our approach in helping the students improve their professional and personal skills by integrating new courses within the project, monitor their group dynamics, and also use digitisation to provide an online-only solution. This paper presents the challenges regarding soft skills and collaborative work as well as the chosen approach on how to integrate digitisation, monitoring, and self-organisation skills into the lecture to face the challenges.

Keywords: Digitisation, self-organisation, project-management, monitoring

1 INTRODUCTION

Classical mechanical engineering curriculums teach design contents in theoretical lectures during the first semesters and lack practical activities. Students often do not draw connections between lectures and struggle with exams, as these only focus on the repetition of this theoretical knowledge. Since the Bologna process, more and more attention has been paid to competence orientation in degree programmes. Generic competencies such as communication skills, problem-solving abilities, and self-directed, cooperative work are becoming increasingly important alongside subject-specific competencies [1]. For this reason, the lecture IDEE – Integrated Design Engineering Education – was created. It connects methods and knowledge from different fields to give insights into product development and complex processes while working in interdisciplinary teams. The lecture is given in the second semester, when students are quite new and at the start of the curriculum.
Over four weeks, we teach several bits of theoretical information, that are needed for a design project, for instance, there are lectures in Design Theory, Mechanical Design, Computer-Aided-Design (CAD), and Project Management. During IDEE, there are just some small bits of information, as all these topics are afterwards given as a full lecture during the bachelor curriculum. The students (appox. 150 in total) are organized into groups of about 10 – 15 while having three months to finish their design project from scratch. During this period, the groups have 6 meetings with their tutors – researchers from different mechanical engineering disciplines – to review their progress and discuss the next steps. In the end, each group must present their work in form of a business pitch to professors and researchers. They should highlight design aspects, as well as special features, that could convince potential customers to buy their respective products. The main idea is not having a perfectly designed product at this point, but to give

the students a first insight into the daily work of designers and explore working in a group of peers to strengthen their soft skills. It is also the first time for many to work in an intercultural team, as 10% of the students are internationals, especially from China, Cameroon, and Rwanda, while 90% of the students have an educational background from German-speaking countries.
The project was awarded a price for excellent concepts in teaching by the German conference of ministries of education and by the donors' association for the promotion of humanities and sciences in Germany in the year 2009.

2 CHALLENGES

In the last years, the students did quite well in building their first design projects, but in a more stressful and difficult way than we imagined. There are different reasons, why the project is so challenging for the students. First, there is a huge gap at the professional level. The students only have short introductory lectures for the different fields of engineering, design, and project management, as it is impossible to fully teach all aspects at this point of their studies. This leads to an overwhelming situation for all students, as they cannot develop professional competencies on that basis.
Second, students also lack soft skills. Since this project is the first group work with randomly selected peers from different cultural origins, there were often friction and miscommunication, which resulted in controversies. During the project management lecture, we shared some information about communication and conflict management, but the students could not use this knowledge on their own within the project teams. For efficient cooperation inside such groups, it is not sufficient to just have professional competencies. It is necessary to develop ideas, test them, and, if necessary, discard them. Compromises have to be found and it is important to work constructively on problem-solving. Many factors determine group performance such as group composition, the role of members, group size, etc. However, at the end of the day, the basic social, methodological, and personal competencies of individual team members and the team leader determine the performance of the group.
These competencies include self-organisation, self-reflection and self-motivation, teamwork and critical thinking skills, empathy, and type-appropriate communication as well as analytical thinking and presentation techniques.
During the final presentation, many students had difficulties focussing while giving a presentation, how to choose the right mixture of text and images and how to address the audience. Some, but not all students have these competencies, so that a random group could be chosen, where all students had a systemic lack of these skills.
Most of the time, tutors could assume the presence of problems in groups, but the students did not communicate them publicly, while there was no way to gain insight into the hidden dynamics inside the groups.
A third challenge is tools for collaborative work. There are three deliverables at the end of the design project: The students must upload a fully connected CAD model, a presentation of their work, and documentation with all requirements, functional logic and product architecture, mechanical dimensioning, and other project-related documents. At last, the Corona pandemic forced us to realize this course entirely online.

3 IMPLEMENTATION AND EVALUATION OF SOFT SKILLS AND DIGITISATION

Hence the biggest challenge mentioned previously is social and self-organisational skills of the students, we searched for partners to add specialized training to the course. At the TU Kaiserslautern, the Self-Learning Center (SLZ) offers various programmes to support students. By taking part in these offerings, students can strengthen their self-directed learning and self-organisation skills. Within the framework of the BMBF (German Federal Ministry of Education and Research) project "Selbstlernförderung als Grundlage. Die Förderung von Selbstlernfähigkeiten als integratives Konzept universitärer Lehre" (promoting self-learning approaches as an integral part of university teaching), we set up some additional courses in the project. Their objective is to build up specific competencies within the project, as well as generic competencies, which are promoted directly and indirectly. Most of the implementation was done in 2019, before the Covid19-pandemic and adapted to online-only in 2020.

3.1 Presentation Skills

The course has been expanded in 2019 to enhance the presentation skills of the students. While in the first step, all students received theoretical input in form of a lecture, and those who were chosen to present the project were given the chance to practice their presentation skills in front of an audience. Their performance was filmed and rated in real-time by their peers with the Live Feedback tool. Live Feedback is a web-based feedback tool developed and implemented in the Department of Didactics in Biology at the TU Kaiserslautern within the BMBF project U.EDU: Unified Education. Via a web interface, Live Feedback enables the capture and recording of feedback data by clicking a "thumb-up" or "thumbs-down" button during the presentation from any smartphone, tablet, or computer. Statistically processed and visualized, the feedback can be displayed over a timeline and the associated scenes of the presentation can be called up by clicking on the timeline. With the help of this feedback recording, tutors from the SLZ consulted the students on how to improve the presentation skills and avoid mistakes. Aside from this individual feedback, the SLZ offered a one-day workshop, in which the students who presented their project learned about presentation methods and could further improve their skills.

At the end of the project, those students who already presented at the beginning were asked again to give a presentation, this time on the business pitch of their project. These presentations were recorded and rated again and tutors from the SLZ analysed the improvements, which they discussed with the students.

In 2020, there was no possibility for live presentations in front of an audience. We had to change the original concept. Instead of the first "training" presentation session, we adapted an online course "presenting successfully online" especially for those students, who presented their project work at the end. In the online course, the team members had to work in tandems to gain knowledge in preparing and delivering an online presentation and how to integrate online tools into the presentation process. In four weeks, the presenters received weekly assignments to help them design their presentation slides step by step. Also, SLZ tutors gave feedback on the submitted assignments. Later on, the resulting presentations were given and recorded. By using a gamification approach, e.g., rankings, the tandems competed against each other and strengthened their self-directed learning and presentation skills [2].

3.2 Team Building

Another way to meet the challenges of the initial course concept in 2019 was to offer a workshop for the team-leaders of each group. This one-day workshop was designed interactively and included hands-on activities on how to lead a team. Students should learn to motivate their team, deal with conflict situations, and work cooperatively.

In 2020, the course was specifically designed online for the role of team leaders. The online course lasted 13 days and consisted of three learning units, which were unlocked gradually in the learning environment. The topics of the subsequent learning units consisted of "fundamentals of communication", "team and team development" and "motivation". Each learning unit included video screencasts and assignments. The students could explore the role of team leaders, support each other, and share ideas inside the group of team leaders.

3.3 Feedback and Monitoring

Within the framework of constructive conflict management in teams, it is important to recognize early on when problems in a group's dynamics arise, that could influence the outcome of the work. As these processes are hidden to tutors and students do not speak about group problems in public or do not recognize them as such, we again used the tool Live Feedback, this time for a hidden survey. This allowed the students to anonymously report their satisfaction with the teamwork and team dynamics at any time during the team formation and project work process. The students could give feedback regarding the parameters "workload distribution", "online communication", "satisfaction with their role", "professional difficulties", "conflict management" and "online cooperation" regarding their group. This feedback data was stored and timestamped in a database, statistically processed, and displayed by the tool. In this way, the tutors were able to get valuable information about problems or disagreements within the teams at an early stage and address them in the next team meeting. This allows adjusting the work-process for the upcoming time to solve problems. A tutor can see, if students have problems in solving their tasks and can give additional hints or check the understanding early on, before the team meeting.

We also used this tool during the live presentations in 2019. Students can vote on parameters like presentation style, content, visualization of the contents, and sales arguments for the designed product during the presentations. The votes are recorded and synchronized with timestamps in the video of the presentation so the SLZ tutors can discuss the reason for positive or negative feedback at a given time with the students.

3.4 Student Tutors

As mentioned, another big challenge is the huge gap between the professional knowledge required for a design project and the status quo of the students' knowledge at this time of their studies. The project is therefore often overwhelming. With the Live Feedback tool, we are now able to track the occurrence of those professional problems. Since the researchers in their role as tutors do not have enough time to fully support all teams, we hired student tutors. They serve as a coach on "eye-level" and help students inside the online classroom forum. They can give hints and provide insights from their own experience in past semesters. They also encouraged especially female and foreign students, who are often found to step back when it comes to presentations.

3.5 Collaborative CAD

In the past, the CAD software "Siemens Solid Edge" was used by the students, which is a classical single-user CAD system, that works with documents on a computer. For collaborative projects, all files have to be shared and synchronized in the group. This created problems, as students are not experienced and often used folders on their computers, that were not shared with the rest of the group. Especially when downloading machine elements like screws or bolts, the students implemented them right from their "Download" folder and forgot to add them to a shared project folder. Due to the need for synchronization, it is also hard to work with multiple people on a project at the same time, as one does not know what anyone else is simultaneously changing in this specific file.

We figured out two possible solutions for this problem: Product Data Management (PDM) or Product Lifecycle Management (PLM) software is designed to collaboratively work on projects, share data to ensure smooth workflows [3]. Another approach is cloud-based CAD [4]. As PLM would also add more complexity to the project work, we decided to solve this problem by using cloud-based CAD software. Over the last years, CAD software like Autodesk Fusion 360 or PTC Onshape became popular. They allow having either the file management in the cloud, while using an app on the own computer like Fusion 360 or working completely browser-based like Onshape. In 2017, after testing the software in a lecture with a smaller group [5], we chose the online-only approach of Onshape, to give the students the easiest possibility to work collaboratively. For each group, we set up a document, where all parts and assemblies could be created and modified. All members of the group have access and can work either remotely or in a group at the same time. Also, the tutors can check the progress of the groups at all times and evaluate the model easier than with paper drawings or images derived from Solid Edge. To track the progress and ensure, that the students cannot modify their project after the final deadline, we use the versioning feature in Onshape as shown in Figure 1.

Figure 1. Versioning and project result in Onshape

3.6 Virtual Learning Environment

Virtual learning environments can increase students' self-organisation and self-direction learning abilities. In addition to providing course contents, the learning environment can be didactically structured in a way that promotes generic competencies, while working on subject-related problems [2]. By working in groups, communicative and cooperative skills can be tested, and self-directed learning in groups can be improved [6]. OpenOLAT, based on open software, is the central Learning Management System (LMS) at the TU Kaiserslautern. It bundles various tools and functions to support communicative, coordinative, and cooperative processes. In such a course environment, events can be managed and organized, and materials can be made available. For IDEE, we created a new course environment in OpenOLAT. In the course, the contents of the lectures were provided and used to organize the assignment to the groups. This course was also used to provide access to the monitoring tool Live Feedback, as well as the CAD software Onshape and additional online training materials. For the exchange between students and their student tutors, we used a forum where all questions and answers were to be found. Also, the evaluation took place in OpenOLAT, where all documents had to be uploaded to a submission folder.

3.7 Switching to online-only

Although many tools have been used to enable online-only work, lectures, meetings between tutors and students, workshops and presentations required physical presence. As this was not possible due to the Covid19-pandemic, we switched as many contents as possible to online courses. The previous chapters include our approach regarding the workshops and presentations. As for the lectures, we used the principle of a flipped classroom. For some lectures, videos were recorded and provided inside the virtual learning environment, additional lectures were provided by written materials with the possibility for students to make appointments to ask further questions or ask for advice from the tutors.

The meetings, in which every group has to regularly present their progress to get feedback and ask topic-related questions were transformed into online meetings with the conference tool Skype for Business, which also supports the sharing of screen content. This allowed for broader participation than in the last years since there was no need for physical presence at the campus. The teams could present their current status and by muting / unmuting students, the tutors could very well monitor and control an equal collaboration of every group member.

As for the group work, there was a collaborative working platform for each group inside OpenOLAT, as well as an enterprise chat solution, where the groups could organize themselves. Over the last years, these solutions were partly available, but not used much. In 2020, the usage increased significantly, as the need for well-structured tools became clear to the students and physical meetings as a substitution for these tools were not possible.

As mentioned above, the presentations were recorded by the groups and rated by the tutors. Based on this rating and the performance of the groups during the design process, the project ended with a virtual award ceremony where groups with the best overall performance and the best presentation were honoured with small gifts.

3.8 Evaluation

To monitor the student's progress made concerning self-organisation skills, we initiated a voluntary survey at the beginning and the end of the lecture. 66 students participated in the initial survey and 35 in the final survey. To compare the results of both surveys, every student got an individual code. 15 respondents (n = 15) participated in both surveys. The following values refer to the 15 respondents which took part in both evaluations. In both surveys, the respondents were asked how they assessed their own presentation, teamwork, moderation, and self-organisation skills. Each item was rated on a 5-point scale (poor = 1, fair = 2, good = 3, very good = 4, excellent = 5It was found that the assessment of competence concerning teamwork and moderation skills increased more than about presentation and self-organisation skills. 26.7 % of the respondents rated their teamwork skills as 'excellent', while in the final survey 50 % of the respondents rated their teamwork skills as 'excellent'. In terms of moderation skills, 35.7 % of the respondents rated their moderation skills as 'very good' or 'excellent' in the initial survey, whereas 50 % of the respondents rated their moderation skills as 'very good' or 'excellent' in the final survey. There are fewer discrepancies in the student's self-assessment concerning presentation and self-organisation skills. In the initial survey, 20 % of respondents rated their presentation skills as 'very good' and none of them assessed these skills as 'excellent', while in the final

survey 13.3 % chose the category ‘very good’ and 6.7 % chose the category ‘excellent’. This might indicate the participants became more aware of their respective abilities and reflected on them. Self-organisation skills were rated as ‘very good’ or ‘excellent’ by 64.3 % of the respondents in the initial survey. In the final survey, the figure was 73.3 %. Based on this small group, an increase in assessment was seen in all four skills. This might indicate that the lecture IDEE initiated reflection processes for all topics addressed and made students aware of their performance. In the next run of the lecture IDEE, improvements should be made to increase the return rate of the survey to get more significant results. Also, the project can be further developed to improve presentation, teamwork, moderation, and self-organisation skills.

4 CONCLUSIONS AND OUTLOOK

IDEE is an approach to implement practical projects into the early phase of the mechanical engineering curriculum. This is quite overwhelming for students, as they lack professional and personal skills at this point in their studies. Therefore, we designed and implemented several measures to strengthen personal and team competencies, as well as provide more suitable tools to develop and design the group project. In 2019, we used on-site training and online tools as a mix, in 2020, we switched to an online-only approach. By integrating workshops in team-building and presentation, the students have improved their skills significantly. OpenOLAT and Onshape are good solutions for a virtual classroom, in which students can work collaboratively. Online-monitoring is a good way to detect problems early. The key factor for the success of this lecture is the combination of different engineering disciplines with monitoring of the students and opportunities to improve soft skills. At the moment, we plan to transfer the self-directed learning opportunities from IDEE to other lectures early in the curriculum and move the IDEE lecture into a later semester, as the lack of professional skills still is a huge challenge for students. Even with the end of the Covid19-pandemic at sight, there are huge opportunities in the online teaching approach. All teaching materials are available 24/7, tools ensure collaborative work and feedback loops are much shortened. On the other hand, personal and social interaction is more complicated, therefore, in further semesters we will try to include as many online elements as possible and mix these with on-site events for a better social and personal collaboration.

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A MINIMUM VIABLE SERVICE TO FACILITATE INTERNSHIP FOR DESIGN STUDENTS

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ABSTRACT
This paper poses the question how design students perceive organisation and learning outcome of an internship if the resources facilitated by the university is based on a minimum viable service. Data is gathered from a longitudinal study in the period 2008 to 2018, where students from the Department of Design participated in a 10 ECTS elective internship course. We aimed at balancing available resources with student learning, offering a minimum viable solution.
The students were fully responsible to establish contact with a business and make an agreement to conduct an internship. The business was responsible to provide students with a supervisor. University responsibility was to formalise and ensure quality. The main scope of the course included 180 hours of documented work in a business and a written internship report. The internship reports should answer to the course description and assignment criteria and have been the main data source for the study. A qualitative analysis has been performed and the results are then categorised and quantified to map the level of students' knowledge and skills. Kirkpatrick's evaluation model has been used together with learning outcome and the course assessment criteria. Findings from the study show that students seem to be satisfied with the organisational structure of internship. They also seem to benefit from the imposed responsibility, but there is no evidence of extended self-awareness, reflection, and critical thinking.

Keywords: Internship, experiential learning, work integrated learning

1 INTRODUCTION

Internship is an established form of teaching and learning in various Norwegian study programmes. Several of the study programmes are directed to have mandatory internship, defined in framework plans given by Ministry of Education and Research. Examples are nursing with 90/180 credits [1] and teachers' education with a minimum of 110 days [2]. The collective agreement for journalists encourages members to strengthen journalist education by establishing internship sites [1]. In 2019 26% of Norwegian students was offered a mandatory internship, and 21% was offered an elective internship [3].
A series of reports from the Norwegian Agency for Quality Assurance in Education (NOKUT) is investigating internship in Norwegian study programmes. One statement is that internship is a quite resource demanding form of teaching, from both a study programme leader, mentor, and administrative point of view [4]. Higher requirement of quality assessment, new data protection regulation, and a follow-up of mentors and students result in an increased use of resources for the study programme leader. An increased number of students leads to a need for more internship sites [5]. According to many of the mentors, time and resources are important issues. Lack of time, lack of economic compensation, and high number of students could be a challenge. At the same time, communication is pointed out as important [6]. Communication about the planning and information about the student(s) are mentioned as relevant issues. Apart from the mentioned reports, the question on use of university resources on internship implementation does not seem to have focus in the available literature. This study makes use of a case where an elective internship course was established, trying to balance available resources with student learning. The aim was to offer a high-quality course with a low-level budget.

[1] Journalism newspaper agreement between union and employer's association (NHO/MBL and NJ) § 13.2: https://www.nj.no/dokumentarkiv/journalistavtalen-for-mbl-avis/

This paper poses the following question: how students perceive organisation and learning outcome of an internship if the resources spent by the university are based on a minimum viable service to facilitate the design students.

Focus will also be directed towards the sacrifices made to achieve this, showing how downscaling university supervision, increasing the student's responsibility, and increasing requirements for student active learning affect the outcome of an internship period. Data is gathered from a longitudinal study in the period 2008 to 2018, where students from the Department of Design at NTNU participated in a 10 ECTS elective internship course within three bachelor programmes. The findings will be used to recommend how to prioritise available resources towards student learning when establishing an internship course.

The paper will start by presenting relevant theory and describe the methods used. Then the structure of internship as a learning activity will be explained before the findings from the student reports will be presented within a set of predefined categories. The study concludes with a recommendation.

2 METHOD

The study is based on action research, and in compliance with Levin [7] perspectives. An ethical question is related to the fact that the researcher also has possessed position as course responsible and study programme leader. The benefit from a double role is the in-depth knowledge about the activity being researched. One challenge could be that the researcher has blind spots [8]. To meet this problem, the research strategy is presented in a transparent way to easier become verified by others [9].

The empiric data contains 78 internship reports. They are analysed qualitatively, then the data are categorised and quantified. A summary of the quantitative data is presented with comments and assumed implications. For the analyses of data, a customised version of Kirkpatrick's evaluation model is being used [10].

Table 1. Evaluation model

Category	Description	Sub-categories
Reaction	An evaluation of how the participants find the training favourable, engaging, and relevant.	Process, work task and relevance, workload and schedule, internship site, supervision
Learning	To which degree the participants acquire the intended knowledge, skills, attitude, confidence, and commitment.	Recognising tools, methods and procedures, team, and communication, apply own knowledge, business culture, student active learning
Behaviour	The ability to reflect on internship as experiential learning.	No sub-categories
Result	Indicating if targeted learning outcomes would give further career advantages.	No sub-categories

The model was developed for evaluation of business training programmes and contains four main categories. The customised version is also inspired by Praslova's Adaptation of Kirkpatrick's four level model of training criteria to assessment of learning outcomes and programme evaluation in Higher Education [11]. In this paper the learning outcome and assessment criteria from course description are entered into sub-categories of the 'reaction' and 'learning' categories. Since the categories 'behaviour' and 'result' in Kirkpatrick's evaluation model are defined as external criteria, they are likely to be influenced by factors other than learning. This could be in an organisational or economic context. 'Behaviour' will in this context have a focus on the learning context, and 'result' will focus on additional outcomes like employment and career opportunities. The four categories with description and sub-categories are to be found in Table 1.

3 THEORY

This research is based on the theoretical paradigm closely related to individuals and community, internship, and experiential learning. Terms like practice, praxis and practitioners are discussed by Whittington [12]. He points towards that performing actions depends on the knowledge and skills possessed by each individual. This context could be used to elaborate on the distinction between agreed

practice and the performed practice in a business. This leads to the assumption that the practice established through common understanding, culture and understanding also needs to be interpretated by everyone. In this context, agreed and performed practice could deviate. An internship student could experience that situations are handled differently by different people in the same organisation. On the other hand, Nicolini [13] states that practice theories are based on the relationship between individual and community. Practice must be accepted as joint achievements in a mutual dependent situation. With a focus on practice and community, interaction, collaboration, and co-production seems more important than functions and hierarchies.

Experiential learning is described by Kolb [14] and Schatzki, Cetina, and Savigny [15] as learning directly connected with realities. They emphasise the significance of strengthening the connection between education, employment, and individual growth. In this way a necessary connection between professionally competence with corresponding learning outcome could be established.

According to Lave and Wenger [16], all learning is located to social situations, and learning would likely happen in a community of practice. Wenger [17] states, «Since the beginning of history, human beings have formed communities that share cultural practices reflecting their collective learning». The term legitimate peripheral participation is being used to describe how participation in a community could take different forms, and that individuals' affiliation could be more or less comprehensive [16]. In their conceptual model, Hatchuel, Le Masson [18] emphasise the importance to understand the connection between use of a tool, and the culture in which the tool is being used. In this understanding, learning to use a tool in the university is different than using the tool in a workplace.

4 IMPLICATIONS OF INTERNSHIP WITH A MINIMUM VIABLE SERVICE

In 2008 an internship course was established as an elective, available for students at the Department of Design. The criteria were that an internship should be an extension of the classroom, learned skills should be transferable, run for a defined period, learning objectives are defined and mentoring is performed by a professional [19]. The decision was grounded both in the wish of adding a more experiential learning [13, 14] to the curriculum, learning as part of a social practice [16] and a wish from students to increase the practice-based part of their education. As mentioned by Kantardjiev and Wiggen [4], managing student internship could be resource demanding. Thus, on both study programme level, department level, faculty level and university level, decisions need to be made regarding the extent and the role internships should take in order to balance available resources with student learning. In practice this could mean that resources are limited and that teachers must make do with minimum viable solutions. The case used in this study managed within a budget corresponding 70 man-hours.

4.1 Organising the internship course

Establishing the course and making sure to take care of the core principles of experiential learning in a community of practice [16], and to fulfil the academic learning outcome, was of high importance. A 10-credit elective course was offered in the third year of three bachelor programmes. The third-year students were considered the most mature and independent. With an elective course one could assume fewer, but more motivated students than if the course were mandatory. Calculated workload was 250 hours of which minimum 180 hours present in business and up to 70 hours organising and reporting. Responsibility was shared as follows: 1) The students have full responsibility to contact and agree with the business about an internship period, organise the period, and reporting back to university. Two report deliveries have two different intentions: the status report is intended to keep university attention on how each intern progress. The full internship report is to be graded. 2) The business is responsible for serving relevant work tasks and mentoring the student. Leaving the mentor role to the business create both a risk and an opportunity. A risk because quality could be more unpredictable, an opportunity because of disconnecting the university culture. 3) The university verifies, accepts, and formalises an agreement, to ensure quality before starting up, and involves the mentor in evaluation and grading. A start up seminar has also been provided. The mentioned sharing of responsibility is supported by Sweitzer [20] describing the successful internship. The key features of success relate to engagement, and to be active and take responsibility are key factors.

5 STUDENTS' PERCEPTION – DATA FROM THE INTERNSHIP REPORTS

In the period 2008-2018 78 students from the Department of Design have fulfilled the internship course, one student started an internship but dropped out. During the years 2008-2016 the number of students

increased from 2 and up to 8 students annually. During the years 2017-2018 this increased to 11 and 17. The internship course was not offered in 2019 and was implemented as mandatory in 2020. Internship reports (2008-2018) delivered at the end of the internship period will be analysed in this chapter. From the statistics it seems like the students are eager to find an internship site of interest. Since almost 40% of the students choose an internship site located more than one hour travel away from campus, it seems like relevance is prioritised before distance. Workload is documented in the reports and confirmed by the supervisors to be at least 180 hours at the internship site. There is no evidence in amount of work hours spent on planning and documentation.

5.1 Data from the internship reports

The analyses of the internship reports are based on Kirkpatrick's evaluation model. The four categories reaction, learning, behaviour, and result, with corresponding learning outcomes from the course description, are being used to describe student perception of participating the internship course.
The analysis is done by objective evaluation of written statements with focus on how the candidate describe his/her experience of each of the categories. The score indicates whether the candidate is highly satisfied (1), satisfied (2), less satisfied (3) or not satisfied (4). Last score is if the category is not mentioned at all (5).

Table 2. Reaction, an evaluation of how the participants find the training favourable, engaging, and relevant

Highly satisfied	Satisfied	Less satisfied	Not satisfied	Not mentioned
42%	10%	11%	2%	35%

The category reaction should measure the level of participants satisfaction and if the participants find internship favourable, engaging, and relevant. The sub-categories are mentioned in Table 1.
Findings show that the students' reactions are mainly positive. 52% of the reports contains statements that indicate satisfaction "highly" or to "some degree". The sub-category "Process" stands out by not being mentioned in 76% of the reports. Somehow this does not match with the corresponding category "student active learning" in the next section. Also, the sub-category "supervision resources" have a higher rate of "not mentioned" in the reports. Only 2% of the reports contain description of any negative experiences with supervision, and those are mostly about lack of resources. It seems like many of the reports document an expectation that being an intern equals independent work.

Table 3. Learning, to which degree the participants acquire the intended knowledge, skills, attitude, confidence, and commitment

Highly satisfied	Satisfied	Less satisfied	Not satisfied	Not mentioned
58%	12%	14%	0%	16%

The category learning relates to the course learning outcome and assessment criteria. The analyses focus on conveyed improvement of knowledge and enhancement of skills. This also include change of attitude, confidence, and commitment. The analyses have focused on the sub-categories mentioned in Table 1.
Findings show that the students' reactions are mainly positive. 70% of the reports contains statements that indicate that satisfaction is "highly" or to "some degree". The sub-category "team and communication" gets the lowest score with 49% "highly" or to "some degree". With the expectations of internship as high level of independence, this do not need to be negative. As mentioned in the previous section, "student active learning" get a quite high score with 58% "highly" or to "some degree", and a negative statement is only found in one report. In 24% of the reports the topic is not mentioned. This leaves an impression that being student active is considered to be a positive requirement. "Team and communication" are also considered to be important parts of the internship learning the learning outcome could be influenced [16]. The score is close to 50%.

Table 4. Behaviour, what students learned during training

Highly satisfied	Satisfied	Less satisfied	Not satisfied	Not mentioned
14%	13%	25%	3%	45%

Behaviour is about change of attitude and whether the students can apply what they learned. This is also about whether the candidate shows the ability to be critical and reflective about their experiential learning. Almost half of the reports does not mention anything about this, 27% is "highly" or to "some degree" positive, and 3% states some negative experiences. Being aware of a change of behaviour is

highly connected to the ability to reflect on a learning experience. It seems like the low score in this category could be due to either lack of ability to reflect, or that this topic has not been seen as important when writing the report.

Table 5. Result, indicating if targeted learning outcomes would give further career advantages

Highly satisfied	Satisfied	Less satisfied	Not satisfied	Not mentioned
12%	13%	13%	3%	59%

Result is the category where it is considered whether the targeted outcomes would give further career advantages. The candidate should reflect on their goals and whether they have achieved more than described in learning and behaviour. In 25% of the reports, it is stated that interns are "highly" or to "some degree" satisfied. Typical answers would be better knowing your career direction, understanding other educational issues, or getting a job offer. In 59% of the reports this category was omitted. It would have been noteworthy to also know the experience from those students.

5.2 A corresponding survey

A survey conducted with a group of alumni design students showed that they appreciate internship as a course giving insights to important topics as creative processes and knowing the use of important tools [18, 21]. Another finding was that students find internships realistic and see it as an experience preparing for working life. The internship was appreciated also because the students felt it helped them prepare for workload and expectations from a future employer.

6 RECOMMENDATIONS

Using a minimum viable service means a trade-off where less faculty involvement results in more responsibility for each student. Nevertheless, when a mandatory internship is established, the university must be responsible to ensure that all students will be in connection with an internship site. A formal network of businesses is established to support this concern. To assist the time-consuming management of networking and internship issues, a web application is developed. The application will support both student active processes and formal activities like communication, internship applications, signing of contracts, and mentor feedback (ready to be used fall 2021).

Engagement is one of the key features of a successful internship [20]. The students seem to be able to bring the active and engaged position created by the search and apply process further into the internship period. This was probably one of the benefits from using the minimum viable service. The process where students are responsible to approach businesses and apply for an internship will be continued, now supported by the network of available businesses. This active start will hopefully continue to bring a boost to the student engagement, resulting in an increased learning outcome.

By nature, the learning outcome from an internship is dependent on the student, the internship site, and the supervisor. Both being supervised and participating a team is important in the sharing of cultural practices and collective learning [9, 10]. One challenge is that learning outcome from an internship period is also dependent on the business attitude towards supervising and available work tasks. One might need to accept that a diversity within supervision is present, thus resulting in a diversity in learning outcome at different internship sites. This difference could be balanced by the student being active in seeking supervision and to become a part of the community of practice at the internship site [17]. Also, a more active use of the business network could increase engagement between business and university, resulting in awareness about the shared responsibility. Despite the less predictable situation when using business mentors in supervising the students, this feature is recommended to continue. This is because the assumption that learning outside the university culture is more important [14, 15] than offering equality.

For the students to be able to understand change of attitude and the result of an internship, they must be able to reflect on their participation [9] and how they apply new knowledge. Findings show that the student's ability to achieve this is quite low. This could be because of the minimum viable service. To extend self-awareness and critical thinking, the start-up seminar needs to add an increased focus to this aspect. In addition, the students should be obliqued to hand in a preliminary version of the internship report to enable feedback before making the final delivery.

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FROM CO-DESIGN TO CO-EDUCATION: A COMMUNITY COLLABORATION STUDY CASE FOR DESIGN EDUCATION

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ABSTRACT
Design education aims to serve environmental, technological and societal changes and challenges. While evidence suggests a worldwide increase of cross-disciplinary working as partnerships transcend the confines of predefined and historical silos. Thus, the premise of this paper is that the field of design needs to engage design students more regularly with community collaboration and broaden the application of design skills into more diverse arenas of creative problem solving.
Co-design activities are emphasised as an approach which is focused on processes and procedures of design, not just a design style. In this case, as part of an experiment teaching project in Tongji University, College of Design & Innovation undergraduate programme, we tried to bridge co-design methods with design education process in environmental design studio course, in which the second-year students are required to be aware of design process and the ability of cross-disciplinary working and collaboration.
This paper will introduce the course syllabus and processes on how to involve in co-design method and community collaboration and will also examines how those pedagogical approaches has been applied in three different school years: 2016, 2018 and 2019. It will detail the different approaches each year have used to construct learning opportunities, along with a profile of the participants, resources and methods utilized. The findings will provide a structure to compare and contrast different approaches used in different years in order to draw conclusions regarding outcomes. The research is still in its early stage, while aims to raise discussion about how to educate students who can effectively tackle the multi-disciplinary wicked challenges of the future.

Keywords: Design education, co-design, community collaboration, pedagogical research

1 BACKGROUND

Evidence suggests a worldwide increase of cross-disciplinary working as partnerships transcend the confines of predefined and historical silos. The challenges of this era are no longer defined in single discipline or individual effort. Design education aims to 'serve environmental, technological and societal changes and challenges. Thus, according to the challenges, we need new studies to investigate and explore the issues involved in methods of design education as well as methods of practice. (Lou YQ.2013) We need an innovative and inclusive educational ecosystem that will enable the application of new knowledge and methods to generate social and economic changes.
It is a fact that design research, as a way of interpreting and producing knowledge on the reality, has enhanced, in the last decades, by applying a certain range of tools and practices that currently are recognized under the umbrella of co-design. Today co-design is understood as the transversal approach to lead design research into different design domains of application, from user driven projects conducted by design firms to more open innovation projects lead by companies or designers that want to collaborate with their users in innovation generation. (Francesca Rizzo. 2011)
Co-design activities are emphasized as an approach which is focused on processes and procedures of design, instead of just a design style or physical outcome. The activities are usually applied to enhance idea generation and strategic concept design, which are benefit and characterized by the participation of non-designer's stakeholders and lead by designers.

With this background, we begin to experiment in a proactive way in design education, connecting and sharing experiments through educational practice, improving co-design methods and tools that can apply in a variety of educational courses contexts. The impacts then be measured not by individual student's design drawing skills, but by their abilities to solve problem in the more complex context and the abilities of collaboration in a wide range of situations.

In this case, supported by the Pedagogical Research Projects in Tongji University, we tried to bridge co-design methods with design education process in environmental design studio course (1), in which the second-year students are trained to be aware of basic design skills and process and also capable of interacting with and understanding specialists from a wide range of disciplines and functional areas.

The environmental design studio course (1) provides interdisciplinary design training and education to students at Tongji University College of Design and Innovation, including its international and exchange students.

The idea of this research is to create an alternative educational opportunity that more regularly engage design students with community collaboration and broaden the application of design skills into more diverse arenas of creative problem solving. There is nothing more challenging to the students than placing them into a real world context where it is impossible to work without immersing with the users and the context in order to move on to idea generation. And there is no more challenging context to understand than the social context in community regeneration.

2 CASE INTRODUCTIONS

2.1 Curriculum

Contact Hours: 136 hours (17 weeks, 8hours/week)

Major: Industrial Design, Environmental Design

Assessment: Course work and assignments

Prerequisite: Design Basics

Students: maximum 36 (divide into 6-8 groups)

Course Objective and Requirement:

The course is the first specialized design studio for the students of Environmental Design Programme. The students are required to synthesize the various knowledge and skills, to use holistic, human-centred and sustainable way to create and enable a sustainable life-space, including experience, communication and space that facilitate interaction of humans with their surroundings. Based on "problem-based" learning approach, the course will involve projects with real contexts. The topics of the studio will focus on today's real-world challenges especially community renew issues. At the same time, the course encourages the collaboration with industries, government or community in the critical and prospective view.

The overall objective of this course is helping students have a substantial increase in terms of in-depth understanding of the programme, ability of design process, design methods, and skills. The course helps students:

a) to better understand what basic design process is, including define problem, collect information, brainstorm & analyse, develop prototype, test ideas and get feedback, improve design. The course will evaluate whether there is a compelling research, methods and processes.

b) to stress both the holistic skills and the design outcome. They need to seek their answers in a broad and interdisciplinary context, address its ecological, societal and commercial impact, as well as the relationship with other disciplines.

c) to present their outcome. The course will focus on training students' holistic communication skills. The course will organize an exhibition as a part of the final presentation and invite guests from industry, community and university.

The course is structured in five modules:

1. Lectures and Seminars 1 (2 weeks)

Based on the selected project, curriculum and schedule, the course will have selected lectures, mainly to introduce the relevant theory, research and design skills, and expertise related to the subject and so on.

2. Workshop 1 (4 weeks) (group work)

Project related with basic place making and communication. Indoor or outdoor mall scale design such as street booth, pop-up exhibition booth etc.

3. Lectures and Seminars 2 (2 weeks)

Based on the selected project, curriculum and schedule, the course will have selected lectures, mainly to introduce the relevant theory, research and design skills, and expertise related to the subject and so on.

4. Workshop 2 (8 weeks) (group work)

Project in the real world with real community users and needs such as small-scale community renew. With more complex context and stakeholders to communicate and research, students will need to use more broad knowledge and skills to solve problem. The selected design works need to be implemented.

5. Exhibition and Presentation (1 week)

At the end of the course, an exhibition and seminar will be organized for experience exchanging and sharing.

2.2 Methodology

Rationale for comparison:

These three year courses are sharing the same curriculum in many ways in: students background, course structure, objective and teaching team. The differences are mostly in the third and fourth modules about how to choose the working project. These similarities and differences offer a unique opportunity to compare approaches to teaching.

The courses' results are distinct as a reflection of three years different projects, scope and working requirements:

Table 1. The comparison of Module 4 project in three years

year	Project of module 4	Stakeholders	Methods		Real-life exposure
2016 33 students	Space renew in College building	-Students -Teachers -College staff -visitors	observation	personas	10%
			survey	scenarios	
			interview	quick prototype	
2018 32 students	Residential Building Public Space Renew in Siping Community	-Residents -Government -Visitors -Community workers	observation	personas	30%
			survey	interview	
			storyboard	scenarios	
			quick prototype	user journey map	
			co-design workshop	Implementation	
2019 34 students	Space Renew in Siping Community (students should define their own design location and scope)	-Residents -Government -Visitors -Community workers	observation	personas	50%
			survey	interview	
			storyboard	scenarios	
			user journey map	quick prototype	
			co-design workshop	solution evaluation	
			community meeting	Implementation	

Through the process observation and the questionnaire of students, we find out that some of the methods had significant effect on the course objective which involved the "real" stakeholders in the design education process. The following methods or steps exposed our students to the real life and through which the students got increased skill on collaboration, communication and understanding of the real world changelings, while at the same time active young students and fresh mind brought the community (the Siping community is a typical aging community in Shanghai) change and energy. With this background, education methods and process transferred into a double side benefit way, after reviewing the whole feedback of the case, we turned out to call it **Co-Education** process.

-Field Visit and User Observations Database
The first field visit and user observation are usually frustrated to the students. Lack of understanding of the project, most of the residents refuse to collaborate and even oppose to them. For the students, lack of experience to work with real user, they even do not know how to start communication with strangers. This experience helped students to think and learn from real life, to face the real world challenging that may never appears on a textbook.
-User Interview
With the help from teaching ream, our students had progress on user interview part. They start to think how to work with different stakeholders and how to encourage them to engage more into the project. It became a spontaneous learning process, and it is more effective than imparted from teachers.

Figure 1.community meeting

Figure 2.3.Co-design workshops

-Community Meeting
We encourage students to invite their target user to participate in the meeting, in which teachers will introduce the overall project and answer questions from the residents. Students and their users sit in group and have activities to warm up and build trust.
-Co-design Workshop
Among all the methods used in the teaching process, the co-design workshop addressed with deviation that may arising in both the design and educational process. In the year 2018 and 2019 module 4, We organized expert designers who dedicated in community social innovation design, government managers, residents and students, to carry out co-design workshops several times with two main purposes. One was to enhance idea generation and strategic concept design also inspire design process by communication with different stakeholders, and the other was to help students training the ability of trans-disciplinary working and thinking in more diverse perspective.
-Implementation
From the above processes, residents understood more about the design objective, got familiar with their young designers, some of them even involved in the decision-making process. Most of the users showed supportive to the implementing process and even tried to help in many ways. It was touching that some of them provided water and fruit and even invited students to have dinner in their home. This experience helped students understand more about the core of co-design “from design for people, to design with people”, and in the questionnaire some students said at the moment they felt the value of design.

Figure 4. the implementation process

2.3 Results
As a result, the course not only encourages collaboration between students, but also closely relates to emerging real-world challenges.
Real project practice allows undergraduates to obtain knowledge from more than a single discipline with a sufficiently broad perspective (Hobday et al. 2011). Embedded co-design methods encouraged students to communicate and get quick feedback from the real stakeholders. We see this as a viable experiment that is able to respond to Don Norman’s criticism on general design education - trying to encounter complex and comprehensive challenges from the real world but failing to do so due to a lack of necessary knowledge and skills (Norman, 2010). In its essence, the experimental educational case we envision here is, using co-design methods to break the rigid barriers between disciplines, and integrating

knowledge and skills at different levels to satisfy the needs and to realize the values arising from this changing world (Buchanan, 1992).
Using the survey results, we identified two notions that reflected outcomes from the class that we felt could be emphasized to the course research:

Table 2. The comparison of feedback from students in three years

year	Feedback questionnaire from the students		Course rating (100)
	positive	negative	
2016	-Learned how to think more open-minded. -Diversity, group work. -Time management. -Idea generation.	-Hard to work in team -lack of design analysis methods	87.5
2018	-The chance to work with real users. -The way we work as team to find solutions and generate ideas. -Set of creation and co-design. -Flexibility. -Very challenging in the 2nd project. -Design thinking and methods.	-Very challenging in the complementation phase. -Frustrated while communicating with some residents.	90.7
2019	-Real practice opportunity. -Confidence communion. -Diversity, group work. -Negotiation skills. -Time management. -Solid ability of co-working. -Idea generation. -motivation	-Consuming a great deal of time outside class. -Lack of complementation knowledge. -Hard to define and narrow down the problem.	89.9

3 FINDINGS

According to students' free responses to university administered surveys, there were increasing positive feedback among students who participated in the course among three years. However, the average overall course rating slightly decreased in year 2019, and students spent more time on their projects outside of class time than students in previous versions of the course.

3.1 Teamwork

Even though our design students do not have teamwork experience in previous courses, and are not trained to have teamwork skills, it showed that co-design working process with community residents and diverse methods using helps the students to response more active when facing collaboration problems. "During the community project, I turned to find out that the tools help us to communicate with the community residents, could also work in our team members. They are great methods that helps to facilitate and avoid useless struggle in the process." One student said after the course. This is also coupled with observational experience of watching student teams during the three years in the process. They tend to be willing to take initiative and jump into the more open-ended process.

3.2 Working and learning location

Location for the module 4 projects of learning experiences is critical. In school, students feel like students, in the off-campus community spaces, they feel and behave more professionally. This helped the students to be more focused and have a sense of mission. It seems that standard classroom space is not conducive to creating these types of learning experiences.

3.3 Soft skills

Some of the greatest benefits for students participating in these co-design workshops are soft skills that are more challenging to measure. It is clear that this type of experience working with the real world users presents best practices to prepare students for real teamwork in the future environment, as they are working across significant disciplinary boundaries. As in the case, students express being more empowered to take less-defined challenges such as module 4. Being connected to real-world challenges,

they see themselves as agents of change in the world and are motivated to participate. Showed from the teachers' observation and students' feedback, students' soft skills for working with others, dealing with complex context, and presenting through are clearly enhanced.

3.4 Values

The focus of these course experiences is to better prepare students for the changing future world, not to only provide professional skills. Meanwhile, in this course project experience, the real value is both for the students and the community. Communities get significant value from the work that students do, though it may not be complete or fully refined in the end. However, the co-design process activates the residents and other community members to think about their own environments' problems, helped framing and solving community issues not only related with the course defined project scope. And students, beside teamwork and soft skills, develop their professional skills in a hybrid academic-professional environment and more willingness to take risks.

Moreover, those values are true for students as well as faculty. Faculty team step out of their comfort zones and expend their areas of expertise during the process.

4 CONCLUSIONS

This paper is a novel approach to embed co-working methods in design education process and at a theoretical level as a very early step. Appropriately defining the project challenge and desired outcomes is critical to the education outcome. From experience in year 2019, leaving the project too broad, and expecting student teams to define their own challenge, tends to get solutions complicated and hard to push into the implementation phase. On the other extreme in year 2016, being too narrow with the problem defined denies students the opportunity to discover and define their own challenges and decreases intrinsic motivation among students. While the research has strong institutional support and a refined efficient structure and is expected to continue in the coming years. The joint team will continue to explore the educational offering for the students in the diversified group with new challenges from the economy, society and technology.

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A TOOL FOR PROMOTING INTRINSIC MOTIVATION IN TEAMS: A CASE STUDY OF PARTICIPANTS' MOTIVATION DURING A DESIGN PROJECT

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ABSTRACT
Intrinsic motivation is a prerequisite for creativity. Research requires more studies on the prerequisites for intrinsic motivation where design thinking is used as an approach to develop a tool. In this case study, such a tool was developed to help project managers understand what creates intrinsic motivation in team members of a student project. The research question was: How can product design help project managers prevent demotivation in project work? Qualitative methods were used to gain an in-depth understanding of what strengthens, or weakens, intrinsic motivation. Data was collected from a student's insider perspective of daily documentation of a creative project, 'Design Studio', with participants from three levels of education, where the third year students were leaders in a Department of Product Design. Inspired by a 'grounded theory' approach, the analysis process pointed to three categories in which factors were identified that seemed to strengthen motivation. The three factors were commitment, sense of mastery and productivity. The discussion revolves around how such a product design-based tool can help project managers map what strengthens or weakens commitment, sense of mastery and productivity among team members. The conclusion encourages project managers to use evaluation during the process, with the intention of mapping when and how the three factors were strengthened or weakened, and logging the data using the tool.

Keywords: Adaptability, engagement, education, management, collaboration

1 INTRODUCTION: LEADERSHIP AND CREATIVITY

Studies have been conducted that address how motivation affects creativity. An article on leadership behaviour and the work environment for creativity [1] and a model for creativity and innovation developed by Teresa M. Amabile [2] both point out that inner motivation is a prerequisite for creativity to unfold in project work. Internal motivation occurs when the motivation is driven by interest, pleasure and the challenges of the work tasks [3]. Some external motivational factors can be seen as important when it comes to creativity [2]. External motivation is driven by external sources that are not directly related to the task [3]. Objectives, reward systems, evaluations and pressure are aspects of the creative work environment that are considered external motivational factors [2]. It has been discussed whether the external motivational factors can be used with a sensible approach to promote creativity. In 2016, Amabile published an article, in collaboration with Michael G. Pratt, in which new theories were developed within the same framework. The research built on the theories that were published in 1988 [3] and generated new knowledge in the field. Theories stating that external motivational factors can have an effect on creativity were not rejected, though it was emphasised that a strong inner motivation for a task is absolutely decisive for how creativity takes place in a project [3]. This background provides the research question: How can product design help project managers prevent demotivation in project work? Relevant sub-questions that are taken into account to answer the research question are: 1) What factors strengthen or weaken motivation among team members in the context of project work? 2) In what way can project managers facilitate motivation among team members? The study searches for answers to this to form a holistic picture of specific ways in which project managers can facilitate motivation among team members.

1.1 Relevance of this study

The abovementioned studies provide an understanding of how motivation can have an impact on creativity, and that intrinsic motivation is a prerequisite for creativity. However, they provide little information about how the inner motivation arises. There is potential in researching how motivation can be facilitated, and how activities that are not controlled by inner motivation can be facilitated. The study is considered relevant to project managers working in teams.

1.2 In what way is design competence important in this discussion?

'Design thinking' methods represent an approach that can be used in connection with problem solving in product design. The approach is a people-oriented way of working, innovating, and developing, and involves ways of solving problems that can provide valuable benefits [4]. In this study, the method was used to develop a tool which project managers can use to form an understanding of what creates motivation in their team. The analysis of the database provided insights that were used to prepare the tool.

2 METHODS: A QUALITATIVE CASE STUDY

2.1 Collection of data

Qualitative research was used through case study [5]. The purpose was to gain an in-depth understanding of the factors that strengthen or weaken, motivation among team members in the context of project work. The research is limited to a project that took place in the fall of 2019. The team consisted of product design students, and the project goal was to develop sustainable packaging. The project was one of several projects that were carried out in connection with Project Design Office, an annual collaboration project involving first-, second- and third-year students at the Department of Product Design at Oslo Metropolitan University. The third year students are project managers, and one of the learning objectives is to experience the leadership role. The project used in this study had 11 participants: four leaders and seven team members from the first- and second-year cohorts. The study was directed by source-oriented research [5], and the approach facilitated the use of existing information derived from documentation of practice.

2.2 Analysis of data

Analysis of the empirical data in the case was inspired by grounded theory [5]. In the context of this study, the method was simplified and limited to dealing only with data collection based on documentation and reports from the current project. During the analysis of the documentation, searches were conducted for factors that strengthened or weakened the inner motivation of the team members. These were synthesised into three categories, and three factors, and formed the basis for the development of a tool that shows project managers how they can facilitate motivation among their team members.

3 DATA COLLECTION: THE PROJECT AND THE PARTICIPANTS' MOTIVATION

The source-oriented research was based on a database that originated in one systematic documentation of each working day during the three weeks of the project. The documentation was performed by the leaders and consisted of an evaluation of the working day. The daily evaluation was made at the end of the day, in plenary, with both the leaders and the team members present. The evaluation was based on the following points: 1) What was done today? 2) What worked well? 3) What could have worked better? 4) The leaders' own reflections on how the feedback could be used for planning the subsequent working days. The changes and adjustments the leaders made based on the feedback during the evaluation, and how they played out in practice, were also recorded in the document. The documentation will later be referred to as the 'evaluation'. The document comprises a total of 17 A4 pages. The database was anonymised for privacy reasons and was not published. In the reference list, it is referred to as 'Dynamic Project Leadership BAPD3000, Oslo Metropolitan University 2019' [6] with a link to the course, including information and contact details for the course leader. The database was valid for the entire analysis.

4 CATEGORISED DOCUMENTATIONS FROM THE PROJECT

In the analysis process, the connection between the various activities and tasks, and whether team members experienced motivation were interpreted inspired from grounded theory methods. The changes that were made to facilitate and adapt activities and work tasks during the process, and the results, were also taken into account during the analysis process. The analysis mapped patterns that indicated situations that created both motivation and demotivation.

4.1 Category 1: The use of warm-up exercises

In general, various forms of exercises and games were used, independent of the project objective. The purpose was to prepare the team members for the subsequent tasks, and the preparatory exercises had a clear connection with the work tasks. As a preparatory exercise for idea generation, the team members played, for example, a form of Chinese whispers, a game that basically involves visualising different words and explaining a word visualised by one's opponent. The preparatory exercises had a very positive effect on the subsequent work that was performed that day, according to the evaluation. The exercises resulted in a low threshold for working on idea generation, and generally created productivity and engagement. On days when no preparatory exercises were done, the team members found it difficult to get started on their tasks. As a result, several team members experienced low productivity, a low sense of mastery and demotivation.

4.2 Category 2: Dynamic work

At some stages in the project, some team members felt they had nothing to contribute. The evaluation of those days show that this created demotivation and weakened the team members' sense of mastery. The leaders' initiative was to start the working day by defining different focus areas, such as: 1) work on a graphic profile for the packaging, and 2) create prototypes. The team participants had to choose which work tasks they wanted to take on and collaborated in small groups on performing them. They were free to change work tasks during the day. The flexibility in the working day was defined as 'dynamic work'. An example shows team participant 1 starting work on the graphic profile, but during the working day choosing to assist the group that was working on the prototype. The evaluation shows that this created commitment and strengthened motivation. It also proved to have a positive impact on the ideas that were developed when the team members could build on each other's ideas to a greater extent.

4.3 Category 3: Demotivating with schematic tools

On the first working day of the design process, the team used schematic tools. The activity was led by the leaders and was done in plenary. There was made agreements on goals and criteria for the project. The purpose was to form a common basis for the project, and the tools were carefully introduced to the team members. The evaluation of the day shows that the team members saw the value in the tools and understood the reason for the tools being used. At the same time, it gave an insight into what the team members experienced as demotivating when using the schematic tools. The work was described as boring and monotonous, and concentration and interest among some team members in implementing it were weakened. One of the feedback comments read as follows: 'Filling out forms is not always fun, but it has to be done'.

4.4 The three factors that facilitate motivation

In the three categories, three factors emerge that strengthen motivation. Situations where motivation was strengthened showed clear connections with the work tasks being engaging, that the team members experienced a sense of mastery and that the working days were productive. The use of preparatory exercises proved to be an appropriate use of the working day, to create productivity in the working day. By opening up for dynamic work, team members were given the opportunity to assist with work tasks to which they themselves felt that could contribute most. This created commitment and strengthened their sense of mastery. In the analysis, three categories were identified, as well as three factors that played out in the categories. The categories and factors seemed to be important in strengthening inner motivation.

5 DISCUSSIONS: USING A TOOL TO MAP MOTIVATION

5.1 Evaluation

As a project manager, it can be useful to use daily evaluations where input from team members is taken into account. The data shows that the feedback gave the leaders insight into, and an understanding of, how the team members experienced the work on the project. In this way, the leaders got to know their team, and they got the opportunity to facilitate and adapt activities, depending on what the team members found motivating and demotivating. As shown in categories 1 and 2, motivation was strengthened after the adjustments were made. Using the feedback actively can give leaders an opportunity to facilitate motivation in their team.

5.2 Going from 'this is what I *need* to do' to 'this is something I *want* to do'

Establishing a common goal for a project is absolutely crucial to its success [7]. The goal of the project can be guided by an inner motivation in individuals, or from an external source [3]. The schematic tools used in the project were used under the auspices of the leaders, and the data shows that the team members considered it something they had to do (Section 5.3). One can therefore say that the activity was not controlled by the intrinsic motivation of the team members.

In cases where work tasks were not governed by intrinsic motivation, it may be appropriate to look at what weakened motivation. Drawing on inspiration from activities and tasks that have been shown to have a strengthening effect on inner motivation in other situations can be a way to facilitate inner motivation. Category 3 is an example of a task that weakened inner motivation. The reason was that the schematic tools did not engage the team. The data, on the other hand, shows that involvement occurred in those cases where preparatory exercises were used. Therefore, it may be appropriate to look at how preparatory exercises can be implemented in processes where the team uses schematic tools. For example, it might have been appropriate to implement play in connection with completing the schematic tools. A prerequisite for the leaders to be able to facilitate internal motivation in this way is that they are familiar with activities and work tasks in which the team members have demonstrated a genuine interest in implementing.

5.3 Strengthening inner motivation with a tool

The way in which the project managers adapted the activities based on the feedback through daily documentation of the evaluation indicates that the evaluation gave them an understanding of which factors characterised motivation within the team. Despite the fact that this form of documentation gave results in practice, the document can become confusing and difficult to map and apply in practice. Therefore, this study proposes a tool which may help managers establish a database of activities and tasks that can implemented where demotivation occurs (Figure 1). The tool is based on the three factors of intrinsic motivation that were defined in this study. The purpose of the tool is to give project managers the opportunity to experience and understand the situations where motivation was both strengthened and weakened. By using the database, they can use the activities and tasks that strengthened motivation, in those situations where inner motivation is weak. Using activities that have been motivating can help change attitudes towards activities which team members feel they need to do into something they want to do. Internal motivation occurs when activities and work tasks appeal to a genuine interest in implementing [3]. The mapping creates a database that indicates what has strengthened, or weakened, the engagement, the sense of mastery and the productivity.

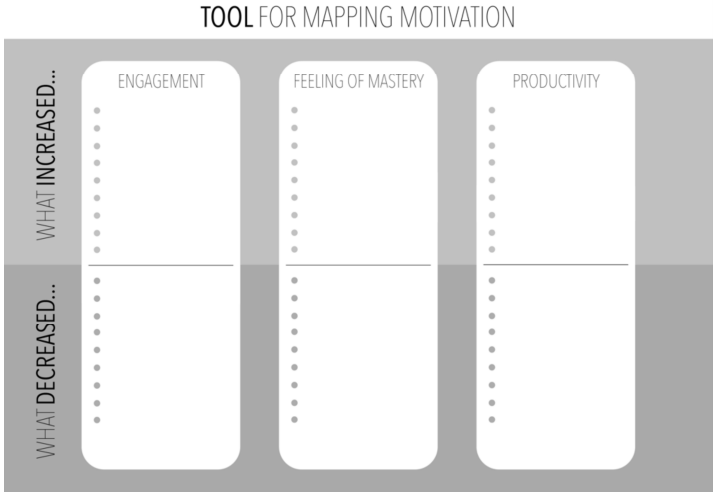

Figure 1. Proposed tool template for mapping motivation in teams. The mapping creates a data base that indicates what has strengthened, or weakened, the commitment, the feeling of mastery and the productivity.

5.4 Limitations and assessments of the study

In this case study, three factors were identified that strengthened motivation among the team members during a specific project. A tool was also developed that can be used to ensure motivation among team members. This study was limited to looking at what weakened or strengthened motivation among product design students during the specific project. The database was structured and informative and was a strength in this study. Nevertheless, it will be appropriate to study several teams and projects, both interdisciplinary teams and teams working on projects in other professions, to nuance the findings. In this connection, it is recommended to study how motivation unfolds to see whether findings are similar to or different from the findings of this study. The tool that was developed in this study should be developed and tested in various practices. The goal of the testing can include assessment of whether the tool is helpful to project managers, and whether using the tool helps strengthen inner motivation in cases where it was previously weakened.

6 CONCLUSIONS: POTENTIAL AND FURTHER RESEARCH

This study has sought to understand the factors that strengthen or weaken motivation among team members in the context of project work. The purpose was to give project managers guidance and a tool that can help them prevent demotivation among team members during project work. The study provided insight into situations where inner motivation occurs. The findings illustrate that it occurs when: 1) work tasks are engaging, 2) the team members experience a sense of mastery, and 3) the working days are productive. An important prerequisite for preventing demotivation is that project managers know their team members. It may be appropriate to make use of daily evaluation where team members are encouraged to provide input on how they experience their working. The database can be of valuable importance and absolutely essential to facilitating working days that create motivation among team members. Project managers are encouraged to map which activities and work tasks that create motivation, and to implement them in work situations where team members experience demotivation. Such a tool can help leaders analyse and change a situation considering whether motivation was strengthened or weakened based on the three factors. It remains to nuance the three factors by conducting similar studies of other projects, and by testing the tool in various practices.

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BLENDED LEARNING TECHNOLOGIES IN PRODUCT DESIGN EDUCATION

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ABSTRACT
One of the notable consequences of the COVID-19 pandemic has been a radical shift to blended learning across education settings, including HE. Blended learning has risen to prominence in the last year as students and tutors have been forced to adopt and adapt to new ways of working. Creative subjects such as design which rely on studio practice, peer-peer learning, and hands-on material experimentation have been challenged through adoption of these changes. This paper explores the short-term changes which have been made and assesses the impact for the near and long term future of design pedagogy. The study focuses on three contrasting accredited UK BSc product design courses; (1) top 40 rank HEI (2) bottom 20 rank HEI (3) online HEI. The authors reviewed course materials, suitability and adaptability for online teaching and student outputs from the last 3 years, including the use of online environments and digital prototyping to try and establish virtual design studios. Feedback from students and tutors is included and evaluated. The contrast between intrinsic and extrinsic motivations in students from the 3 different teaching institutions is discussed along with examples of learning and teaching activities and their efficacy. The findings conclude that while innovative teaching methods are evident, there is a lack of design iteration and innovation, peer-peer learning and practised understanding of form and proportion. While new teaching methods and techniques show promise, the present need to maintain physical studio and learning spaces and to enhance the culture of practical, physical working is noted.

Keywords: Blended learning, studio practice, virtual design studios, digital prototyping

1 INTRODUCTION

The Covid-19 lockdown forced 1.6 billion children and students [1] out of schools and universities worldwide, pushing many onto a steep edtech learning curve. The move from physical to distanced models has challenged many educators [2] and acutely affected design and engineering, where the removal of studios, laboratories, workshops, and shared learning spaces have forced many to rethink the design and delivery of their learning, "*going from denial to acceptance*" (Brown, 2020). For some, the edtech boom is long overdue. Andreas Schleicher, head of education at the Organisation for Economic Co-operation and Development (OECD), described the pandemic as *"a great moment"* for learning [3].

1.1 Blended learning

In May 2020, New York governor Andrew Cuomo publicly questioned why physical classrooms still exist at all, as he announced that former Google CEO Eric Schmidt and Bill Gates would help rethink education in the state [4]. Critics like Naomi Klein say tech giants were quick to see Covid-19 as an opportunity to accelerate their education ambitions [5]. *"In moments of crisis, people are willing to hand over a great deal of power to anyone who claims to have a magic cure"* [6]. In June, Microsoft published a position paper on Remote to Hybrid Learning called Education Reimagined. *"The fallout from Covid-19, continuing advances in digital technology, and intensifying pent-up demand for student-centred learning have combined to present an unprecedented opportunity to transform education across whole systems."* [7]. But will we continue this digitally enhanced approach, post-pandemic? Covid has given an impetus to adopt more functional digital edtech tools, comments Hannah Owen, of the Nesta innovation foundation, and *"it's likely, and optimal, that we'll move to blended models, where remote and digital platforms support in-person classroom teaching and minimise teacher workload."* [8]. But there are challenges, such as assessing which students have understood a question *"that's a lot harder to do with video conferencing software or digital worksheets"* [9] and could be more time consuming, not less. Another area which could rise to prominence is the use digital tools to identify who needs help

and if used well, analytics and big data could help engage students and individually help tailor input. Some found that virtual learning environments helped students engage better, gain more control over their learning, work in ways that suit their needs, and minimise anxieties by engaging via the chat [8].

1.2 Virtual studios

Critical to a blended learning approach is not only to covey learning material but also to support peer-to-peer learning, which is typically practiced in a studio environment. A common concern of blended learning for design education is that quality of student output will deteriorate if students are unable to compare work during formal or informal critiques, group activities and group learning. To overcome this, virtual studios have become prominent in the shift to online learning. One of the first virtual studios Open Design Studio (ODS) has been created by the Open University (OU) in 2010. One of the key factors for success is the ability to view other students' work, thus demonstrating a stronger (or equal) correlation of student success compared to any other behaviour measured [10]. Students on OU design courses can choose to share visual ideas and design solutions with their peers. They can also comment on peer's work, and with around 500 students active on a module at any time, form part of a virtual learning community, giving great feedback potential, more so than in a physical studio. Engaging these feedback and community behaviours is part of a larger set of social learning behaviours that contribute to an *'ecology'* of digital studio learning [10]. Viewing other students' work, far from being inactive or passive learning, was found to be an intrinsic motivator and contributed to a positive learning experience, noting that measuring student engagement in this process was important – the issue of 'not leaving a mark'. The shift to remote learning has challenged the use of physical studio environments – how can we re-think approaches to design education, evaluate, and learn from this experience and understand how design can adapt to emerging virtual learning environments and future design studios?

2 METHODOLOGY

In order to understand the impact of blended learning and studio environments this study focuses on comparing and contrasting the interaction, engagement, technical adoption, and output of 3 accredited UK BSc product design courses; (1) top 40 rank university (2) bottom 20 rank university (3) online provider. This included an analysis of course material, suitability and adaptability for online teaching and final year student outputs over the last 3 years. A particular focus is the adoption and inclusion of online environments and digital prototyping to establish how, and if, virtual design studio spaces are utilised. The contrast between intrinsic and extrinsic motivations of students is discussed along with examples of learning and teaching activities and their efficacy. The results are analysed to draw out key themes about the use, uptake, and output of student work in a virtual studio environment. The findings have been split into four themes across each course: technology uptake, student engagement, quality of design output and future industry demands. These four areas demonstrate critical elements to ascertain the effectiveness of approaches and inform recommendations for blended studio practice moving forward.

3 TECHNOLOGY

Advances in technology have offered additional tools and experiences to enrich the virtual element of blended learning, beyond traditional OBS. Critically for design, some web-based tools assist in creative activities such as group ideation. Platforms such as 'Mural' (*Figure 1*) and 'Miro' offer a space where groups meet and work virtually and collaboratively and enable functions encouraging engagement, such as voting, templates to stimulate thinking, and icons and sketching tools to enhance spontaneity. These tools are important as they lower the point of entry and enable students to engage with a stream of visual content which resonates with those who naturally engage with social media platforms. However, these technologies and remote collaboration lack the social dynamic of a physical environment. Currently, it is a very different experience to be working over a digital platform than it is to be around a physical table. In all 3 institutions this was identified as a continuing challenge. Group learning is different, traditional points of discovery or clarity are hard to detect when online. Therefore, consideration of this is important when working in a blended environment, the application and facilitation of physical workshop activities into a virtual space is very different to that of a physical one. Students often note how group exercises are reliant on one or two individuals doing much of the work or talking, rather than a team effort. Physical engagement can often help to alleviate that problem, via intervention and observation of participants. Serendipity, as a design tool, is not as easy to encourage or witness in a

virtual space. This in turn means that critiques of work become far more considered due to the mindset of the participants being more focused when posting comments rather than verbalising them. Tone of voice, cadence and physical expression are not apparent and count for a lot in those scenarios. In addition, it was highlighted that building trust becomes difficult due to the anonymity of virtual spaces, it is hard for participants to truly understand each other at distance, which can make the difference between a student engaging with subject matter or not. We are inherently social, and this dynamic is a rich element in current models of learning and communication. The blended approach allows for fewer opportunities for physical interaction, which poses the question - how can they be effectively replaced? How are we changing our social habits and design methods in a learning landscape that is becoming more virtual?

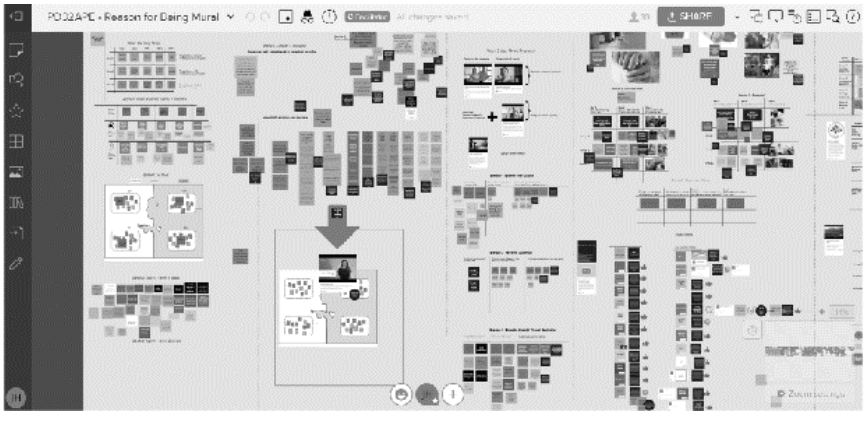

Figure 1. Second year collaborative design group work on Mural

4 ENGAGEMENT

Student engagement and collaboration is key to successfully achieving learning objectives and enriching the education experience. In each of the 3 institutions studied it was identified that participation can manifest itself in many ways from passive observation and listening through to active posting and contribution. Engagement as a metric is harder to measure in a digital space, it is easier for students to *'drop off the map'* [9]. Feedback from group exercises indicated that this type of activity can be alienating to some (due to others taking a lead) as well as being too easy to sit back and watch rather than engage. A key finding was that we must consider character types and how content can be structured to sustain engagement and adjusted to ensure an appropriate barrier to entry when it comes to participation. An example of this was identified by one institution using *Mural* to discuss the feelings and emotions portrayed by contrasting designed objects. Students posted keywords on individually coloured notes. This low barrier to entry facilitated effective engagement with the activity, which then ramped up to empowering students to critique their own and others work in the platform (*Figure 2*).

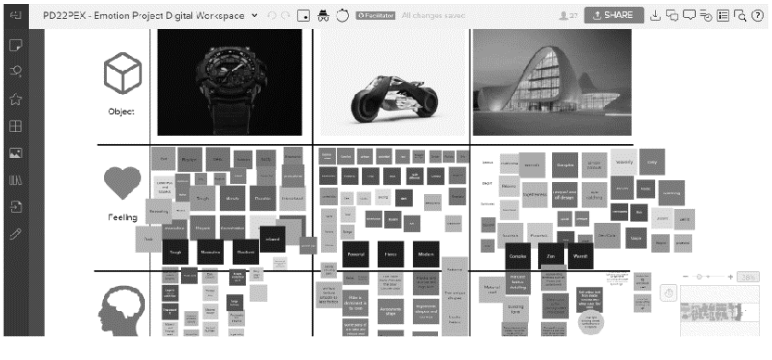

Figure 2. Keywords to describe feelings and emotions provide a low entry barrier into the application

To encourage engagement, regular feedback on work generates a feeling of progress and flow similar to engagement on social media. Collaboration spaces offer a 24/7 opportunity to discuss work, with students witnessing an emerging body of work which often has a positive influence. Creativity can be seen and shared, providing inspiration moving forward. Virtual spaces allow for visual exploration – using parallels and creative approaches (metaphors) to express new thinking and approaches. Fresh content helps maintain momentum, weekly updates of new videos, podcasts and exercises add to understanding. Material helps to stimulate debate and interaction, fuelling conversations, empowering collaboration. Learning in isolation is one route students can take from virtual spaces, however the richness and reward from partnerships of group and peer discussion offer valuable context and perspectives. Encouragement of positive behaviours and attitudes helps nurture this mode of working with those new to it. Supporting dialogue, visual stimuli (imagery and emojis) are useful and drive a familiarity to the virtual medium. It is useful to clarify etiquette with regard to engagement. Parallels can be drawn with social media platforms; this can shape a mindset, but posts should be monitored.

5 STUDENT OUTPUT

Critical tests for digital studio environments are quality of student outputs, attainment and evidence of design thinking, awareness of visual design language and balance between product form, function, and end user ergonomics. It was identified that in a virtual online environment there is a greater focus on design thinking and developing and critiquing ideas. However, it is evident that there is a loss of physical prototyping and testing. Although it is evident that some students will photograph low-fidelity models and upload them to gain feedback, there are a number of steps to this process. Students often feel that a low fidelity prototype is not of sufficient quality to publish on a virtual platform. For the Instagram generation, pictures are routinely filtered and edited before uploaded. There may be a fear that poor quality images and work will stay online forever, and this could damage the student's reputation (*Figure 3*). These issues can be present in a traditional studio space, but when students show their work it is typically on the table/wall for a short period of time and then removed quickly to improve. This presents a contrast on the one hand students enjoy brainstorming and linking to new product ideas but are less keen to have a visual critique. It was identified that the uptake and engagement of this activity was significantly lower, but by removing low fidelity work directly after critiques this effect was reduced.

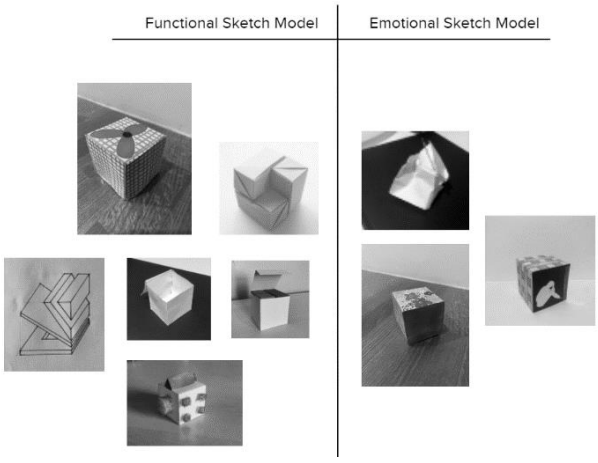

Figure 3. Low fidelity sketch models presented in Mural

The final design output, typically at an end of year assessment, highlights that most students produce less convincing design solutions, which are often more conservative, safe and lack the depth of development which is seen in a face-face studio. When looking at purely digital outputs it was expected that free from traditional prototyping constraints students would show greater levels of experimentation and innovation, yet the opposite happened. Instead of pushing the boundaries it was evident that students placed their own virtual boundaries, tried to anticipate the comments of workshop technicians, and

instead held themselves back. An example of this was seen in outputs in 2020 (*Figure 4*) compared with the start of 2021 in which face-face studio practice happened (*Figure 5*). It is evident that that the depth of development, innovation and sensitivity to form is lost when the 3 best students are compared. This is reported to be due to a lack of face-to-face feedback, physical prototyping and testing available online.

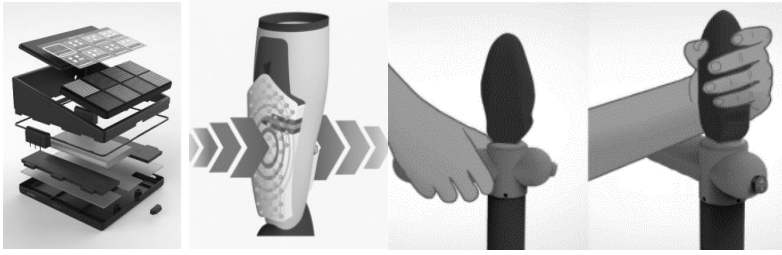

Figure 4. Highest achieving students in remote studio environment

Figure 5. Highest achieving students in physical design studio

6 INDUSTRY EXPECTATIONS

Blended learning offers opportunities to collaborate beyond the constraints of lecture theatres or traditional classroom environments. The ability to incorporate external collaborators into modules is enhanced through the ability to hold virtual seminars, with geography no longer a barrier. This way of working shares parallels with industry during the pandemic, satellite teams and virtual collaboration have become prevalent out of necessity. This allows for companies to recruit globally, without the need for relocation, tapping into a broader talent source of talent. Within design this can enrich thinking, offering perspectives from a mixture of different references and cultures avoiding 'group think' from local teams. Looking forward to employment, blended learning delivers an opportunity whereby students develop the mindset to become more independent learners. Depending on the module and its delivery it is possible to steer the student to content creators, platforms and topics allowing them to leverage large amounts of information available online. This skill of following others, seeking views, and networking within digital communities can prove to be an important and enriching skill when in employment. Video presentations, use of social channels and leveraging the digital relationships of one-to-many are becoming more prevalent. Covid 19 has accelerated remote work and virtual collaboration.

7 CONCLUSIONS

In a post-COVID world there is an increasing challenge to justify physical learning environments and balance the adoption of digital tools and virtual learning spaces. This paper goes some way to further this discussion in relation to design education. The findings demonstrate that there are advantages to remote working and digital studios, but this comes at a cost to human interaction, degradation of physical prototyping and mixed levels of engagement. Virtual studios have been shown to work in the initial stages of design projects, to generate ideas, capture inspirational content and to develop team thinking. However, this is reliant on each student being actively engaged during the whole process. The design outputs suggests that there is a fundamental need to maintain physical studios and practical prototyping.

It is easy to slip into a mindset whereby direct comparisons are made between classical and blended learning environments. The objectives of imparting knowledge and encouraging growth are common. However due to humanistic elements such as group dynamics, expression, and interaction the individual experience can be very different. For the blended approach to be successful we must consider the medium carefully, not to fundamentally change the learning objectives but to impact the method of delivery. Students are being asked to learn in a way that few have experienced previously. In easing this transition the authors are piloting several initiatives and approaches to support the learning experience:

- Encourage and celebrate online collaborative behaviour, including online participation in exercises, posting of work and progress, commenting and supportive critiques of other students
- Leveraging benefits of online working by hosting guest speakers and presentations, integrating content from online platforms and channels into delivery, giving new perspectives and context.
- Exploring online collaboration opportunities with other groups (internal and external), building diversity of thinking and reference points. Exploring activities to engage different personalities and individual skillsets such as votes, sketching, metaphors, competition, and gamification.
- Personalisation, giving the student more control over the consumption of material with a HyFlex model of hybrid learning in a flexible structure of pre-recorded deliveries, digital space to socialise work, providing guide rails with supportive content rather than explicit data points.
- Structure, duration, and tone of online sessions – considering the passive versus active balance of content in order to give students a variety of experiences. Break-up screen time with spaces for reflection, a chance to take a break, stretch muscles etc. Give freedom for students to watch content in their own time, whilst explaining the synergies and benefits of group learning.

Institutions and students are mostly not used to these ways of working, so adaption and scaffolding of learning will be necessary. This may ease as hybrid lifestyles become embedded within society, and the benefits to students of a flexible structure with options of modes of attendance according to needs and preference are clear, however we must not lose sight of the benefits of physical design learning spaces.

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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

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ABSTRACT
Two characteristics of the Tec21 Educational Model at Tecnologico de Monterrey are learning-based-on-challenges (LBC) and the attempt to provide memorable experiences during university education. These challenges and experiences are being created through activities to develop problem-solving competencies in the students. These activities where they apply their classroom learning are designed to be attractive and challenging for the students. The Industrial Engineering and Design departments of Tecnologico de Monterrey have merged the design of experiments and design thinking to create a methodology that allows students to design successful academic activities and provides added value in education.
During the last 12 years, students at Tecnológico de Monterrey have experienced various activities both in *Semana i* and *Semestre i* (new class periods created under the Tec21 Educational Model). The learning activities contained challenges to resolve during the school periods, which evidence significant learning, as reported in the end-of-semester evaluations. By proposing academic activities based on a multilevel factorial model, a statistical model has been generated to find the best combination of the component factors and levels to give us a probability of success greater than 90% when implementing the activities. Following the design-thinking methodology allows the institution to immerse with the students, be empathetic, and clearly define our expectations of them and, consequently, have a robust activity design. Various design factors are built into the activities to make them attractive and challenging for the students and enable them to apply their classroom learning.

Keywords: Design thinking, design of experiments, competencies, educational innovation, higher education

1 INTRODUCTION

According to Henriksen [1], the problems faced by educators in professional practice are complex, varied and difficult to tackle. These problems include teaching and learning issues, social or community problems, trouble in the classroom environment, and many others. The problems are multifaceted, interdisciplinary, derived from human activity, and rarely resolved through simple or linear approaches [2]. Moreover, confinement due to the COVID-19 virus has added additional problematic layers to resolve.
In 2019 Tecnologico de Monterrey started the full implementation of its new educational model known as Tec21 which is based on LBC and memorable experiences such as *Semana i*, *Semana Tec*, *Semestre i* and *Semestre Tec*. For these activities to be truly memorable, they needed to be designed to be attractive to students, obey academic rigor, and lead students to develop real-world skills. The proposed methodology for the activities' design is based mainly on combining two design tools: Design Thinking (DT) and Design of Experiments (DOE), and other creative phase techniques.

2 DEVELOPMENT

The design of activities within Tec21 has unique characteristics that differentiate Tecnologico de Monterrey from other educational institutions. The differentiation includes challenging, engaging curricular activities to develop real-world skills and leave a deep educational footprint. Since 2012, Tecnologico de Monterrey has been designing an educational teaching model based on challenges that develop assessable skills in students for 21st century. The challenge to be resolved must engage the students, motivate them to work collaboratively, boost knowledge acquisition, and develop the necessary skills in the best possible way.

Henriksen [1] notes that while creativity is considered a core 21st century thinking skill, many people are hesitant to identify themselves as "creative," or they are uncomfortable with intellectual risk-taking and openness. In her article *Why DT works,* Liedtka [3] describes a seven-year study looking closely at 50 projects from various sectors, including business, healthcare, and social services. She found that another social technology, design thinking, can innovate the way we do things by unleashing people's creative energies, thereby improving several processes radically. Therefore, design thinking as a tool in current education can promote real-world problem-solving, enabling students to develop competencies to address economic and societal issues.

The proposal consists of using design thinking and the design and analysis of experiments to confront the posed challenge and propose the best possible solution. Creative and statistical thinking work together to achieve optimally creative solutions and, consequently, the desired skills. Wattanasupachoke [4] suggests that the most innovative organizations use design thinking. Carlgren et al. [5] identified five characteristics of the design thinking framework: attention, understanding the problem, prototyping, iteration, and diversity. These characteristics are summarized in Table 1.

Table 1. Design thinking framework, Carlgren et al. [5]

Characteristics	Alternative labels
User focus (attention)	● User orientation ● Customer focus ● Human-centred
Problem-framing (understanding the problem)	● Unconstrained view of the problem ● Question the problem ● Problem exploration ● Problem focus
Prototyping	● Visualization ● Making it tangible
Iteration	● Iteration and testing ● Action-oriented ● Experimentation
Diversity	● Collaboration ● Systemic perspective

Meinel, Eismann, Baccarella, Fixson, and Voigt [6] found that teams applying design thinking develop better product concepts than teams that apply quality function deployment in terms of feasibility, relevance and specificity, but not a novelty. Researchers claim that the design thinking approach to innovation has several positive outcomes. It helps develop superior solutions, reduce the risk of failure, achieve employee buy-in, and increase the firm's innovativeness and dynamic capabilities for innovation [7,8,9,10]. Design thinking is a methodology that had its origins at Stanford University in California. It focuses on the user and their needs. Although DT is commonly used in product design, it can be applied to the design of academic activities, challenges and experiments design. This is shown in Figure 1.

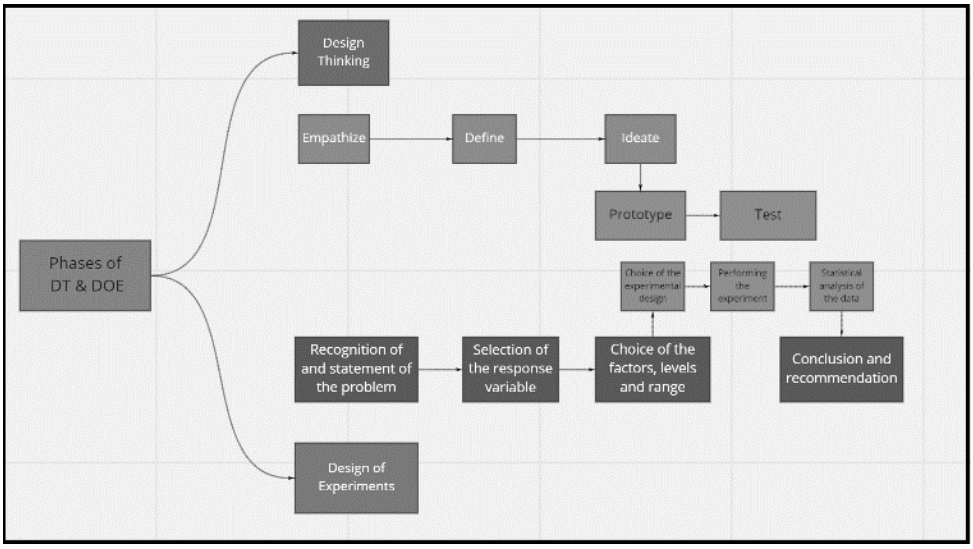

Figure 1. Phases of Design Thinking and Design of Experiments Self-elaborated.

Empathize means putting yourself in the user's shoes, having a deep sensitivity to see from the student's eyes, feeling their needs. In this phase, mind maps and brainstorming are used, and the design of surveys aimed at gathering the needs and proposals. Hüseyin [11] proposes a methodology to select the ideal questionnaire for information collection. In this case, it would be the interview with key clients in which the interviewer collects data from people who have unique insights that would otherwise not be available to the researcher.

In the Ideate part, methodologies are used to define the activity, the challenge, or the problem. The most common are the creative phase technique (brainstorming, mental maps, etc.), engineering thinking (mathematization of ideas based on set algebra), and Kepner's and Tregoe's criteria for identifying and defining problems [12]. In this stage, the hypothesis is defined by describing the users' needs (e.g., the students), the competencies to be covered, the academic content, and the current environment's demands. In the Ideate phase, solutions are proposed based on a correct definition of the problem. The use of thought engineering (see Figure 2) is vital. Set algebra is used to isolate the determining factors.

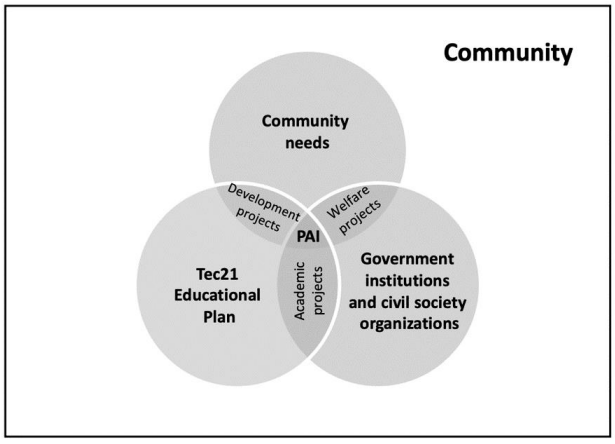

Figure 2. Example of thought engineering. Own source

During the Ideate phase, thought engineering was used to determine the factors that give a solution to the problem and a test is used to determine if the factors are correct. This stage is commonly done by trial and error, which prolongs the time it takes to propose a solution. To solve this, the use of a factorial experiment design of two or more factors and limiting it to 2K designs where the K is the number of factors, and 2 represents the levels (categorized as high or low.) was proposed.
The activity design [13], such as the beta version or the prototype, is made starting from the brainstorming structure. The academic activity begins to be written following the steps that were previously defined. When a teacher talks to the students about problem-solving, he or she asks them to generate a prototype that conceptualizes the idea. For the *Semana i* and *Semestre i* projects, teachers point out that in the prototyping stage, three phases are proposed: a) the conceptual prototype, where the physical form of the idea is given; b) the functional prototype, where the product has the materials and operates according to specifications, and c) the sellable prototype, in which a product is created with proven materials, functioning according to specifications and meeting all quality and safety requirements.
A similar analogy was used by the teachers to design activities and challenges that meet all the academic requirements and guidelines established by the Vice-rectory. In this prototyping stage, the group of teachers lives the challenge; that is, they carry out the activities of the training unit's curricular project. By doing this, they can adjust the times to carry out each stage of the challenge; the materials' requirements are also established. Adjustments to the instructions and necessary corrections are usually made when testing a prototype.
At the trying phase, the proposed solution's desirability and feasibility are checked, so the experiment's design must be present. If a factorial design [14] is used, the factors can have more than two levels. This is very practical in the design of a new product. However, if the academic design of activities and challenges is analysed, then the use of a 2K design is needed where the levels are low and high. One of the problems that faculty face is creating data to carry out the experiments, but these can be obtained based on simple simulations or the generation of random numbers based on a specific probability distribution. In the case of the activities and challenges, the normal or binomial distribution is used. In contrast, for a solution or product design, a triangular or Poisson distribution is used. The experimental design generates the value of the parameters of the factors or variables under study. By testing them, the development time can be reduced because the experimenter only has to readjust and not look for the appropriate values based on trial and error.

2.1 Theoretical framework

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 [15]. Sanders J. and Goh P. [16] 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 programme 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 [17].
Experiments are used to study the performance of processes and systems. The objectives of the experiment could include the following:

1. Determine which variables have the most significant influence on the Y response.
2. Determine which X adjustment has the most significant influence on the y variable, so it is almost always close to the desired nominal value.
3. Determine which X adjustment has the greatest influence, so the variability of y is reduced.
4. Determine which X adjustment has the most significant influence so that the effects of the uncontrollable variables $z_1, z_2, ..., z_q$ are minimal.

Usually, one of the experimenter's goals is to determine the influence these factors have on the system's output. The general approach to planning and experimenting is the experimentation strategy. The successful integration of good experimental design practice in engineering and science is crucial in future industrial competitiveness [18].

2.2 Implementation and innovation results

The methodology described above combines the Design of Experiments and Design Thinking to create activities for the *Semana i* and *Semestre i* of the Tec21 Educational Model. It is also a methodology for the solution of challenges. The projects derived from these activities increased the development of disciplinary and real-world competencies.

This methodology has been implemented in the last three editions of *Semana i* by teachers from the science, civil, mechanical, industrial and auxiliary departments. The results of the teachers' evaluations were measured using the students' comments and the numerical evaluation in the item "*Would you recommend this activity?*".

Impressive results were achieved both from teachers using the methodology to design *Semana i* and *Semestre i* activities and the students researching and developing projects for new products. Table 2 shows the results of the *Solidarity Route of the Sierra Gorda* activity. It displays the student evaluation results since 2016; the average evaluation for all years was 4.70 out of 5 possible points. Each year, the activity consisted of approximately 15 social development activities in surrounding communities.

In an average of 200 activities per *Semana i*, this activity was in 24.75th place of ranking in average.

Table 2. Results of the students' evaluation of the activity "Solidarity Route of the Sierra Gorda."

Year	Enrolled Students	Proposed projects	Fulfilled projects	Efficiency	Student evaluation	Total activities	Ranking
2016	43	14	12	85.71%	4.9	116	8
2017	38	17	16	94.12%	4.8	114	21
2018	40	19	17	89.47%	4.38	128	51
2019	80	21	20	95.23%	4.7	117	19
Average	50.25	17.75	16.25	91.13%	4.70	118.75	24.75

This methodology has allowed students to carry out their projects, analyse the situation accurately, correctly define the problem, and solve it with creative, viable, and feasible solution proposals.

A comparative survey was carried out with 130 students who applied the methodology in *Semana i* activities and their final projects in various semestral courses. Even though 52.4% did not know the Design Thinking methodology and 57.1% considered the Design of Experiments to be a complex statistical technique, only 4.8% had problems implementing the methodology. This resulted in 100% of the projects in semestral courses being carried out and 94% of the projects in *Semana i*.

Besides, 86% of those surveyed considered this tool very useful to them in their professional and academic lives. Although 23% stated that they felt it difficult due to lack of prior knowledge, they could learn it by themselves and achieve an excellent use of the technique.

3 CONCLUSIONS

Academic innovations may take place in several scenarios. However, perhaps for those who carry out this research, the best thing is to propose methodologies that promote fun academic activities, solving real-world problems where students develop real-world skills for their professional and personal lives. They should feel empowered to propose viable and feasible solutions.

For teachers, the experience of applying the methodologies created fear, but not the type that paralyzed and led them to follow the established guidelines. Instead, this fear made them prepare the methodology even more, test it, and have the courage to allow students to find their own path to learning during the experiment. Although the results were very encouraging, we heed the comments that were not entirely positive. The methodology must be refined to fully develop the competencies defined by the Tec21 Educational Model for the students.

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CREATIVE PROBLEM-FINDING: A SHIFT IN FOCUS FOR CREATIVE TOOLS

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ABSTRACT
Identifying and forming problems is an important first step in the problem-solving process in the design field (and beyond). A valuable definition of creative problem-solving includes, on the one hand, the production of original, high quality, appropriate solutions, and, on the other hand, novel, complex, ill-defined or poorly structured problems that challenge these results [1]. Researchers, namely Wakefield (1985) argued that finding a problem is in fact more important than solving it, because it expands the potential to discover new possibilities [2]. However, the process of finding and identifying relevant problems remains fuzzy. An important reason why creative problem-solving fails, is related to the problems' nature [3]. With this research we aim to offer a better understanding on how design problems are defined, by means of a tool, a graphic canvas. The purpose of most creative techniques is solving problems or generating ideas in the development of new services or products. Considering the added value of practice and coaching of problem-finding abilities in industry and education, and also the intrinsic goal of creative tools to develop the capacity of people's innate potential, a method for problem description was developed. In order to validate the tool, we implemented it in the search process for master's thesis topics. By sharing our insights on the canvas/template creation and user feedback in the context of design education, we support the increasing attention that is given to the need of exploring problem-finding with an essential shift in creative problem-solving tools.

Keywords: Design education, creative problem-solving, problem-finding, creativity

1 INTRODUCTION

Since the 1960's there has been a noticeable interest in the creative problem-solving process, especially in the constructs divergent thinking and problem-solving [4]. Recently, we have noticed a shift in both research and (educational) practice towards the process' initial phase: problem finding. Lee et. al. (2020) define this 'problem-first design process' as follows: 'A design process that emphasizes defining and understanding a presented problem as a starting point, followed by a search for solutions' [5]. We notice an emerging call for designers who are consciously monitoring our environment, trying to spot problems with high urgency. The closer the expected time to start directing these problems, the more impact and value possible solutions might have. Moreover, a common assumption nowadays both in the industrial and academic domain on product design and development, says it is crucial to improve problem-solving skills to reach valuable innovations [6]. However, there is not yet a consensus on the process that evolves when individuals detect, pose or formulate problems [4].

In this paper, we share our insights on both process and outcomes of a tool created to facilitate design students to better develop the problem definition for the topic of their master's thesis. Once they have discovered an issue or a problem, our tool would potentially help to delve into it. A particular point of attention is given to the background of the designer/student: several questions about the designers' motivation, expertise or competence were added to the tool. In this way, the students are stirred to reflect not only on which problem they want to tackle, but also why they should try to solve it. After contributing some background information on this ongoing evolution, the paper continues with the development of the tool and its implementation in our design curriculum. To conclude, we bridge our findings based on interviews with students and recommendations from literature.

2 BACKGROUND

2.1 Creative design problems' ('wicked') nature

In their definition of creative problem-solving, Mumford and Gustafson (2007) revealed several characteristics of the problems designer's address: they include a level of novelty and complexity, and are, additionally, ill-defined and poorly structured [1]. Indeed, the opposite of mild, manageable problems has been introduced in 1973 as 'wicked problems' [7]. While wicked problems would have more chance to lead to novelty [8], their nature is an important reason why conventional creative problem-solving fails [3]. One possible reason is that solving one aspect of it, may uncover or stimulate another challenge that potentially remains unsolved. Furthermore, the core issue is probably linked to a combination of dynamic and multidisciplinary causes that hinders to resolve isolated sub-problems one-by-one [9]. Therefore, it is worth examining how to facilitate the exploration of a (wicked) problem, which is both intriguing and potentially problematic.

2.2 Problem-first design process

Traditionally, the emphasis of research lies on the product or outcome of creative processes rather than on an understanding of the process by which these creative endeavours happen [10]. Although the effect of problem finding on creativity itself is perhaps not fully recognized [4], researchers have found that when paying more attention to the careful statement of (wicked) problems, the related solutions exceed business-as-usual or uninspired puzzle-solving [9]. Several problem-finding strategies have been identified: *exploring the underlying needs; defining a problem space with deliberate boundaries, applying intentionally different points of view on the problem; broaden the inquiry towards the context and the stakeholders of a problem* [4]. Although research has confirmed that design problems can evolve even with the realization of solutions throughout a design process, reasonable efforts at the beginning have their significance during the subsequent search for satisfactory solutions [11]. Hence, several tools have been created to assist this important quest.

2.3 Benchmarks

While searching for existing creative tools that focus on the initial stage of the design process, different instruments are observed: on the one hand, those who support a *divergent* thinking approach in freely guiding a stream of consciousness, and, on the other hand, *converging* medium's structure one's thoughts in the direction of a decision.

The 'Opportunity Mind Map' from Mindshake is based on the work of psychologist Tony Buzan and has specifically been created for implementation in a design-thinking-towards-innovation process [12]. What we appreciate in this divergent thinking-instrument is the non-linear notetaking and its visual approach that aims at stimulating user's motivation. Furthermore, we agree upon the advice given that involving guests in a second or third iteration of the tool would gather new insights on the central subject [12]. From the same Mindshake-toolkit, the convergent Intent Statement clarifies for the user the orientation of the innovation challenge while asking the following questions: *What is your intention? What are the opportunities? What is the new value you are creating? New for whom: the company, the city, the country or the world? What is your target group? What are the risks of a possible flop of the project?* Users are instructed to use this template as a starting point rather than as a document of which the input is no longer considered editable [12]. We believe that providing such a clear and unambiguous examination can be very beneficial.

Finally, another tool concerns the 'User Innovation Toolkit' that includes a primary phase where reflecting on the features of innovation challenges is required: S.M.A.R.T description. According to De Marez, problems should be described as Specific, Measurable, Achievable, Relevant and Time-bounded entities [13]. This framework is narrowing down the options users still did not define. Although we take other features of (wicked) problems into consideration, this example shows how indicating the key elements of a problem, can be of great value.

3 TOOL DEVELOPMENT AND IMPLEMENTATION IN DESIGN EDUCATION

Students in design education usually get a predefined assignment or can choose their own subject within a certain framework based on the learning goals of the specific course. However, if we want to educate the future designers to be able to discover valuable challenges themselves, adequate exercises that stimulate this skill need to be provided. It is by far more difficult to come with an idea for a problem

from scratch [14]. Surely, this focus on problem-finding should be introduced in a scaffolding way. Similar to many design schools, the students of the Industrial Design Engineering programme at Ghent University are confronted with this challenge for the first time: at the time they start searching for a master's thesis subject in their third year of their bachelor's programme. Although different anchors are given, e.g., the students can contact companies that are familiar with the programme and their teachers provide a list of topics, we stimulate the students to come up with a self-defined proposal.

3.1 Context

A coherent group of twenty-six, third year bachelor Industrial Design Engineering students were asked in the context of their course on design methodology to reflect on their master's thesis subject. The final deliverable was a text to explain which valuable challenge they consider tackling and which particular methodology they would apply in order to solve that. At several moments during this first semester course, we familiarized the students with the process of searching a subject (Figure 1). At first, there was an introduction presentation with general facts about how master's topics are collected and categorized under specific learning lines. Prior to that presentation, students had been asked to brainstorm during five minutes on plausible subjects coming from their own interests. Immediately after describing the applicable guidelines, half of the students were given our tool, whereas the other half of the class were told to brainstorm freely. Eventually, time was taken to explain the tool to the entire class group. All students were asked to complete the tool (anew) before the following class, the week after. Finally, we suggested to perform the tool for a final time before they started writing their text.

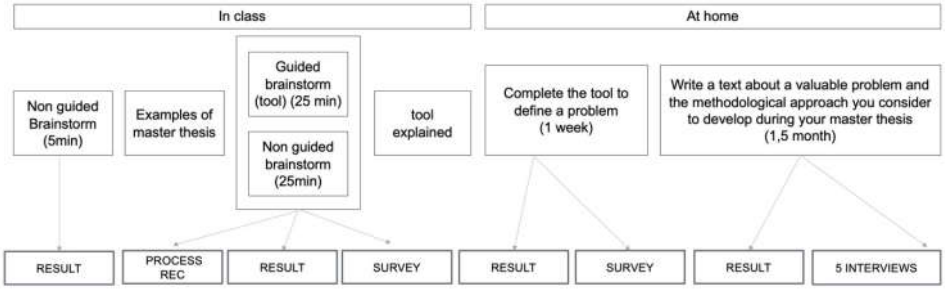

Figure 1. Process of context and feedback gathering

3.2 Tool development

Dorst (2006) clarified the dissimilarities between well-structured and ill-structured problems, emphasizing that those dissimilarities can be related to the skills of the problem solver. The designer's interpretation of the problem based on his/her prior knowledge and experience, should be given some attention [15]. Moreover, inspired by the Self-Determination Theory, we encourage values as autonomy, competence and relatedness to, on the one hand, stimulate students' internal and external motivation, and, on the other hand, help to estimate the achievability of their goals [16]. Therefore, on the left area of the graphic canvas, students were asked about their motivation, capabilities and resources.

Our tool aims at helping the students formulating their chosen problem. While Dorst and Cross (2001) defined this as 'alter presented characteristics to align with imposed frames and establishing problem boundaries' [11], this framing should as well stimulate to apply different perspectives and viewpoints to the problem: the personal view, the sectioning in subproblems, the focus on its novelty - the opportunities - and the reflection on its possible disadvantages [1]. Also, an early mention of stakeholders contributes to broaden the topic [4].

In particular, these wicked challenges are usually positioned at the crossings of multiple disciplines, therefor several input fields are provided to reflect on the kind of information needed to solve the challenge and the necessary resources. 'Who can you have a functional debate with about the described problem?' is an example of such an input field.

Also, attention is given to some of these problems' characteristics. As mentioned above, there is at least a minimum of complexity and opportunity for novelty. The problem can initially be ill-defined, which eventually will be clarified. In principle, we aimed for an open tool without a strict order to complete it

and one that would invite its users to reflect for a longer time on the listed items. Eventually, the completed canvas could serve as a conversation starter to discuss both their search process and proposed subject.

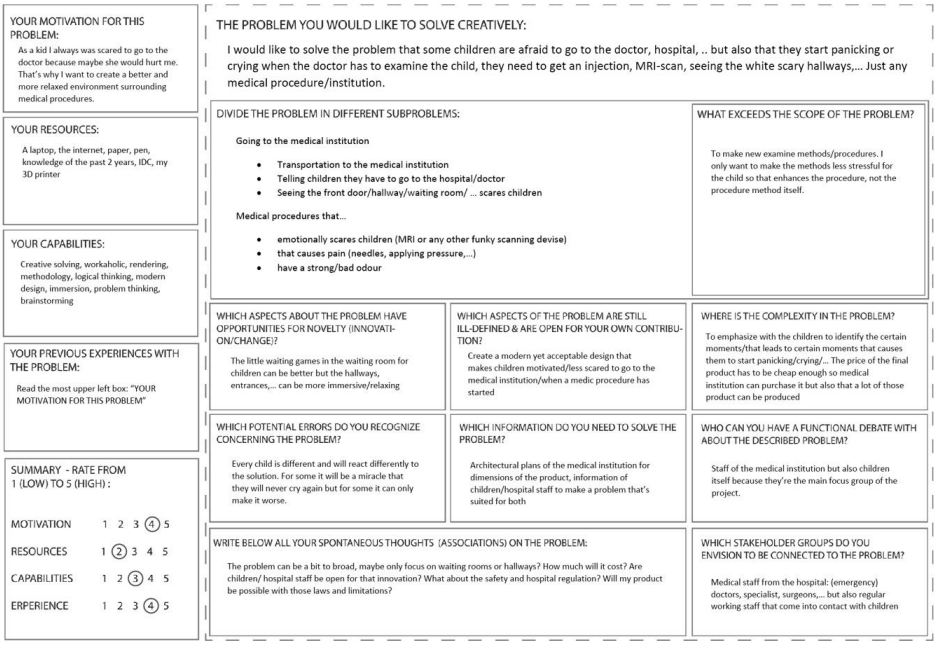

Figure 2. Tool completed at home (1 week), by one of the interviewed students

3.3 Gathering feedback

By means of screen and voice recordings of the students (capturing their thinking-aloud process), we got insights in how the brainstorm sessions (both with and without the tool) were proceeded. An online survey that was completed after the in-class brainstorm and repeated one week later, augmented our understanding in the students' reflections on both the tool and their quest for a thesis subject. Ultimately, we expanded our learnings by interviewing five students. Three out of these five scored above average on the final deliverable, while two underperformed. These scores were given by all three authors independently and based on a rubric. The interviews were semi-structured and based on an overview of the collected materials, i.e., deliverables and completed surveys by these five students. The outcome of the interviews has been processed under the next section of this paper.

4 FINDINGS & DISCUSSION

An overall remark showed that the task given was not sufficiently clear for the students. Providing a checklist (with the most important expectations regarding master theses) at the beginning of this process, would give students some essential grip without asking them to complete a fixed canvas at that stage. Furthermore, our guidance could become gradually more structured during the process: at first posing some questions during the divergent subject exploration [17], but then a more converging version of the tool to select several subjects of interest and translate these into wicked problems. Just as suggested by the proposed benchmarks, the students should pass through several iterations, so they would gather sufficient information to make a substantiated choice between the various challenges that excite them.
Some students seemed to struggle with the 'self' as a starting point. One student said, "I have the feeling that I did not do anything, besides writing about myself". Others took this opportunity for a related topic of interest and even balanced their own capabilities to a more general validation of the subject. For the intended purpose, to increase the students' internal motivation, we must formerly make students feel

comfortable about this self-examination, and subsequently raise the awareness of modifying their interests in objectified challenges [16].
Furthermore, the user should be informed that potential causes or consequences not necessarily take place in the present [18]. Validating their initial ideas or own reasoning, by means of scientific literature or expert opinions, would not only strengthen the relevancy of the subject, but it would, additionally, lessen their lack of confidence. As long as student's thinking is predominated by their wish to succeed in their master's, no brainstorm or exercise will be totally spontaneous. Also, if more time is spent during the introductory brainstorms, students might, after summing up their ideas, start to evaluate them [17]. How can we delay critical thinking skills in this process?
Although students recognized the benefit of iterating the tool multiple times, most admitted they did not do so, neither had they the intention to do this in the future. This can be linked to the lay-out of the canvas, which unintendedly is perceived "closed" and "final". As a result, some students selected kind of randomly a topic to explore - "the last thought in my mind during the brainstorm"-, while others finished all steps -"with a broad subject that still leaves options open"-. And by doing so, did not make a manageable choice even at the end of the process. Perhaps, leaving a few input fields out of the canvas, and stimulating the students to only complete these during a next (validation) phase, could motivate an iterative use of the tool.
Compared to straight forwarded challenges, it is much harder to relate these complicated and ambiguous problems to previous solved questions. We try to avoid giving students a false sense of security, which would have been the case if we would already ask for solution-search directions [19]. The tool should find an equilibrium between confronting the users with the complexity of the spotted problem and proving some grip to keep the user believe in the achievability. We must challenge the users to switch off their analogy thinking when trying to fit a new topic into a former box. Surely, as long as one focuses exclusively on similarities, the envisaged possibilities remain limited [20].
Finally, asking for a list of subproblems might also be problematic when the users consider these as detached from each other and are planning to deal with them separately. On the contrary, addressing single parts of the problem-puzzle does not guarantee a successful solving of the underlying challenge, and might be contra productive [9]. An improvement of the tool should provide a larger input field where relations between the several subproblems can be drawn. The canvas should be able to show that conflicting requirements are possible and can be fruitful [5].

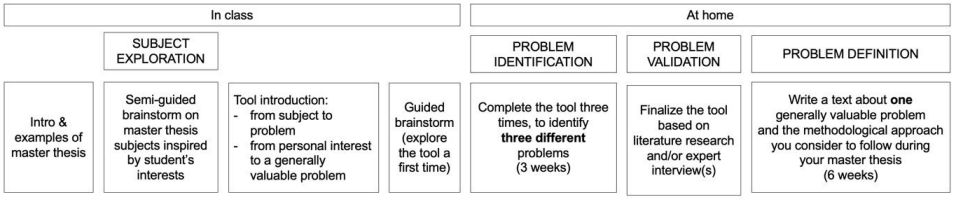

Figure 3. Proposal: adjusted master thesis search process

For future steps, we propose an enhanced version of the process in which the tool is implemented (Figure 3). We plan to test both this process and an adjusted canvas with next year undergraduates. By sharing our findings, we hope to inspire our peers to try out alternative ways to let students experiment with problem-finding, before they start thinking on solving these wicked issues.

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VIRTUAL AND AUGMENTED REALITY TO EXPLOIT STEM-SKILLS-BASED LEARNING FOR ENGINEERING STUDENTS USING THE TEC21 EDUCATIONAL MODEL

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ABSTRACT
The worldwide confinement due to Covid19 has boosted creativity in academia to develop learning activities with role-playing games and multidisciplinary workshops brought to our students' homes. Tecnologico de Monterrey, like most universities in the world, is delivering classes remotely using internally developed and external platforms designed to continue the practices that were done every day in laboratories, facilities, and visits to companies and institutions.
This document describes the migration of academic activities, designed under the university's Tec21 Educational Model guidelines, to an internet platform that adopts virtual and augmented reality to deliver learning with the same academic quality as the traditional face-to-face classes. Our training partners in industry, government, and not-for-profit organizations can communicate and access the practice activities on the virtual platforms.
The Tecnologico de Monterrey School of Engineering and Design has worked to generate a simulator of an ERP (Enterprise Resource Planning) system based on the educational platform "Tec21 Car Assembler." Using virtual reality, the student can apply the virtual classroom's theoretical learning to practice, guided by an academic figure who collaborates with training partners from companies and institutions associated with Tecnologico de Monterrey to transfer knowledge to students.
Through virtual and augmented reality, the students have been able to interact with the scale car assembly through the EON XR platform, where teachers have designed different lessons based on car assemblies and subassemblies, in this case, Jeep. We are developing our own platform for assembling Meccano designs that can be made by students first using second and third simulations until they can be taken to assembly, using augmented reality and finally, virtual reality.

Keywords: Augmented reality, virtual reality, gamification, educational innovation, higher education

1 INTRODUCTION

This research is an extension of the work presented in the 2020 edition of E&PDE [1]. We share the impact of simulations through playful STEAM tools [2], mainly, Meccano developed by students in Industrial Engineering and Design. Beginning March 2020, we were affected globally by the confinement brought about by the COVID-19 virus, so the challenge of this education was elevated. We brought practice activity to the virtual world using a platform that simulates a car assembly plant with virtual and augmented reality.
Virtual reality (VR) focuses on the design, engineering, and research connected with immersive interactive systems. These virtual reality systems synthesize environments or worlds in realistic simulations that are usually rendered with three-dimensional images, sounds, and robust feedback [3]. This type of technology allows us to immerse ourselves in environments and processes altered to our reality, intensifying the experience and imagination, thus boosting our students' research and learning processes.
The use of Virtual and Augmented Reality allows the environment to become interactive, colourful, and three-dimensional. It allows us to create immersive experiences, where the users can witness experiences and events that seem to be real.

Studies have shown that VR and AR experiences have increased student motivation and helped them acquire research, critical thinking, problem-solving, and communication skills through collaborative exercises. The benefits of VR and AR technology are reflected in our students' results as learning achievements, better learning outcomes, increased motivation and more positive attitudes. They demonstrate emotions of happiness as they "learn through the game"[4].

According to Gartner Inc. (2008) [5], there are various significant emerging technology trends. He highlights the technologies that will significantly affect companies, society, and people in the coming years. These include technologies that enable businesses and society to regain confidence in technology. AR technology is booming exponentially because its use in innovative educational applications in the classroom is increasingly prevalent, allowing students and teachers to "interact" more thoroughly in their activities and the teaching-learning process. In an institutional way, in Tecnologico de Monterrey, we are using the Flexible and Digital Model [6]. It is a challenge-based learning model that integrates innovative teaching strategies and cutting-edge technologies. The model proposes a flexible and digital learning experience that emphasizes content, interaction, learning activities, technological tools, and evaluation.

Various research studies in the educational environment have shown that experiences with emerging technologies such as AR and VR have resulted in the following parameters (in descending order): learning advantages (43.75%), motivation (31.25%), ease of interaction (15.63%), collaboration (18.75%), low costs (12.5%), learning (12.5%), just-in-time information (12.5%), in-place learning (9.38%), student-centred (9.38%), student care (9.38%), enjoyment (9.38%), exploration (12.5%) , increased capacity for innovation (6.25%), positive attitude (6.25%), awareness (3.13%), anticipation (3.13%), and authenticity (3.13%) [7].

At Tecnologico de Monterrey, the instrument for measuring the classes' effectiveness was the ECOA, an institution-wide student opinion survey. During the pandemic, this instrument yielded information that our students wanted educational platforms to bring them closer to laboratory and professional practice experiences with training partners. These include goods-and-services companies, civic organizations, and government. Performing projects with them offers our students a more connected real-world experience.

Independently of the ECOAs, we have conducted surveys on the first day of classes since the school period August to December 2020, where we ask the students three fundamental questions to measure their mood:

1. How have you felt about the health situation we are experiencing in the country?
2. How do you feel about online classes?
3. What have you not liked in the online courses that you do not want to be repeated in this class?

We found that most students have emotions of frustration, despair, and sadness about the current situation and require intellectual stimulation through dynamic and disruptive teaching to face challenges and experience their university life as they knew it before confinement.

The safety and health restrictions and confinement due to COVID-19 have led us to design platforms with virtual and extended reality using an ERP simulator designed by this research group. The platforms enable interactions among students, teachers and training partners to improve students' knowledge and develop competencies through simulations of realistic situations encountered in society and companies. This research article describes the methodology for the simulator design and the results obtained so far.

Despeisse [20] mentioned that gamification and experiential learning are increasingly used in education as they create an immersive environment to simulate students and promote deeper learning. In industrial engineering education, computer simulation and digital games are commonly used to teach skills in supply chain theories learnt and reflect on the impact of their decisions, also describes that other hands-on games can also foster the development of professional skills such as leadership, teamwork and communication, in Tec21 educational model is called competencies.

In different universities, mainly IMT [21], many simulators have been developed that can be used on computers, such as the game of beer and fish banks. For the ERP concept SAP has his own simulator. There are many educational strengths in these simulators, which have been used by the industrial engineering department for many years, the weakness is that they are games focused on certain disciplinary skills, such as logistics and decision-making. Our proposal has the educational innovation of simulating several disciplines concurrently, in addition to making use of augmented and virtual reality technology.

2 METHODOLOGY

The research methodology fuses two disciplines, Experiment Design and Design Thinking, to construct the simulator with current ERP platforms (Enterprise Resource Planning) [8]. Figure 1 shows the methodology applied to this research.

The first step in design thinking is empathy. To approach this, we analysed the institutional surveys (the ECOAs) and those applied by the research group in the school periods February-June 2020, Summer 2020, August-December 2020, Winter 2021, and February-June 2021. The surveys gathered students' opinions, which we analysed at the beginning and end of the school period. Doing this allowed us to determine both the mood of the students and their needs.

In the definition part, we used engineering thinking based on the algebra of sets to determine the most critical characteristics that the simulator should have. Among them, we selected the hook, academic rigor, transversal and disciplinary competencies, gamification, technology, and degree of difficulty. Using nominal techniques and interpretive structural modelling, we defined three critical variables: student engagement ("the hook"), academic rigor, and transversal competencies. Having done this, we began to define the parameters for these variables and proposed the experimental design.

Three hypotheses were defined to be tested based on the use of our simulator:

a) That statistically, the students' learning would be high, defining as high a score greater than or equal to 85 points out of 100.
b) That statistically, the students would develop transversal competencies, evidenced by a rubric to assess learning.
c) That the students would use the simulator on average more than 50 hours in the school period.

Through the experimental design, we could determine the area for which the simulator should be designed. Determining this, we made a prototype that tested five groups (classes) in a sample of 271 students. The final design of the Tec 21 VEP (Virtual Enterprise Planning) was completed after analysing the exit survey results.

3 DEVELOPMENT

One of the biggest challenges of distance learning is achieving fun and practical learning. It can be done by integrating new technologies into the learning process [9]. One of these technologies is Augmented Reality (AR). AR is defined as the technology that allows virtual objects to superimpose on the real world so that they seem to coexist with the real-world objects in the surroundings [10]. This technology has already been used in the military, medicine, engineering design, robotics, manufacturing, maintenance and repair applications, consumer design, and psychological treatment, to name just a few [11]. Employing interactive techniques supported by this technology, the user can change the position, shape, or other characteristics of virtual objects (also called augmented components) in ways never before possible.

Various studies have shown the advantages that this technology offers in education. Georgiou & Kyza [12] investigated whether the impact of immersion in learning in location-based AR environments was influenced by student motivation. The study focused on 135 tenth-graders who used an AR application for environmental science learning. The results showed that the immersion positively impacted domain-specific motivation and cognitive motivation. In turn, the gains in conceptual learning were also positively related to the level of immersion that the students experienced. Mumtaz et al. [13] compared students' learning and motivation using AR technology in blended-learning contexts and the classroom, respectively. Their results showed that using AR positively affected the students' learning experience, elevating their confidence and motivation.

Stoyanova, Kafadarova & Stoyanova-Petrova [14] employed Mobile Augmented Reality (MAR) applications in teaching practice as an innovative way to transfer knowledge. The results showed that AR technology awakens students' interest in learning content and promotes their cognitive activity, offering a more engaging and amusing educational experience. Salmi, H., Thuneberg, H., & Vainikainen, M. P. [15] analysed learning through AR technology and its cognitive, motivational aspects in an information-learning context. They found that using AR in education offers advantages for all, particularly for groups that previously showed less success. On the other hand, Ibáñez, Di-Serio, Villarán-Molina, & Delgado-Kloos [16] examined methods to improve students' focus in meaningful activities. As a result, they observed that students in the experimental group achieved a higher learning level than the control group.

Given these advantages, we might wonder how to use AR technology in learning activities involving simulations that explore the effects of specific decisions regarding a system's components. Ibáñez, Di-Serio, Villarán-Molina, & Delgado-Kloos [17] investigated the effects of using AR-based simulations on student interactions and learning performance. They found that AR simulations helped students learn the fundamental principles of electricity. Crandall et al. [18] tested an AR game that focused on basic enzymatic kinetics in food chemistry. They found that AR games can be used to provide students with multiple perspectives and contextual learning. They facilitate learning transfer and extend skills and understanding of the game to the real world. Hwang, Wu, Chen, & Tu [19] proposed competitive gaming in AR to support learning activities. They found that this approach improves students' attitudes and learning achievements.

Gamification boosted the students' interest in the activities. So, we designed the simulator to replicate the manufacture of a Jeep to scale with Meccano parts. It emulated the actual process of a car assembly plant. The simulator was based on an ERP system where students could visualize the interactions among an organization's various departments. The simulations also generated random events such as production line failures or other production problems.

The final design is a flexible model that comes from the customer orders for the different car models assembled. The information enters the software that processes them, which, as a result, suggests production orders and materials purchases. To accomplish production, the users must input the system with the parts' specifications and make the BOM (bill of materials) and the MRPs for each product, with its quality and product-design specifications. The simulator does the transactions through screens (dashboard), making suggestions for decision-making. The student must apply theoretical learning in decision-making. The ultimate goal of using the simulator is to assemble cars with the required quality, obtaining the best margin of utility for which grades are obtained. When the student dominates the theoretical part and, consequently, makes the best decisions in the simulator, he or she obtains higher grades.

The digital part of the VEP virtual assembler interfaces with the EON XR system. Through augmented reality, virtual reality, and 3D graphics, the student explores the components and assembles the product. The activity design is placed in a CANVAS system module where the educational intent is specified. The student is instructed to install both the VEP and EON XR simulator to experience in a virtual environment an assembler's role, analyse real problems, and create models that can abstract that reality and give solutions that are measurable and quantifiable. Also, a training activity was designed for students to become familiar with the AR and VR tools.

The specific learning objectives were defined as follows:

1. Learn to abstract a problematic situation and define problems.
2. Learn how to map a company's information flow and processes and illustrate them in diagrams that synthesize and explain the flows and processes.
3. Define and create databases with the provided information for analysing; develop or obtain sensitive metrics.
4. Build solution proposals with systemic, simultaneous, and forward-looking thinking.
5. Develop resilience in the students to overcome difficulties and arrive at propositions of value.

Also, putting a significant challenge in an activity design in the face-to-face and online courses was crucial. The challenge was implemented in both types of courses at Tecnologico de Monterrey. In the online course, a total of 192 out of 318 (60%) students opted for the car assembly plant called the "Tec21 Car Assembler." Implementing it challenged us much according to the learning objectives mentioned previously, and we counted on the support of the external professors who taught the subject. The development of the activity, the EON-XR tool, the teacher training, and the design application to the students are summarized in Figure 1.

4 RESULTS

The students could see the virtual plant's entire operations and experience a virtual learning environment within the assembly plant. Thus, they became familiar with the different products' details, experienced real problems, and created models to propose different measurable and quantifiable solutions. The results of using the VR and AR tools are compiled in Figure 2 for the online class application, where the students could experience live class demonstrations.

Figure 1. EON-XR tool, teacher training and design application

The results were medium to high grades depending on their experience with the tool in the real-time demonstration. The learning outcomes achieved around 80% (in presential class) and 81.2% (online). For the activity design practice, the average grade was 76.2% (in class) and 73.2% (online). The achievement of objective parameters (70.4%, 70.2%), ease of use (70.6%, 70.2%) and utility of the application (70.4%, 69.4%) averages were practically similar.
In short, the overall evaluation by those who used AR and VR in real-time was 76.2%, and 74.8% for online students. The survey and feedback from the EON-XR tool experience only came from students who used the AR and RV app in the online course during the August-December 2020 academic year

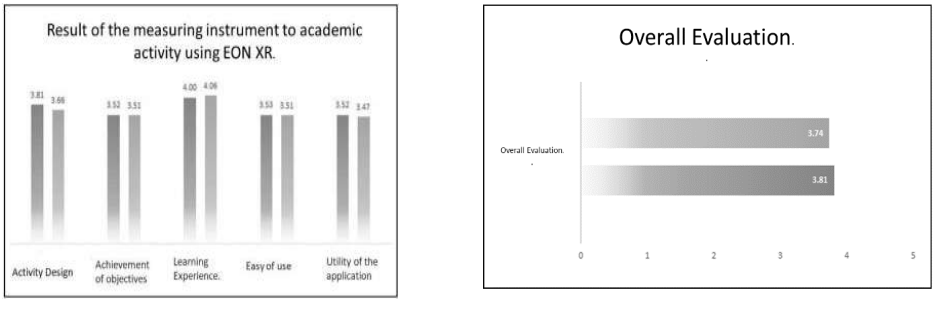

Figure 2. Results of the overall evaluation of the VR and AR tools in the face-to-face and online classes

5 CONCLUSIONS

The project addressed the issues of distance education in the Engineering and Design subject for our students through a simulator design. It was potentialized by virtual reality and augmented applications. The institutional student opinion surveys found that their perception of the learning model improved. In the virtual classroom, we could infer the change in the students' mood from what it had been at the start of the school term. In the end, the students motivated by gamification mastered the methodologies studied in the course and achieved higher grades. They also had the opportunity to experience the reality of an assembly plant through augmented reality. It empowered them to manage the day-to-day situations of a real manufacturing plant.

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DESIGN AND DOUBLE BIND COMMUNICATION IN PUBLIC SERVICES—THE MODEL OF LOGICAL PARADOXES

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ABSTRACT
This article introduces the understanding of double bind communication from cybernetic theory and describes how a synthesized model of logical paradoxes can serve as a means for systems analysis of double bind communication inherent in the relationship between clients and service providers. The study is oriented in the context of the Norwegian Labour and Welfare Administration (NAV). Double bind can be described as communication that is paradoxical in contexts where, for example, the client, in this study the citizen, seeking help in difficult life situations, encounters dimensions of being disciplined and helped as two facets of a conversation with the service provider, in this study a public servant representing a welfare provider.
We have explored communication sequences in citizen–public servant conversations in relation to cybernetic theory and Bateson to understand and design services that meet users with double bind communication in welfare services in particular and service design in general. This is to design a mutually trustworthy relationship between the citizen and welfare provider. It is suggested that the model of logical paradoxes synthesized in this research should be introduced to design students. This will enable a wider understanding of double bind functioning and thus create a method to design for situations where double bind communication is detected or unavoidable.

Keywords: Systemic design, cybernetic theory, double bind, design method, public services, sustainable welfare system

1 SYSTEMS ANALYSIS OF DOUBLE BIND COMMUNICATION IN THE CONTEXT OF WELFARE SYSTEMS

Designers with various backgrounds from product design, design for user experience, service design, design research and systemic design operate in complex contexts in their practice. A typical example of such a complex situation is the creation of fruitful communication sequences between the Norwegian Labour and Welfare Administration (NAV) represented by a public servant and the citizen as part of the total welfare service system. In today's system, there are existent communication sequences where the public servant must discipline *and* support the citizen in the same conversation. An example of this is when a public servant, who is instructed to motivate the citizen to take part in an activity—a course on how to apply for a job or write a resume, a motivation course, an education programme, etc.—is also required to discipline the citizen if he or she does not take part in the activity agreed upon. On one side, the organization is set up to support all citizens to be able to live independent lives. The system that is built to effectuate such support consists of offerings such as free education, monetary benefits, and support for living accommodations. However, to receive such support from NAV, citizens who may be in a burdensome situation due to sudden change in life through major events, such as illness, depression, or loss of job, must comply and perform in accordance with the demands listed as prerequisites. These double bind communication situations in NAV occur due to internal organization and the internal distribution of tasks and operations. Another reason double bind communication situation occur is the enforcement of national laws and regulations as criteria to receive welfare support. The principle that has emerged out of this organizational structure can be explained as follows: aid is given if the citizen performs, and this represents a paradox since the citizen approached NAV in the first place because he

or she could not perform. Paradoxes, such as the one described, referred to as double bind in systems theory [1], øllø m0, are not unusual in the public services sector. Interestingly, most designers that work to handle such complex situations lack knowledge about double bind communication situations and thus miss out on the disclosure and ability to handle them.

1.1 Double bind

Double bind is a term coined by Gregory Bateson [2] and is briefly described by his daughter Mary Catherine Bateson as *"a communication function that conveys contradicting messages at different logical levels"* [1]. She further elaborated on the double bind as *"an abstract pattern of relationships that might show up in particular exchanges, but these always depended on the broader context."* She then refers to her father's example of such a situation, which he described on the basis of an observation of *"a young man who had been in hospital and was somewhat recovered from an acute schizophrenic episode when he was visited by his mother."* Gregory's account of the event: *"He was glad to see her and impulsively put his arm around her shoulders, whereupon she stiffened. He withdrew his arm, and she asked, 'Don't you love me anymore?' He then blushed, and she said, 'Dear, you must not be so easily embarrassed and afraid of your feelings.'"* [1]. In this sequence, the young man seeks to communicate his affection for his mother, which is rejected. His subsequent need for confirmation of his mothers' love for him is punished and serves as a supplementary rejection. The failure of his mother to communicate her love for him is laid on him. As M.C. Bateson stated, *"The double bind is created in interaction between two or more parties or entities (I am deliberately avoiding saying 'persons' here, which is the usual phrasing – really we are dealing with parts of some larger whole) in a significant non-transient relationship that continues over an extended period, with the same pattern repeated again and again. In this pattern there is a contradiction between messages at different logical levels: a primary injunction and a second injunction at another level affecting the interpretation of the first. There is some real emotional danger or threat in this situation, no possibility of withdrawing from it, and no possibility of naming the problem"*[1]. Double bind is not a countable measure; however, it describes a phenomenon destructive to communication and functioning. Hence, a service that represents double bind functioning may be destructive and work counter to the goal with the service [3] and, by extension, the policy intended. Double bind may not be possible to prevent, but we can be aware of the phenomenon when designing welfare services.

1.2 Double bind situations in welfare services

Citizens and public servants behave and adjust in accordance with the systems that enable encounters between them. Both ends of the communication know that one must behave in a specific way to achieve desired outcomes. Citizens adjust to monetary and social support systems that shape their behaviour. The public servant, being on the other side, behaves in line with the power structures, hierarchy, administrational system, execution of laws and regulations and so forth. The intention of a welfare system is to arrange for the citizens to receive various types of benefits or support during a troublesome period. However, the communication systems may work to the disadvantage of both citizens and welfare systems because the relationship represents different perspectives and goals. Accordingly, the nature of the relationships may hinder the welfare provider and the functioning of the programme itself when the communication function hinders or demotivates the initiative from benefiting the citizen who is in need of support. Double bind or double communication occurs in various systems, as for example M.C. Bateson pointed out: *"Living in an individualistic Western society, we are double bound by being told we are free and by being subject to a large number of social controls that make us unfree, we are unwilling to analyse the contradiction between our purposes and our survival (as individuals or as a species) or the contradiction between being organisms that necessarily must die and being convinced of the need to stay alive"*[1]. Thus, the understanding of being free for a child within a family structure may represent such double bind messages: You are free but also controlled by the same parents that say you are free. In educational systems, pupils and students are encouraged and evaluated by the same system and in design education, particularly educators who typically make demands of students using messages such as *"You must be free, you must make your own choices."* As Bateson points out, *"There is a contradiction: If you must be free, then you are not free"* [1]. Based on the latter example of a paradox in logic, we developed a model that describes double bind communication between citizens and welfare providers as a process of developing a design method that stimulates awareness and understanding at different levels of complexity for the designer.

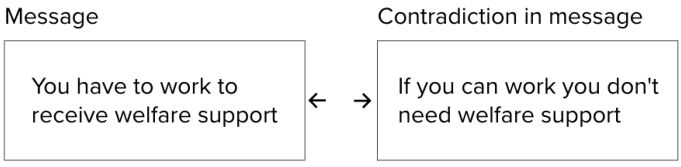


Figure 1. Example of double bind communication in the context of welfare service systems

The intention with the examples in the boxes that illustrate contradiction in messages typical of NAV and the welfare system context is to exemplify and contextualize double bind communication for design students that want to learn about public services and designers in organizations such as NAV. To prepare design students to work within such complex situations as described, systemic design education has emerged.

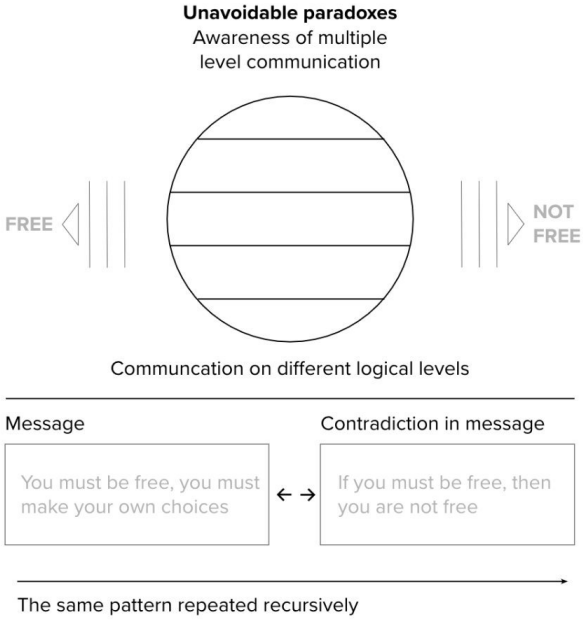
2 UNDERSTANDING COMMUNICATION SYSTEMS IN SYSTEMIC DESIGN

Systemic design is a combination of design practice and systems theory. Systems represent exceedingly complex networks of relations in eco-systems, environments, society, organizations, services, and social systems, including circumstances i.e., and cannot be approached with standard design or engineering methods [4]. The systemic design methods that enable designers to explore systems, environments, societies, organizations and public services are, therefore, linked to complexity and systems theory. Systemic design thus serves as a methodology for design in such complexity. By systemic design practice and research, the method of GIGA mapping has emerged. GIGA mapping is a method that designers use in cooperation with stakeholders, clients and users i.e., to create an overview of situations that make the origin for future designs by visualization. GIGA maps thus often serve as a platform to visualize all systems within the imagined scope of a project. Visualizations of main systems connected systems, their functioning, relations and the structure the systems depend on and represent thus make up a total picture of the complexity of the situation at hand. The GIGA map functions thus as a holistic approach by visualizing the whole *report*, which in turn invites all participants to see all *pages* of the report simultaneously and thus work, synthesize, connect, react and add i.e., to the content of the work. Visualizing all the empirical data into one or more GIGA maps does not, however, ensure quality. The designer must have methods to analyse the complexity of the data to reach new solutions by design. Knowledge about systems theory marks the origin for such analysis in systemic design that can inform the design team about the existing systems at hand, what structure they depend on and the organization of these self-producing qualities, systems functioning and related networks of relations, reinforcing and balancing feedback loops and strong or weak connections i.e. In systemic design, hindrances or so-called problems caused by, for example, programme errors or user experience design that stimulate misunderstanding receive little attention since they solely represent structural dimensions and thus have a minimal potential for systemic change. The emphasis in systemic design lies within system functioning, system malfunctioning, connected systems or missing connected systems. For example: *"Missing feedback is one of the most common causes of system malfunction. Adding or restoring information can be a powerful intervention, usually much easier and cheaper than rebuilding physical infrastructure. ... That's a perverse feedback, a positive loop that leads to collapse"* [5]. Accordingly, we have directed our research to produce insight about communication and double bind communication in complex systems in particular, the discussion about how these dimensions can lead to the emergence of a discursive design method that stimulates design students and designers to seek understanding rather than imitate problem solving, and a discussion about facets of double bind in service design.

2.1 Designing communication systems with awareness of double bind functioning

Bateson stated: "It is rather generally believed that 'causes' or 'reasons' for alcoholism are to be looked for in the sober life of the alcoholic" [2]. By this formulation, he suggested that we all seem to research what others do and within the same logic. This way of thinking, which involves exploring the other end of a situation, is what is referred to as "negative explanation" or cybernetic analysis [2]. To develop a method that stimulates designers to research another logic and stimulates discussions about logic in systems themselves, we used negative explanation as a process. By combining the negative explanation

of being or feeling free, which originates in Bateson's example of double bind and freedom and double bind communication, we synthesized a method for design discussions and exploration. Free can be analysed within the range of free to not free. That is, we suggest that designers seek understanding about free by examining what is not free. The different levels of communication that are represented in a public organization, company i.e., may represent different logics between these two ends.



THE MODEL OF THE LOGIC PARADOXES

Figure 2. The model enables designers to identify similar logical paradoxes in the contexts they practice and to formulate the specifics of such contradiction in messages in the project

2.2 User-orientation and systemic insight

Service designers working with user-oriented processes typically emphasize user satisfaction to provide good user experiences between the service user and the service provider and the value exchange between them. However, the immediate gratification of such experiences does not necessarily equal quality in service functioning over time. Hence, service design could benefit from processes that stimulate thinking about the experience of the citizen as a whole by, for example, exploring experience in relation to time. As an example, a tobacco-free city does not offer citizens immediate gratification, but it does when welfare is considered in the long run or as part of a whole.

Hence, service design methodology neglects a holistic perspective by the user-orientation, emphasizing the immediate experiences as a central method of services. That is, the methods lack thinking about forms of communication systems, overlapping dependent systems and thus the need for system insight and knowledge about the system characteristics, functioning and malfunctioning.

2.3 About the method, the logical paradoxes

The research describes various situations and kinds of functioning of double bind within NAV, involving phenomena and tensions in encounters between citizens and a welfare system and the functioning of double bind between systems in general. We have witnessed a need for a flexible and in-depth understanding of the system dynamics concept combined with the observing concepts from cybernetics to work for open-minded thinking processes for design students. As designers are increasingly involved in designing services for the public sector, a field of complexity, uncertainty and unknown unknowns, designers are expected to handle such uncertainty. Through this article, we seek to explore pedagogical

methods to understand the systemic character of systems, which often have invisible elements, however concretely such elements, such as a communication system, can define the functioning of the system.

2.4 What did we do?

We used theory from cybernetic and system dynamics, the concept of double bind and Meadows 12 leverage points [5], to form the model of the logical paradoxes. The negative explanations that describe a phenomenon and the other end of a phenomenon (free–not free) represent the level of contradiction in a message/communication. To discuss the different levels of logic involved in creating paradoxical messages, we used Bateson's perspectives on communication as circuits of praxis (detailed descriptions of behaviour) [2] by visualizing the praxis of citizens forced to document their recurring misery over time in a conversation with NAV supervisors (that may create a thinking pattern in the citizen that can produce lost self-confidence, the opposite of the goal of the welfare system). We called these elements *the message* and *the contradicting message* in the model of logic paradoxes. The focus of the research was to include elements in the context of these messages to be able to understand the system from a holistic perspective and to grasp what type of dependencies lie within the system characteristic that allows for these double bind messages to endure. Systemic design requires an understanding of the relationships between elements in a system. The model encourages visualizing patterns of thought and communication to learn how a citizen receives a message and how a welfare system communicates a message. "Double bind is not something that happens to a mind but something that happens in a mind" [1].

3 IMPLICATIONS FOR DESIGN

The model of the logical paradoxes is a tool for design as inquiry towards understanding rather than for problem solving. It is a tool for investigating patterns in communication and encounters between citizens and public services to identify occurrences of double bind communication on different logical levels. It is thus a discursive tool for design thinking and learning about logical paradoxes inherent in our world and in services developed in a complex field and for experimenting through the design process with different models containing different stakeholders' perspectives and objectives. The model facilitates an exploration of the relationship between people and services through a communication lens on different logical levels to spark a reflection about communication systems, abstract immediate systems, physical structures, forced communication, absent communication and so forth. The model of the logical paradoxes may serve to elicit discussions about how we can design public services that provide a trustworthy relationship between citizens and the public sector that contains a minimum of double bind communication.

4 DISCUSSION AND REFLECTION

This research investigates how we can provide citizens with financial security as part of a service while also allowing the public servant to be a "good helper" who "pushes" when needed. That is opposed to today's situation where the public supervisor is forced to "discipline" the client because of a rigid system. It represents classic double bind situations, which are a problem for the citizen, the public servant and the welfare service system. NAV is concerned with solving this problem in a better way; however, this seems to be impossible without being able to disclose double bind functioning.

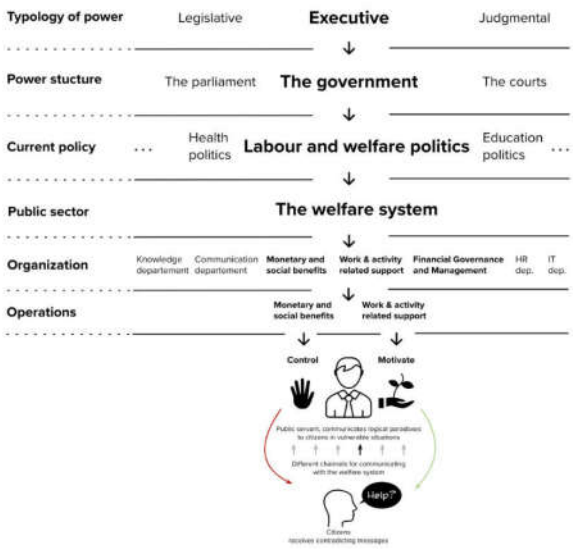


Figure 3. The model shows a praxis analysis of the communication between the citizen and NAV supervisor. The communication represents a double bind situation in which the supervisor promises aid if the citizen complies to be controlled. The double bind praxis is positioned by visualization within the structures for a welfare system. The designers may utilize such holistic practices to detect relevant structures, information flows and other dynamics relevant for communication systems and thus double bind functioning on different levels

A systemic design approach seeks to understand organizations and services holistically and to reveal their systemic character and functioning. The outset is to understand encounters, interactions, and communication between citizens and public servants, which are often described as dysfunctional conversations and exchange of information. The double bind communication in these encounters can lead to the cementation of a citizen's troublesome situation. Due to the control function, the public servant must execute and force the citizen to document his or her illness or otherwise problematic life events in exchange for welfare support. However, if not detected and designed consciously, the double bind functioning of these services may even be destructive for the person seeking help. We, therefore, suggest that the model of logical paradoxes is utilized in design education to help future designers handle such complex issues.

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STUDENTS' PREPAREDNESS TOWARDS WRITING A BACHELOR THESIS; A SURVEY-BASED INVESTIGATION

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ABSTRACT
This paper investigates how students perceive their preparedness when they start writing their bachelor thesis. Students at the University of Agder (UiA) will, in their first semester, receive lectures in ethics, academic writing and referencing to equip them for future writing, mostly academic reports. In the Civil Engineering Department, an IMRAD report template is used during their bachelor thesis. The Civil Engineering Department also requires lecturers to use variations of the same template for every report to prepare the students for their bachelor thesis. This paper will use this year's bachelor students as a case study.
In January and February, the students attended a workshop and followed a course titled "TFL200 – system course for engineers". The workshop gave the students a recapitulation in academic writing, referencing, the writing process, project management, and how the template is structured, explaining the template's different parts. TFL200 covered ethics, systems theory, innovation and LCA, sustainability, and academic writing.
In the spring semester, two surveys were sent out to third-year bachelor students in Civil Engineering writing their bachelor thesis. The first survey was sent out at the beginning of January, before the students started their course and workshop. This survey investigated to which degree the students feel prepared, motivated, and ready to write their bachelor thesis. The second survey was conducted in late February to evaluate the effects of TFL200 regarding the bachelor project and the workshop, measuring the student's current preparedness, motivation, and to which degree the students feel competent.

Keywords: Survey, civil engineering education, students, peer review, supervision, academic writing, motivation

1 INTRODUCTION

According to Imel [1] the way of learning how to work in groups is by working in groups. However, working in groups on a project can be challenging. In Burdett's study [2] the students experienced that working in groups was particularly challenging when projects were graded. They were concerned that some students would end up doing all the work to achieve good grades, while other group members got a "free ride" by not participating. Even so, the results of Burdett's study show that the students gained competencies. A clear majority said that they learned to negotiate with other group members, manage tasks effectively, share responsibility, solve complex problems, resolve conflicts, and develop a shared vision for the group.
Several analyses [3-5] have confirmed that feedback to students is essential for the learning outcome.
During the students' bachelor thesis, this is provided through supervision. Each group will be assigned a supervisor from the university, who is competent within the subject of the students' bachelor thesis. The students' expectations do not always match reality. It is therefore, according to Lovitts [6], important to clarify the expectations regarding the supervision early in the process. Even when this is clarified there can still be some challenges in supervision. Lundgren and Halvarsson [7] discovered that students worried about their supervisors' competence with the written structure of a thesis. Since the Civil Engineering Department at the University of Agder requires the students to use an IMRAD-like template many of the supervisors do not necessarily have the required competence. Hence, we have tried to solve this by organizing workshops and peer reviews. During the workshops and peer reviews the

supervisors who were present knew the template and formalities regarding writing a bachelor thesis. By having these workshops and peer reviews, the students have an extra arena where they get supervision. As stated by Mulder et al. [8] and Gielen et al. [9] there are several benefits in using peer review in higher education. One being that the students get better at evaluating their own work. In addition, the quality of the written work can increase.

National Guidelines for engineering studies [10] require students to have general competencies in environmental, social, health-related, and financial consequences around their work in Civil Engineering and put this into an ethical and life cycle perspective. They also require the students to know how to work in groups, to be able to write academically and to do credible research. When the students have studied for two and a half years, they start their final project: their bachelor thesis. This is where they can showcase their skills learned throughout their studies. So, how prepared are the students when their final semester starts?

2 CASE

To identify the students' preparedness towards writing a bachelor thesis, this year's third-year civil engineering bachelor students were used as a case study. These students originally started their bachelor's degree in 2018 and will finish in the spring of 2021. This class consists of 62 students. When students write their bachelor thesis at the University of Agder they must work in groups varying from 2-4 individuals. Parallel to writing their thesis, the students participate in the mandatory course titled "TFL200 – system course for engineers". The course covers ethics, systems theory, innovation and LCA, sustainability, and academic writing. The final semester thus consists of 30 credits; 10 awarded for TFL 200 and 20 for the bachelor thesis.

We were interested in the students' competencies concerning the report template, the subject of their thesis, academic writing, referencing, motivation, planning a project, supervision, and group dynamic, both before starting their final semester and after having the TFL200 course for almost two months. The study programme tries its best to prepare the students towards writing their bachelor thesis. Hence, the students must work in groups from the very beginning of their study. They will have a minimum of one group project every semester and will hopefully learn some group dynamics. That students learn to work in groups is also an important part of the National Guidelines for engineering studies [10]. In one subject the students also learn how to use a progress plan to plan a project, which is required to be used during their bachelor thesis. The students have also had several exams consisting of reports, where academic writing is a part of the grading. Supervision is the only topic investigated in this paper which the students have not experienced prior to writing their bachelor thesis.

In their final semester the students started the 6th January. We arranged a workshop for the students on the 8th January where we gave the students a recapitulation in academic writing, referencing, the writing process, project management, and how the template is structured, explaining the template's different parts. In the Civil Engineering Department, the students must use an IMRAD report template for their bachelor thesis. This is the same template they have used previously in the study programme, which means that the students will most likely recognize the structure. Even though the TFL200 course covers academic writing in general, the students were given an extra lecture on the 28th January which emphasized academic writing specifically for the bachelor thesis. In this lecture the students also learned about referencing and information evaluation. Part of the mandatory requirements for submitting the bachelor thesis are that students must deliver their research question and a progress plan before the 5th February. Therefore, a voluntary peer review was held on the 3rd February. We have had great experience with peer reviews [11] previously, so we decided to arrange it equally. This means that the peer review consisted of a 10-minute presentation and 5 minutes of feedback from peers. All the groups had another group as opponent that had prepared a feedback in advance. The peer review was arranged digitally because of Covid-19.

3 METHOD

This paper is based on the feedback from the bachelor students through two surveys. The surveys were distributed on two different occasions in the final semester of their bachelor's degree. The scope of the surveys was to identify the students' preparedness towards writing their bachelor thesis. The questions did not differ much from the first survey to the second survey, mainly the tense of the verb. This was done to identify if there was any difference after almost two months of writing their bachelor thesis. In

addition, the students who participated in the peer review were asked to rate the peer review process before the session ended.
The first survey was distributed to the bachelor students at the start of their final semester; the 6th January. This survey was available for the students to answer for two weeks. The second survey was distributed on the 22nd February and was only available for three days. The surveys were made using the survey tool SurveyXact and distributed through the learning platform Canvas. The first survey contained 15 questions and the second survey contained 14 questions. The questions were designed with a scale from 1 to 5. Depending on the question, 1 meant "not prepared", "very poorly", "not motivated" and 5 meant "very prepared", "very good" or "very motivated" for example. To measure the students' preparedness the following subjects have been focused on; the report template, the student's knowledge about the subject of their thesis, academic writing, referencing, motivation, planning a project, supervision, and group dynamic.
The results were analysed by calculating an average from the ratings in the surveys, and a standard deviation to show the variation in the results. This was not done on the questions that did not contain a 1 to 5 answer option.
The timeline between the two surveys is illustrated in Figure 1. The figure illustrates what the students received of arranged guidance between the surveys. Their supervision has also started in this period.

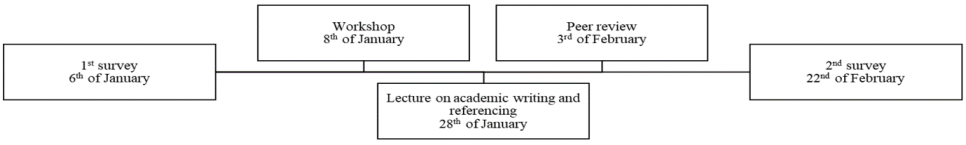

Figure 1. Timeline between the two surveys

4 RESULTS AND DISCUSSION

An overview of the distribution date, number of questions and response rate to each survey is shown in Table 1 below. The first was sent out before the students had started doing their bachelor thesis, and the second when we believe the students knew what was expected of them in a bachelor thesis. This way we could ask almost the same questions but on a different time in their course of study. We could therefore see if what they thought in the beginning matches the reality.

Table 1. Information about the surveys

	Date	No. of questions	Response rate
Survey 1	6-Jan-21	15	64.5%
Survey 2	22-Feb-21	14	48.4%

The results from the surveys are shown in Table 2. The score is a calculated average from where the students could rate the answer from 1 to 5 – 5 being the highest and best score. The results indicate very little difference from the first survey to the second. The three points that stand out are 1, 9 and 10. Understanding the report template had improved from 4.05 to 4.30. So, although 85% of the respondents recognized using the report template previously in their study, they gained some more knowledge about the template after the workshop and working with it. Point 9 and 10 regard supervision, which is new to the students. They have little or no knowledge about supervision from their study before starting their final semester. Perhaps surprisingly, the students report that they receive more assistance from their supervisor than what they thought in the start. The students have experienced peer review at least on one occasion in their study. However, we can see that the expected assistance and benefit from supervision and peer review was lower than what they received. Since the peer review was voluntary, only 17 of the 62 students participated in the process. The participants were asked to rate the benefits from the review. 12 of these students answered and rated the peer review process to an average of 4.0. It is therefore strange that the overall rating of the peer review turned out to be 3.07 when there was a possibility to answer, "was not present". Nevertheless, it indicates that the workshop and peer review

are beneficial for the students. This matches the findings from last year [11], where the students scored the peer review process high but also had high expectations to the process.

Table 2. Results from the surveys

		Survey 1		Survey 2	
		Average score	Standard deviation	Average score	Standard deviation
	Report template				
1	Understanding the report template	4.05	0.72	4.30	0.79
	Student's knowledge				
2	Student's knowledge about the subject of their thesis	4.03	0.72	3.80	1.06
3	Obtain new knowledge	3.89	0.75	3.87	0.68
	Academic writing				
4	Master writing academically	3.68	1.02	3.83	0.99
	Referencing				
5	Master referencing and information evaluation	3.76	1.08	3.73	1.01
	Motivation				
6	Motivated to write a bachelor thesis	4.39	0.95	4.37	0.96
	Planning a project				
7	Ability to plan projects	3.81	0.89	3.75	1.00
8	Punctuality	4.61	0.68	4.60	0.77
	Supervision				
9	Assistance from supervisor	3.66	0.75	4.07	0.83
10	Benefit from peer review	2.89	1.55	3.07	1.71
	Group dynamic				
11	Ability to cooperate	4.57	0.69	4.30	0.99
12	Use of previous experience	4.32	0.74	4.14	0.92

The question regarding if the students master to write academically increased slightly. This could mean that the lecture on academic writing had a small effect or that the students already had the required skills and knowledge. 3.68 and 3.83 still mean that it is possible to improve. The same applies to referencing with an average score of 3.76 and 3.73. According to Almlie [12], who is the actual lecturer in academic writing both in TFL200 and the lecture on the 28th of January, there needs to be a higher focus on writing in engineering studies. Almlie concludes that learning to write academically is a process, not something you learn after a few lectures or workshops. Hence, the grading on all reports during the students' study programme take this into account. In Almlie's study, 74% of the students wrote that they frequently or always use the feedback to improve future performance. However, the results in this investigation show that there is still more we can do to improve the students' skills in academic writing.

The requirements when writing a bachelor thesis is that the students work in groups and deliver a progress plan in the beginning of February. The ratings from the first survey and the second survey on "Ability to plan projects" and "Punctuality" does not differ. This also applies to the questions regarding group dynamic. Some students have previous experience on planning a project with the same planning programme (Microsoft Project) that is used during their bachelor thesis, but all the students have experience on working in groups in projects. The average score on ability to cooperate is 4.57 with a very low standard deviation on the first survey, indicating that this is something the student's master. Since the average score on the second survey is 4.30 it indicates that the requirements about teamwork skills in the National Guidelines for engineering studies [10] is met. The reason can be explained with the findings of Imel [1] – simply working in groups makes the students better at working in groups. The result indicate that this is something the students also recognize since the score on the use of previous experience from working in groups had an average of 4.32 in the first survey, and 4.14 in the second survey. Even though the students participating in Burdett's study [2] were concerned about team members not participating, this does not seem to be the case here because of the high scores on group dynamic and punctuality.

The motivation scores high on both surveys with an average on 4.39 on the first survey and 4.37 on the second survey – both with a low standard deviation. Hattie and Jaeger [4] concludes that the teachers have a significant role in the students' learning outcome. During the students' bachelor thesis, they must use their knowledge and experiences from previously in their study and must obtain new knowledge mainly alone. They do however have supervision. According to the survey, 73.3% of the students have supervision once a week, whereas the rest have supervision biweekly. This means that the students get constant feedback during their bachelor project. Based on Almlie's study [12] 64% said that the feedback frequently or always motivates in their study, and 22% said that the feedback occasionally motivates. This can be a reason for the high score on the students' motivation. The students also answered what grade they were working towards and 90% said an A or a B in the first survey, and 87% still hoped for the same in the second survey. This can also be an indication of high motivation.

5 CONCLUSIONS

This paper investigated the students' preparedness towards writing a bachelor thesis. Because of a small selection it is hard to generalize, but it can be used as an indicator.

- The students were prepared when writing their bachelor thesis based on the results from the survey. When asked before they started their project the students had high expectations to their abilities regarding academic writing, referencing, ability to work in groups, knowledge about the subject in question and the report template. Approximately two months later the students still rated their abilities high, indicating that the expectations and reality align. This is accomplished by having a clear and distinct focus on this throughout the study programme.
- The students had a high score on motivation. They have frequent meetings with their supervisors during their project period which also results in continuous feedback. Feedback have been proved to help the students on their learning outcome and to motivate the students in their work. The high scores on motivation both before and after supervision indicates that the students' expectations were met.
- Having a workshop, lecture, and peer review in the beginning of the students' bachelor project does not seem to have the hoped-for effect. The results from the second survey did not show a significant difference from the first survey, indicating little or no difference in knowledge on the topics covered. The students did however rate the peer review session useful. However, there has not been done any investigation on the consequences of not offering this to the students, meaning that the peer review, lecture and workshop might have a preventive, and thus positive, effect.

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TEACHING DURING A PANDEMIC

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ABSTRACT
March 12th, 2020 was the day that the Norwegian Government put Norway in lockdown due to the COVID-19 pandemic. The implication of this was that all kindergartens, pre-schools, elementary schools, high-schools, colleges, and universities were closed from Friday the 13th March.
The universities, and all the other teaching institutions, were instructed by the government that teaching was to go on as normal as possible, only digitally. In other words, students were not to miss any teaching and there was no adjusting of curriculum. By the following Wednesday, all our teaching was digital; lectures, rehearsals in regular bachelor and master courses, and mentoring of bachelor, master, and PhD-projects. This was done regardless of what pedagogic and didactic background the teachers have. This was also to be done from home, where most of the teachers did not have an office or teaching aids other than their computer.
This paper looks at the didactic methods for digital teaching and mentoring and compare them to how this was done in a crisis, where we had to make it work. The paper also looks at the recommended ways of conducting digital home exams in regards of testing the curriculum and not having the opportunity to control the environment in which the students are taking the exam. And last, it also investigates if the teaching and examination process impacted the students' grades and satisfaction.

Keywords: Teaching, supervision, pandemic, exam, civil engineering education

1 INTRODUCTION

E-learning is a fast-moving trend and is becoming a promising alternative to traditional classroom learning. Alternative methods have been recommended for both exams and teaching. This agrees with the assumptions made by Barr et al. [1] that we are moving from a teacher-centred to a student-centred learning. According to Raaheim et al. [2] the main barriers to change from the analogue methods we use today is lack of knowledge about the alternative solutions and lack of digital skills. A survey done by Heimly et al. [3] discovered that the use of flipped classrooms could reduce the failure rate and increase the students' average grades. The use of flipped classrooms makes it possible for the students to watch the lectures when it suits them. However, Zhang et al. [4] discovered that lectures held digitally, where the students could actively participate, resulted in a higher learning outcome and satisfaction.
During the spring of 2020 the coronavirus disease quickly spread across the world and in March the World Health Organization [5] declared the situation as a pandemic. The Norwegian Directorate of Health [6] decided upon implementing a number of measures, including closing the universities. This affected the way of teaching in a drastic manner, making the teaching completely digital. It also affected the way we planned to carry out the exams in the spring semester. We had to have a plan for this relatively quickly, and plan for the situation where single parents had to be kindergarten-teachers at the same time as they were students and taking an exam. The students in Norway are a diverse group, many of them have children that were to be home schooled. This influenced their ability to study, because they had to be teachers during the day and students at night or at the same time as they were teaching their children. This affected how we made the curriculum available to the students – what type of teaching was best fitted for the situation we were in as a society?

2 CASE

At University of Agder all our teachers shall within two years of being hired, have completed a 200 hour course called "university pedagogics". In recent years, a small part of this course touches on the pedagogics and didactics of digital teaching, but many of the teachers at the university had no theoretical background to support their digital teaching decisions. How did this affect the choices for teaching? The

case used in this paper is the teaching done at the civil engineering department at the University of Agder. The focus will be on the students' learning outcome and feedback, regarding the different methods and tools used by the teachers from lockdown until today. In addition, the exams held in the fourth semester for the civil engineering students is used as a case to look at the development of grades.

3 METHOD

The method used in this paper is an evaluation of the way of teaching during a pandemic. As programme coordinator I can get an overview of the different solutions applied by teachers. At the same time, I am in direct contact with the students and receive their unfiltered opinions and feedback. This paper looks at how the various teachers solved teaching during the pandemic induced lockdown. It also investigates the different types of examination used. The first semester under lockdown came suddenly and brought about a sudden paradigm shift – all teaching went from being based on physical attendance to completely digital. This was therefore done as good as possible with the tools available. In the next semesters, however, the students' feedback, time and competence made it possible to create better circumstances for learning when it comes to supervision, teaching and exams. By doing this evaluation we will be able to identify the solutions matching the students' needs and requirements, and at the same time meet the demands from the National Guidelines for engineering studies [7].

In addition to evaluating these semesters, we collected the grades from three different subjects. The three subjects were BYG124 Water and wastewater treatment, BYG213 Structural design – foundation engineering and structural design and BYG214 Urban and road design. These subjects are part of the second year of the study of civil engineering. The data collection consisted of grades from the spring semester in 2016, 2017, 2018, 2019 and 2020. By comparing these subjects, and not subjects from the first semester, we avoided the insecurity with newer students – especially the students who started in 2019. It was not possible to compare the third-year students because they write their bachelor thesis in the spring semester and will not have any typical examination this semester. The grades were calculated into number values; were an A equals 5 and an F equals 0.

4 RESULTS AND DISCUSSION

The spring semester 2020 started out as normal, with regular teaching of classes and mentoring of students working on their bachelor and master thesis. This meant that in most cases the lectures were done in classrooms and auditoriums and mentoring were done by physically meeting the students and discussing their progress and problems. On the 12th March, the government [6] closed Norway down, and at the same time informed that the teaching at the universities were to continue as close to normal as possible, only digitally, from the following Wednesday. This meant that the teachers had 5 days, including the weekend, to change their teaching methods and adjust the curriculum to accommodate digital teaching. As mentioned earlier in this paper, all teachers at the university must complete a course in pedagogics. In later years, this course includes digital teaching, but many of the teachers have completed this course long before that became a part of the course. As a result of this, the programme coordinators and section leaders had to do a lot of information work towards the teachers, on what tools we had available to keep the courses going. The tools we had was Microsoft Teams and Zoom. Many of the classrooms and auditoriums at campus have facilities to stream the teaching from the classroom live and with recording to the students. However, this was not an option for teaching in the spring semester, because the universities were closed. All teaching had to be done from home, with the resources we had available. However, we had the opportunity to get equipment from our offices – such as external screens, docking stations etc.

The first few days were full of discussions on how to teach the courses in the best possible way. How do you teach and have rehearsals in for example a static course? That is the kind of a course were most of the teaching is done by doing calculations on the whiteboard. How do you do this, when the standard laptop we have at University of Agder, is a standard laptop with no possibility to write on the screen? Some teachers contemplated making step-by-step presentations, with calculations done by writing formulas and solving them in e.g., Microsoft Word. Some teachers had scanners at home and scanned handwritten notes and put them into a presentation. This worked to get started teaching again, but both the teachers and the students missed the step-by-step calculations that were usually done on the whiteboard. There were in the days after we started teaching again, many ways to get back to this step-by-step teaching. The solution for some teachers were to turn the web camera and use it as a document camera, others used their smartphone as a document camera, and some bought pen tablets to assist their

teaching. The university were very supportive when it came to buy these things. As time went by, and we realized that this situation would last more than a few weeks, the department also supported buying iPads or similar products where you can write directly on the screen and save the document and upload it later to the LMS.

At the same time as it was important to keep the teaching going, it was also very important to keep in close contact with the students. This was for many reasons; one was to inform them on the situation and what we knew. Another reason was to know in what courses the teaching was working, and they got the information they needed, and in what courses we needed to adjust better to the situation. It is important to keep the courses interesting for the students as this is one of the main reasons why students drop out [8].This interaction with the students was also so that they felt part of the process and that they felt that the common goal was to give them the best possible teaching and keep them interested in the courses that they were taking. This is in accordance with what Skodvin [9] says; that it is important to engage and arouse curiosity in students. This was very difficult to do during digital lectures. But by keeping them part of the whole process, we feel that we achieved some of this.

Inger Marie Dalehefte did a survey based on 2200 students' feedback regarding access to information, learning arrangements and general conditions before and after the Covid-19, which was published on the University of Agder's webpage [10]. The main findings from this survey were that the students prefer physical attendance, but if digital they preferred asynchronous online teaching with group work. They expressed it to be difficult to see the structure and coherence of their courses. Dalehefte also presented some of the results in a conference at the University of Oslo last year [11]. The conclusion was that 91% of the students experienced poorer learning outcome, but that they felt informed about the situation.

After a while we realized that the universities were to be closed for the rest of the semester, and we also had to focus on how to carry out the exams. There were many things to take into consideration when it came to this, for example many of our students are parents and schools and kindergartens were also closed. Many people were in quarantine and did not have the possibility to have grandparents babysit during the exams. This meant that this also was something we had to take into consideration when planning the exams. The faculty gave us the opportunity to change how the exams were to be carried out, this meant that we could change from graded grade, to passed/not passed. By changing the duration and format of the exams we risked sacrificing the constructive alignment as described by Biggs [12]. Regardless of the circumstances, the students still wanted grading on their exams. The civil engineering section chose to try to meet the students' wishes on keeping graded grades and chose to give exams with long exam time. This meant that the exams were given over 24 hours, with all aids – they could use the internet, books etc. The only thing that was not allowed was collaboration between students. By giving the exam over 24 hours, we informed the students on estimated time to solve the exam so they could still take care of their children and act as teachers and kindergarten teachers for their children. This was successful; however, we later saw through evaluations that many students actually worked on the exams for close to 24 hours. This was not intended from our side, and when we later had to change exams again in the fall semester, this was taken into consideration.

When the fall semester was planned, it was possible to have students at campus, but the capacity of classrooms and auditoriums were reduced due to the pandemic and having to keep our distance. Hence, some courses had to be taught fully digitally and some could have a reduced number of students present. One big difference from the spring semester, was that in the fall we could use the streaming facilities at campus. Some teachers chose to go back to teaching in the classroom with streaming and some chose to keep everything digital, and use Zoom as the teaching platform. Exams were also planned to be carried out at campus. This changed in October, when we were told that once again exams were to be home exams. When we planned these exams, we had fresh in mind the fact that quite a lot of the students worked on the exams for close to 24 hours. So, we changed some exams to portfolio exams, where hand-ins became the basis for grading, and others were kept at the original exam length with graded grades. We informed the students that these exams were prepared to be so much work that it would take the whole length of the allotted time, and that they were given an extra 30 minutes to scan and upload the exam. This worked well, and the students were pretty happy with this arrangement. There were some other things that made this kind of exam possible, one was that the schools and kindergartens now were open, and students with children did not have to be teachers at the same time as they were taking an exam. We also informed the students in advance of both the spring and fall exams, that by uploading their exams answers, they agreed upon that this was their exam answer and that they had not collaborated

or used other aids than what we had said was ok to use. Basically, they had the use of all aids except from collaboration with other students.
At almost the same time as we were told that the exams in the fall were to be home exams, we were also told by the university that the exams in spring of 2021 were to be home exams too. The difference from earlier, was that we now had time to plan the examination process instead of just finding an ad-hoc solution. This led to more courses with portfolio exams or a combination of portfolio and digital oral exams. Others again, have chosen to keep the original exam length + 30 minutes for scanning and uploading. This could have a positive effect by giving the students alternative ways of demonstrating their acquired skills. Looking at Chickering and Gamson's [13] 7 principles for good practice this addresses the seventh principle: Respects diverse talents and ways of learning.
The grading in three different subjects over the past five years is illustrated in Figure 1. The reason to compare these grades is to investigate if the learning outcome or the examination process have been affected by COVID-19. The results indicate a small increase in the grades in the spring of 2020. This is not significant compared to the variance through the last five years. This indicates that the grading is as expected if the semester had been without a pandemic. However, it is worth noting that there is an increase across all three subjects from 2019 to 2020. This is not seen for any other one-year periods. Even though Dalehefte [11] implied that students experienced a lower learning outcome this does not seem to apply in this case. Dalehefte did her survey in May 2020, which was a month before exams. An alternative explanation might be that the students worried about the effect of COVID-19 since 47% of the students also worried about the technology failing during exams. Another explanation to the apparent increase in grades could be that some students perform better under a 24-hour examination process instead of the traditional ones, which corresponds to the theory of Chickering and Gamson [13]. Whether the slight increase is a result of the digitalization which Zhang et al. [4] implied would need further investigation.

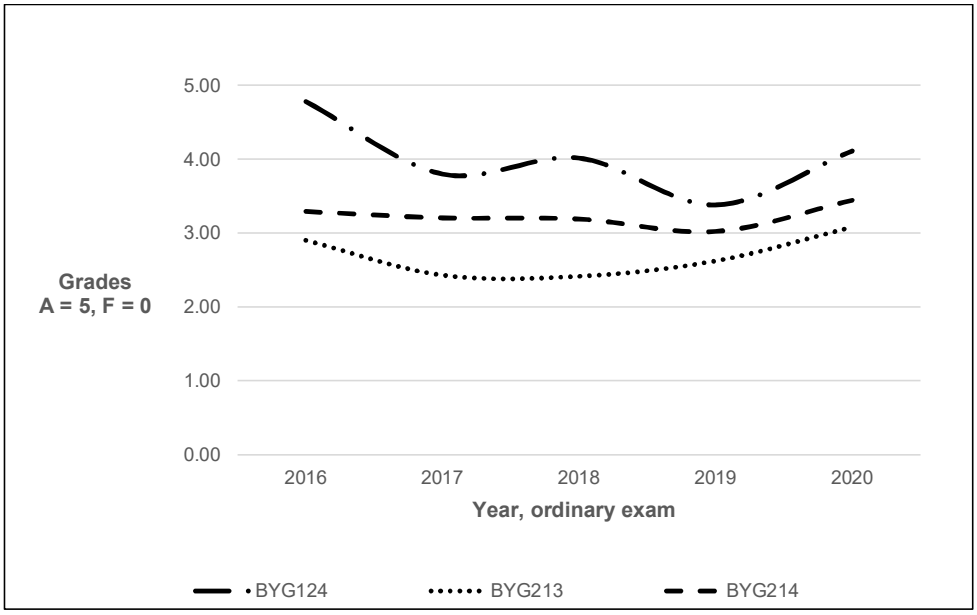

Figure 1. Grade distribution in three courses over five years

The teaching in spring of 2021, was planned very similar to the fall of 2020 – some were to have students in the classroom and use streaming facilities, some were fully digital, and some were to use digital teaching and flipped classroom. Few days before teaching were to start in January 2021, the government closed the universities again. This meant, once again, that all teaching were to be fully digital. There was one big change from earlier though, now we could use the classrooms with streaming facilities. Many teachers chose to use this solution, but without students in the classroom. Luckily, our university were able to open for students in the classroom again from the 1st February.

The courses that were planned with digital teaching and flipped classroom, continued with this solution. By using flipped classroom and problem-based learning, one engages the students in a different way, they get more mentoring but at the same time they work more independent in the course [4]. The courses with flipped classroom are planned a little different, there are some lectures given by the teacher and they also are given access teaching videos at LinkedIn Learning and digital mentoring. The mentoring is scheduled in the timetable, but the teacher is flexible when it comes to when the students can get mentoring. Some students wish for mentoring according to the timetable, but many of them prefer to be able to send an e-mail to the teacher and ask for mentoring when they are working on the problem given in the course. This of course does not suit every teacher, but in these courses, it actually adds up to slightly less time spent on mentoring than in a normal situation where the teacher is available for 2x45 minutes a week. It also means that the time spent on mentoring is efficient, usually the students need 15-20 minutes of mentoring when they ask for it. Most of the time it is 3-4 students in one mentoring session. These mentoring sessions are more fulfilling for the teacher because you can discuss with and help the students when they need help, instead of sitting in a classroom for 90 minutes and maybe spend half that on actually mentoring.

5 CONCLUSIONS

After having an abnormal teaching situation for going on three semesters, it is only natural that the teachers exchange experiences from the last semesters' different ways of teaching. There is some interesting feedback, many of our colleagues say that they do not see that they in the future will return to teaching only in the classroom. They say that they are more open to have a combination of physical and digital teaching. This is especially common in courses were one can use short videos to show how to tackle problems that they know many students are going to ask about. A short video that the students can watch again and again, reduces a lot of questions to the teacher, and the students' time with the teacher can be used for discussions and dialogue instead of lecturing. However, we see that some teachers, often with many years of teaching experience, are saying that as soon as everything is back to normal, they will go back to their old way of teaching. We also see that the same teachers want to go back to how the examination process was before COVID-19. Many of our more progressive colleagues are now discussing different types of exams, instead of just the old fashioned 4-hour written exam, situated in a classroom with inspectors present. The grades for selected subjects in the spring of 2020 showed a slight increase. This could imply that a combination of digital teaching and digital examination produce similar and expected grades to traditional teaching and examination.

The authors of this paper think that post COVID-19, there will be changes to how we teach engineering sciences at the University of Agder. Not because we must, but because we have been forced to think differently about our teaching and have learned a lot on how we can teach differently than pre COVID-19. One of the changes will be 30 minutes of supervision instead of 60 minutes. This has proven to be more efficient, and the students spend these 30 minutes more structured and prepared. Another change is the examination process. By having portfolio as part of the final grade in the subjects the students are evaluated on different qualities, and not only on one single exam. The third change will be the use of digital tools to support traditional teaching. Since the students have seen that there are different ways of being taught and to work with their studies, they also more than likely, want to keep some of these changes.

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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THE CHALLENGE-BASED LEARNING IN HIGHER EDUCATION THROUGH A CREATIVE SENSORIAL BOOTH TO DISCONNECT AND TO BE HERE NOW

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ABSTRACT
Our senses act as sensors that allow us to receive the information of the reality that we perceive, either in isolation or because of their crossing. During the block's challenge called: Formal Representation of Space (FRS), the aim is for higher education students to enjoy an immersive and experimental experience in understanding space through sensory perceptions, taking the students through its material and virtual representation by drawing techniques, both analogue and virtual; putting into practice themes of geometry, perspective, technologies in art, models, and prototypes. The block is based in Challenged-based learning (CBL) and the challenge in Competency-based learning that "Tec-21" offers to the first year Creative Studies professional students. The group is formed from students of several areas such as Architecture, Industrial Design, Educative Innovation, Hispanic Letters, Journalism, Musical Production, Digital Art, Communication, which lead to conformed multidisciplinary teams. The project consists of designing a Sensorial Booth (SB), an installation that seeks to generate a space in which the perception of the environment can be highlighted through the senses in a playful and interactive way. The main objective is to involve the students in a real challenge while acquiring knowledge through a creative project, as well as interacting with a real space of a real institution, which is one of the main purposes of the CBL. Beyond the creative experience that led to the process of conceptualization and materialization 1:1 scale of the Sensorial Booth, prior to confinement by COVID-19, the students realized the importance of giving a comprehensive and memorable sensory experience to people without the need to be connected to a device, while immersing in the reflection of reconnecting with themselves and with the natural environment that surrounded this installation. Regarding to the learning experience, the students enjoyed the challenged offered by the Educational Innovation programme, Block Tec21, doing the most they enjoy, creating, using technology, working with real materials, and collaborating with real former partners.

Keywords: Competencies-based learning, challenge-based learning, Bloque Tec21, educational innovation, higher education

1 INTRODUCTION

The CBL implemented in higher education by Tec de Monterrey since 2019 in the so-called Tec21 system has brought great results in Creative Studies [1]. This innovative educational system seeks to bring theory to practice while developing challenging projects for students and face real-world problems in their learning [2]. In this way, the professor who used to be the centre of attention in the classroom becomes the student's guide and mentor in a new ecosystem learning stage. The main task is that the student can self-manage time and knowledge. Based on disciplinary and transversal competences, the project the student develops is linked to a training partner, the Labyrinth Museum of Sciences and Arts of San Luis Potosí in México, to reach common objectives, which add both to the student's knowledge and to the goals of the training partner. In this way, the student achieves a certain level of experience in a real context, which is the main objective of the CBL [3], [4].

In the first period of the second semester of the Creative Studies entry, from February to March 2020, within the FRS Block, the challenge consisted in designing a Sensorial Booth, in collaboration with the cited training partner, an institution that served as the exhibition space for the physical installation of the pieces developed. It was started from the premise: What if the reality that surrounds us did not exist, or not as we see it? The main objective was for the students to have an immersive and experimental experience in understanding space through sensorial perceptions and their graphic, virtual, and material representation. Thus, while the students review conceptual artists work and approach to postulates of designers and architects to support the conceptual proposal, they made their first sketches individually, and later, as a multidisciplinary team, to arrive at a common proposal. In parallel, inspiration was taken from Bruno Munari's methodology [5] to order their ideas in the design process. Finally, in a collaborative way, the complete project of the Sensorial Booth was carried out, two-dimensionally and three-dimensionally, a model was made and the 1:1 scale model was built.

2 METHODOLOGY

The five-week design process is made up of five phases, one per week. It begins with the immersion phase, reading about space topics and reviewing the work of conceptual artists; then comes, the inspiration phase, making mood boards and collages; next, the ideation phase arrives, sketching the main ideas; to follow with implementation phase, taking the proposal to plans; to reach the last one, the delivery of the challenge, manufacturing the Sensorial Booth 1:1. This final stage included the construction of the booth on campus, where sensorial and resistance tests were carried out, and later, the collective installation was carried out *in situ*, in outdoor spaces open to the entire public of the Labyrinth Museum. It is important to say that students were asked to work mainly with natural materials as wood and natural fabrics to connect with the natural environment around the site. Although the subsequent monitoring of the challenge, which consisted of observing and recording the interaction of the booth with the user, was not carried out, due to the COVID-19 pandemic, the students had a stage of intense immersive knowledge, both in the campus workshops as in meetings with the museum curators, which left them an invaluable experience and learning, which in the previous educational system would not have been achieved. The group of 26 students was organized into six multidisciplinary teams who worked the five weeks on campus, where they began to think up and finish their proposal. During the first week, a visit to the museum was made so that students could explore the environment and therefore, plan their installation. Days prior to the final delivery they had an evaluation in the presence of the training partner and finally the assembly of the six rooms was carried out on Thursday, March 12, which was complemented with an identification card and a QR code that led to the link of a video that showed the creative process.

2.1 Modules

2.1.1 Form and Space

This module offers as a basis the understanding and organization of spaces; the title of Form, space, and order by Francis Ching [6], was followed for this purpose, giving a basic structure for the creation of the living spaces through design fundamentals. In parallel, students follow readings by authors who address phenomenology of space, such as Peter Zumthor [7], Steven Holl [8] and Juhani Pallasmaa [9], to sensitize students on the subject. Students also review architectural works related with authors such as Tadao Ando and Luis Barragan, to observe the way in which they handle emotions, environment, colours, textures, the play of light and shadow, in other aspects.

2.1.2 Visual Communication

The purpose of this module is for the student to recognize the space through freehand and drawing, to learn to represent several materials and settings through various techniques (markers, colours, pencils, etc.) to help them to express spaces, objects, settings, especially ideas that trigger the development of the challenge. In addition, different drawing languages of the architectural world are explored, such as representation of plants, elevations, isometrics, or perspective (sketch-like schematics) using line quality.

The goal of the module is to emphasize in the student that freehand drawing contributes to reinforcing critical and creative thinking, due to the direct connection that the hand has with the brain.

2.1.3 Technologies in Art

In this module, which begins in the third week of the block, the students are prepared to develop skills in 3D modelling for the visual representation of their proposal for a sensory room. There is access to the computer labs of the San Luis Potosí campus, where the software used was Rhinoceros 6 for the virtual model and, Keyshot for the render generation. The campus also has Adobe Photoshop and Illustrator licenses for the generation of photomontages and presentation sheets. This module takes two weeks in which the students develop, first individually and then as a team, the final proposal of their Sensorial Booth. The intention of this module is to generate a preview of the finished project, as well as its materials and context.

2.1.4 Materialization

The objective of this module consists of two phases, first, to generate a volumetric model of the individual proposal, while the 3D model is generated in the module explained above. This tells us that both modules are carried out simultaneously. It is important to clear out that, in the second phase, once the teams are formed, a proposal is chosen, the one that best meets the requirements and parameters of the project. Once this is done, a detailed 1: 5 scale model is developed with apparent materials and setting, meanwhile, the digital 3D model starts to take form.

2.2 Competencies

This section explains the skills to be developed in this block:

Design of creative proposals: Based on the analysis of the social, cultural and arts context. Create proposals using methodologies based on creative iterative processes.

Meaningful representation: Design solutions based on significant intentionality using visualization and materialization techniques. It interprets the conceptual, virtual, and physical environment as the basis for its proposals. Represents design proposals with relevant physical and digital models and prototypes to deliver a message.

Technologies in art: Integrate innovative tools in an experimental way in the design and production of creative projects. It also identifies suitable analogue and digital devices to its experiment and application.

Communication: Uses different languages, resources, and strategies effectively and according to the context, in their interaction in different professional and personal networks with different purposes. Agreements and proposals through the exchange of arguments and emotions, both in the mother tongue and in an additional language, which consider geopolitical and sociocultural contexts.

2.3 Challenge

The goal of the challenge is to bridge the gap between thinking and doing. CBL grabs theory into practice, so the learning experience, where the learning takes places through the identification, analysis, and design of a solution to a sociotechnical problem [2], is the main value of this model. In this sense, the premise is the way in which the students carry out the challenge, build the concept, support the idea, and translate it into the construction of a sensory booth to be used freely by de audience of the Labyrinth, to interact with the space, to disconnect of the “real world”, to reconnect with themselves and nature and, to feel and explore with all the senses. However, as mentioned before, it was not possible to have feedback because of the pandemic; this also resulted in the reduce exposure time of the booths to only one week, from two that had been contemplated in the beginning.

3 DISCUSSION & RESULTS

Carrying out this project in five weeks, from concept to practice, involves an accelerated learning curve for students, both in terms of conceptualization, visual representation, virtual modelling, and development of functional models and prototypes [10]. On the other hand, what other software would be recommended so that students could generate their 3D models? Not all campuses have an active Rhino or Keyshot

license, much less the Adobe suite. They could be considered free software, which does not require a license, such as SketchUp in the 3D modelling theme, Blender as the rendering engine and Figma in the vector theme.
The students had a pre-delivery session, where the Directors of the museum set the final recommendations for the final presentation and installation assembly. In this meeting the 1:1 construction of the sensorial booth was approved. Students were asked for a detailed list of materials, suppliers, and costs, to give continuity to the proposal previously reviewed and approved with the mock-up and 3D model. The personnel of the museum had to review the material list and check the stability of the final structures for security, both for the audience and for the institution. Once the rooms were assembled, they were presented on campus in front of external advisers for their final review and assessment. (to later request support for transportation to the Labyrinth, where all the assembly logistics for the pieces have already been planned.) (no se tenga caso poner esta última frase, mejor hablar del proceso de assessment).

Figure 1. Sensorial booths scale 1:1 installed at the Labyrinth Museum ("Refleja" and "Nido Invertido")

Figure 2. Sensorial booths scale 1:1 installed at the Labyrinth Museum ("Eco", "Biomímesis", "Alighieri", "La Cueva").

4 CONCLUSIONS

CBL is a way to give continuity to the creative process, since objectives and achievements are set together with a training partner, who reinforces the commitment of the students. Transversal skills and competencies, such as collaboration and innovation were reinforced by the challenge. Nevertheless, having different modules and phases, its continuity must be constantly reviewed to be within the established times. This part can be seen reflected in the evolution of the proposals, from the exploration of the form and its relationship with the solution of the problem raised, to the technical feasibility and assembly aspects to be considered for the final proposal. It is, in this last phase, where students put into practice the adaptability of their proposal, which should have considered dimensions that can be managed by them and their transportation and economic possibilities available in the city. This project brings students closer to contemplating all the phases and technical implications of a design and construction project, contemplating the concept and the message it seeks to convey, always being an approach to highlighting the importance of appropriating the space that surrounds us and adapting it to the solution of our needs and the way in which they are evolving.

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WEARABLE TACTUAL COMMUNICATORS: DESIGNING PRODUCTS WITH TECHNOLOGY-MEDIATED TOUCH

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ABSTRACT
In some situations, it is not possible or desirable for communications to take place through voice- or screen-based interaction. People may want to act discreetly around other people; it may not be physically possible to interact with a screen-based product; or it may be inappropriate or ineffective to talk out loud. Furthermore, with the challenges of the COVID-19 pandemic, product touch has been discouraged. In the circumstances, alternative means of communication can be made using technologies that mediate touch. This paper reports on an eight-week graduate industrial design project that required students to explore the sense of touch in the context of user-product-user communication. The aim was for students to learn how a product user interface (UI) can extend beyond the conventional visual and audible modalities, into the relatively under-explored area of touch sensations. Working in pairs, students made research and generated product concepts for communication scenarios that they foresaw would benefit from technology-mediated touch. The result was eight diverse scenario and product solutions that make use of passive touch sensations: some focused on the communication of instructions, whilst others evoked meanings. Learning was demonstrated through the diversity in outcomes, with students proposing unconventional forms of interaction where touch is the primary modality. The study empowered students to showcase innovative uses of technology-mediated touch in product design.

Keywords: Product design, touch, interaction, UI, wearables

1 INTRODUCTION

In our daily interactions with products, the conventional product evaluation process for people with no sensory impairment is for visual experience to take the lead, shortly followed by tactual and other multisensory experience as interaction takes place. Vision is dominant in human information processing and cognition [1]. It is therefore no surprise that the visual domain of product design is at the forefront of designers' decision-making, leaving the tactual domain – as well as other sensory modalities – relatively under-researched [2].

The work presented in this paper was carried out as part of the authors' research agenda investigating aspects of product touch, tactility, surface texturization and user experience (UX). The research agenda aims to generate informative and inspirational exemplars for product design and innovation. The specific project reported in this paper, 'wearable tactual communicators', explored the problem and solution spaces related to the effective design of user-product-user communication through the medium of touch. For example, in some situations it is not possible or desirable for communications between people to take place through voice or screen-based interaction. People may wish to act discreetly around other people; it may not be physically possible to interact with a screen-based product; or it may be inappropriate or ineffective to talk out loud. For such circumstances, alternative means of communication using technologies that mediate touch can be speculated. Aside from generating exemplars for product design, the 'wearable tactual communicators' project had the pedagogical goal of encouraging students to learn how technology-mediated touch can push product user interface (UI) design beyond conventional visual and audible modalities.

2 INTERACTION AND DESIGNING FOR TOUCH

The sense of touch is central to the full experience of many everyday products. There are relatively few products that we look at, or we listen to, for which we do not physically interact. Touch is in many ways

a special sense: it is differentiated from visual and audible modalities because of the complexity of the sensorial information that is involved. Whereas sight is achieved through the eyes sensing light frequencies, and hearing is achieved through the ears sensing sound frequencies, touch is not bound physically to any single sensory organ. Touch is a sensation of the skin and muscle, and as such can be achieved all over the body. Furthermore, touch comprises the discrimination of multiple tactual qualities of things, including softness, texture, and temperature. Touch is considered as active/passive or static/dynamic, depending on the circumstances in which the sensations are created [3], [4].
Passive touch involves an object being placed onto or rubbed against a person's skin. Active touch, by contrast, involves a person exploring an object, often through grasp or dexterous fingertip movements. Touch is most noticeable when it is dynamic; that is, when the stimulation continually changes [5]. This contrasts with static touch, which gives an initial sensation but then goes unnoticed.
Touch is a vital contributor to interpersonal communication. As Sonneveld & Schifferstein [3] state, "touch is […] often considered as our most social sense. Interpersonal touch tells us whether we are safe, cared for and have value…". Different touch types, such as public touch or loving touch, have distinct characteristics [6], whilst emotions and meanings are known to be strongly evoked through touch [7], [8].
Designers need to be aware of factors that influence positive appraisal of touch (e.g., pleasant, comfortable, reassuring). Essick et al. [9] made a quantitative investigation of the tactual pleasantness of an object when passively rubbed on skin at different body locations, through a controlled mechanical experiment set-up. Their work confirmed several assumptions about the variables affecting sensitivity to – and pleasantness from – passive touch sensations: gender, context, stimuli surface qualities, body area, and the degree of surface pressure from low (pleasant) to high (painful).
Marieke Sonneveld laid foundations for 'designing for touch' by bringing the various mentioned principles together. Her 'Tactual Experience Model', originally developed in Dutch [10] and translated into English [11], is shown in Figure 1. It usefully demonstrates the relations between underlying factors in touch experience, by contrasting product and user (human) perspectives. The model was used as a basis for our students' learning on how to enhance touch experiences from products.

3 DESIGN PROCESS FOR WEARABLE TACTUAL COMMUNICATORS

The 'wearable tactual communicators' project was carried by Industrial Design MSc and PhD students over eight weeks of the 'ID535 Design for Interaction' course Middle East Technical University. Students worked in eight pairs to design a physical product (and, optionally, an accompanying app) that provided effective interpersonal communication by passive touch, as an alternative to vision and sound. Prior to the project, students took seven weeks of foundation classes in design for interaction (D4I) and UX [12].

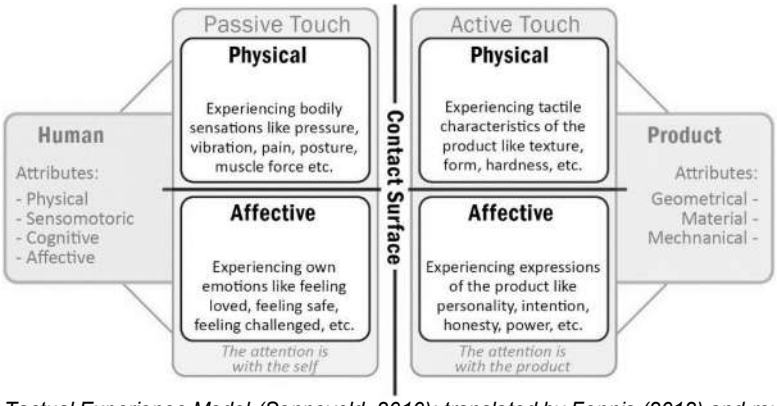

Figure 1. Tactual Experience Model (Sonneveld, 2010); translated by Fennis (2012) and revisualized by the authors

Despite focusing on the UI and interaction, final design proposals were required to show good attention to product styling, materials, finishes and overall visual attractiveness. However, compared with

undergraduate studio projects that are typically longer and with greater scope, the level of technical resolution expected was less, attention to materialization was reduced, and market/commercial justifications were not requested. Students were provided with articles and book chapters to read, to elevate their general knowledge in touch and design.

3.1 Project Stages

The project was managed across seven stages, requiring students to carry out design research, ideation, and technological reviews, whilst developing a heightened awareness of product touch sensations.

3.1.1 Scenario building

Students were asked to generate a minimum of five scenarios (contexts of use) where tactual person-to-person interaction via a product might be effective or desirable. Storytelling was requested to bring the scenarios to life, based on four questions: Who is communicating with whom? Why and what are they communicating? Where are they? When is this happening?

3.1.2 Sensitization activity

Students were asked to bring to class various products possessing pronounced surface textures, surface form features or material tactility, which deliver noticeable touch sensations. Students became sensitized to passive touch by exploring the tactual sensations of classmates' products at various locations on the body (e.g., fingers, forearm, neck, head). In their project pairs, students took turns to be the provider and receiver of passive touch. Subsequently, they were asked to contemplate how touch sensations might be used as a communication language, aside from pleasantness or comfort.

3.1.3 Briefing on technical possibilities

A PhD student working on touch and design briefed students on the various technologies that can make technology-mediated touch possible. Many of the technologies are at an early or prototypical stage of development. As well as becoming knowledgeable about the technologies, students were expected to identify which were most suited to their own project. The briefing covered: (i) haptic feedback technologies (sometimes referred to as haptic rendering) such as vibrotactile actuators, tactile surfacing, thermal changing materials, shape changing materials, and force feedback; and (ii) haptic sensing technologies, such as conductive fabric and force sensors. Students were additionally briefed on common wireless communication technologies (e.g., Bluetooth 4.0, Wi-Fi 802.11n and 4.5G/LTE GSM) as well as their specifications relevant to product design.

3.1.4 Interaction vision and ideation

Following Pasman et al. [13], we directed students through the combination of a design goal (as mentioned in 3.1.1, responding to the question 'why communicate?') and an interaction vision (responding to the questions 'how to interact?' and 'what style/qualities of interaction?'). The interaction vision was prepared as a few words or a short phrase, using carefully chosen adjectives/adverbs so as to be inspiring but also to avoid preconceived ideas. Pasman et al. [13] provide general advice on differentiating design goals and interaction visions, e.g., "The *goal* was to design an inspiring lunch experience for customers of the university canteen, while the *interaction vision* was stated as 'Refreshing Openness'." Students were given the option to also create an A3 inspiration board comprising images of products, surfaces, materials, people, places and interactions that possessed qualities they found relevant to their interaction vision, or which illustrated the vision directly. Initial ideas were sketched, attending to system, service (app), product, interaction and UX requirements for the tactual communicator. Ideation also included a technical appraisal for the kinds of touch sensation that was sought (applying knowledge from 3.1.3), as well as continual scenario iteration. Furthermore, students developed arguments for the specific tactual messages that would be relevant to their scenario and worked on mapping those messages to specific touch sensations, creating a touch vocabulary for their product. The authors gave several design critiques through this stage.

3.1.5 Interim submission

At this stage, students presented their in-progress product design, focusing on tactual messages/language, storyboard of interaction and a draft user guide.

3.1.6 Concept development

The authors gave a further round of design critiques at this stage, with the expectation that students would then be able to interpret their interaction vision into well-defined interaction steps (=what to do) and actions (=how to achieve it), within an overall coherent product design.

3.1.7 Final submission

At the final stage, students prepared and presented a poster, factsheet, and design sketchbook. Some students used initiative to also prepare CAD animations, videos and mock-ups.

4 PROJECT OUTCOMES AND DISCUSSION

The project resulted in eight diverse scenario and product proposals. Some proposals used passive touch sensations to communicate information or instructions (thereby prompting a behavioural/action response), whereas others used passive touch sensations to arouse visceral feelings and evoke meanings (see Figure 2). As a reminder, we did not ask students to exclusively use tactility to replace existing visual or audible feedback. Rather, we encouraged exploration of scenarios in which passive touch can create new interaction possibilities or overcome long-standing interaction problems tied to reliance on visual and audible modalities. A cross-comparison of the key variables across the eight design proposals is provided in Figure 3.

The focus on tactility became a driver for creativity, taking students out of their 'comfort zone' when designing for interaction. Stage 2 of the project – the sensitization activity – was highly valuable for students to 'tune in' to the possibilities of communicating via touch. By reciprocating between the giver and the receiver of passive touch, students engaged in a form of active learning about effective tactual communication. They learnt through practice that tactual communication relies on people's ability to (a) differentiate the feeling of different passive touch sensations, and then (b) give meaning to each sensation. For effective communication, each tactual sensation (message) must be clearly distinguishable and not confused with other tactual sensations offered by the product. These observations were first made during the sensitization activity but became practically relevant once students started to build their interaction vision and generate product ideas at stage 4 of the project.

Since the reported work was completed within a limited timeframe of eight weeks, the design proposals were requested to be communicated through storyboards. The inherent restrictions are acknowledged: storyboards illustrate steps and actions but do not communicate the qualitative experience during interaction very well. As a surrogate, students described their intended user experiences by referring to tactual sensations of everyday products. Educators working in D4I recognize this as a persistent pedagogical challenge: how to bring an intended interaction 'to life'. As a visual communication medium, storyboards are excellent for planning and narrating interactions step-by-step. However, their main weakness is being unable to evoke the feelings or meanings that arise from physical interaction. Therefore, given more time, the use of physical models of various fidelity can be recommended for role-play (at stage 4), whilst tactual experience prototypes may be created for the final submission, allowing evaluation of intended tactile sensations. The creation of experience prototypes would require students to utilize design-and-make skills, inevitably overlapping with skills in interactive prototyping and preparation for 3D printing.

In the absence of experience prototypes, three evaluation criteria suited to the assessment of storyboards were defined for the project: detail of thought in defining user-product interaction; clarity of argument for how the final design concept fits to an intended usage scenario; and technical feasibility for delivering tactual messages within the proposed form-factor.

5 CONCLUSIONS

The project outcomes showed students successfully learned how tactual interaction can be used to create product interfaces for scenarios in which visual and audible modalities are found inadequate or undesirable. In this regard, the project was able to extend 'design for interaction' teaching and learning beyond conventional audio-visual UI. Students learned that tactual communication has multiple dimensions, which demand a systematic approach to design. For success, there must be a clear definition of the kind of tactual sensations to be achieved (intensity, frequency, body location, etc.). Then, a system must be designed whereby the intended sensations are perceptible and technically achievable. Finally, an appropriate mapping must be achieved between tactual sensations and intended messages (whether instructional or affective). This last point was pedagogically the hardest to achieve. It required students

to understand that affect and meaning arising from touch are contextually bounded and can be different for different people. Students working on the ‘wearable tactual communicator’ project were guided through a systematic approach, not for lack of confidence in their creative abilities, but to provide a ‘helping hand’ across what was for all students very unfamiliar territory.

Learning about tactual interaction modalities, and putting them into practice through a design project, is considered a valuable experience for students whose future professional roles may be to design innovative UIs and effective interactions for new generations of product. The project contributed convincing solutions for how technology-mediated passive touch can be used as a language of communication between products and people; such product examples and analysis are not prevalent in literature. In this way, the project empowered students to showcase innovative uses of technology-mediated touch in product design. Experiences during the COVID-19 pandemic, which arrived after the work reported in this paper, have shown people’s yearning for social touch and the importance of a physical connection in interpersonal relations. Wearable tactual communicators as exemplified in this paper may also be developed to help people overcome touch deficits, for example through technology-mediated remote social touch that can bring loved ones and friends together.

Figure 2. Summary of each wearable tactual communicator proposal

Application	Product	Scenario	Rationale	Passive Touch Trigger	Passive Touch Receipt
Informational or Affective? (I or A)	What is the product name?	Who is communicating with whom?	Why are they communicating?	What input is required?	Which haptic feedback technology?
I	Dyad	Alpine climber and belayer (1-to-1)	Keep in contact and updated when out of sight or shouting distance	Controls and head movements	Electro-vibration
I	Boomerang	Bedbound patient and caregiver (1-to-1)	Respond to patient's various needs	Controls	Matrix of electro-magnetic actuators under textile
I	AeroCom	Aircraft passengers, attendants and pilots (network)	Make requests, serve passengers and give instructions	Touchscreen gestures or icon selection	Pneumatic shape memory actuators; vibration motor
I	Ignis+Tactio	Firefighter teams (network)	Report critical discoveries during firefighting and rescue	Touchpad gestures	Vibration actuators
A	Wellmate	Best buddies (1-to-1)	Encourage cessation of bad or unwanted habits	Touchscreen gestures or icon selection	Vibrating and inflating soft silicone actuators
A	AffiniSleeve	Prison inmate and visitor (1-to-1)	Help express positive and negative emotions	Touchpad gestures	Matrix of textile pockets activated by air pressure
A	Sentio'es	Stage artist and audience (1-to-many)	Increase engagement in live theatrical performance	Touchpad gestures	Vibration motor; electro-magnetic actuators
A	Apart	Partners in long distance relationships (1-to-1)	Emphasize togetherness through lost sense of touch	Touchscreen or app icon selection	Texture-changing soft robotic skin

Figure 3. Key variables across eight proposals

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DESCRIPTIVE STUDY OF THE INTEGRATION OF SUSTAINABILITY IN AN ENGINEERING COURSE

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ABSTRACT
Education on sustainability is one of the main concerns of the 21st century for engineers, it is indeed engineers design technologies and participate actively to industrial activities, their education to design for sustainability is paramount. In the literature, engineering skills for sustainability are well identified. Also, pedagogical experiments on the integration of these competences in engineering curricula are reported. This article describes, in a pedagogical situation the modelling of interactions between a technical system, human organizations and the biosphere. The article analyses whether this type of representation can allow students to acquire certain engineering skills for sustainability.

Keywords: Engineering education, sustainability, competencies for sustainability, interaction

1 INTRODUCTION

As a pressing concern, education on sustainability is important. As engineers design technologies and participate actively to industrial activities, their education to design for sustainability is paramount [1]. Since the beginning of the century this challenge is studied, and two different bodies of work are identified.

The first piece of work consists of the research on the meaning of integrating sustainability in design engineering education, and the main skills and competencies to address ([2], [3]). As discussed in Quelhas et al [4], there are different skills to consider when it comes to design engineers' education on sustainability. It also finds an echo in the twelve questions to address the integration of sustainability in engineering curricula identified in [5], and classified in four main topics: implemented practice, subjects and objects of the practice, (other) stakeholders, outcome or results. This model is placed in Engeström's general model of an Activity System which distinguishes Instruments, Subjects, Objects, Rules, Community, Division of Labour and Outcome as structuring elements of practice [6]. The proposal from [4] is specifically dedicated to education in engineering and provide identified cross-disciplinary competencies for sustainability education, which are: critical thinking, working in an interdisciplinary group (collaboration), ability to solve problems (integrated resolution), system thinking, normative competence, self-knowledge, contextualization and vision of the future (anticipatory), strategic competence. [3] uses this model and completes it with specific engineering skills on knowledge and understanding of engineering skills, engineering analysis, engineering design, investigations, engineering practice, making judgements, communication and team working, lifelong learning.

The second piece of work consists of a descriptive study of experiments in educating engineers for sustainability. Case studies are documented and analysed using a specific assessment grid to evaluate the way education for sustainability is reached but also encounters specific difficulties. Many research papers discuss these topics such as [7], [8], [5], [9], [10], [11], [12], [13]. All these descriptive studies are required to experiment and share in order to identify best practices and common assessment framework. Our paper is positioned in this second body of work. Indeed, our work uses a grid from the first body of work (competences from Quelhas [4]) to evaluate the relevance of the pedagogical model. This work describes a learning situation and its evaluation by the competences acquired by the students following the pedagogical model. Indeed, this paper identifies a competencies framework inspired from [4], and describes a French experiment of introducing a specific pedagogical module on sustainability in the engineering curricula at the University of Technology of Troyes in France. Based on the experiment assessment, our paper discusses the interest of a proposed model which represents interactions between humans, a technical system and nature (H-TS-N model). This representation allows

engineers to understand three elements: the planetary limits (i.e., what humans take from the biosphere to design the technical system, with potential thresholds not to be exceeded), fundamental human needs and the functioning of socio-technical organizations within these physical limits and social needs – all those being a preliminary to design socio-technical systems in a responsible way. The H-TS-N model is therefore evaluated by the competence grid proposed by Quelhas.
As the acquisition of the 8 competences presented by Quelhas [4] seem necessary (but maybe not sufficient) to address sustainable design, this paper explores a model (the H-TS-N) to identify if it can be used in engineering education to future engineers creating technical systems for sustainable futures.

2 EXPERIMENT

The pedagogical module presented and tested in this article is the "representation and modelling H-TS-N" pedagogical module. The aim of this course is for the students to model the interactions between humans, technical systems and nature according to several spatial scales. The course took place asynchronously and in English. The asynchronous format was a choice from the very beginning of the course design and not an obligation due to the health situation in 2020. So, it means there was no synchronous session of class or tutorial. This asynchronous format allows us to open the course to several curricula and allow students to be involved in an interdisciplinary project group. This course was open to 3 engineering curricula at the University of Technology of Troyes (mechanical, materials, and mechanical and materials in a professional training curriculum) and a total of 57 students attended. The students had online classes (several modules dedicated to knowledge transfer), practical works to do each week on the Moodle pedagogical platform, and a final deliverable of the H-TS-N interactions.
The representation of the H-TS-N interactions was carried out by means of a graphical representation in the form of a table. This model, only briefly presented in this paper, is a preliminary model that will be improved following feedback from students who have worked with it.
The concepts of the model are as follows:

- The life cycle: the life cycle stages dissect the different stages in the lifespan of a technical system and details it. Students are then compelled to cope with social and ecological consequences of design choice usually made for the use stage on the other stages (raw materials extraction, production and end of life).
- Scales: three levels of scale are present (macro, meso, micro). These scales are to be defined by the students. The levels cover individual level as well as cultural level.
- Interactions: the interactions between the three parts (human, technical system, nature) are present in pairs in the table (TS-N, N-H, TS-H).
- Causes / consequences: the information is structured according to the causes and consequences of the interactions. The consequences refer to the impacts of said interactions.

Those different concepts are not (or only partially) mentioned in the other modules of students. Indeed, life cycle assessment can be seen in one other courses, which is not mandatory. Multi-level impacts ("scales") and the notion of interactions are not addressed in other modules of the curriculum. The aim of the article is to evaluate the acquisition of competences on sustainability by engineering students through this course and thus throughout the H-TS-N model.

3 METHODOLOGY

To evaluate the relevance of the H-TS-N model to help students acquire competences, we developed an analysis grid. The data collected for the analysis is: the evaluation of the students' productions by the pedagogical team, and an online survey for the students who followed the entire course in the fall of 2020 (an online questionnaire of 28 questions and a group interview).
In order to construct an analysis grid of the skills acquired by students during the pedagogical module, we started with the article from [4]. These eight "competences for sustainability" of [4] are considered in our article as "macro competences". From these macro competences, we have deduced competences (in the sense of an ability to act in a complex environment [14]). In order to be able to assess these competences, we have developed indicators and different levels of validation of those indicators. Table 1 shows the different macro competences, competences and indicators. Levels of validation were implemented for every indicator, e.g., "Questioning the structure of the H-TS-N model". This indicator has 4 different levels of validation: no express of critical thinking / not enough data to know (level 1), some criticism expressed but not shared within the project group (level 2), criticism expressed and

discussed among the project group (level 3), criticism expressed, and change implemented in the structure of the model (level 4). The first 8 questions of the online questionnaire were used to fill in the levels of validation.

In developing this grid, using the objectives of the teaching module, we identified that this course could only help students partially acquire 6 of the 8 competences mentioned by [4]:

1. *Critical thinking:* the students had to analyse a socio-technical system they were interested in. The analysis of the H-TS-N interactions forces the students to question their initial vision of the system under study, as well as selecting and justifying the sources on which they rely.
2. *Work in an interdisciplinary group:* the project groups are comprised of engineers from different curricula at several levels: the students' disciplinary field (mechanics, materials, or both), the level of study (3rd or 5th year), the type of study (in a professional training contract or not).
3. *Systemic thinking:* students had to identify, understand and formalize interactions between different technical systems (a car wheel and a road for instance) in different perspectives (i.e., different scales), and this competence has been present during the entire course.
4. *Normative competence:* students were expected to explain the current standards and question them in relation to the basic needs that were presented to them in class.
5. *Self-knowledge competence:* students were expected to question the role of engineers in the design of the technical system (when relevant).
6. *Contextualization and vision of the future:* students were expected to contextualize the current situation (by the description of the H-TS-N interactions).

To give you an example of the grid, here are 3 macro competences (Table 1).

Table 1. Analysis grid (only 3 competences)

Macro competence	**Competence**	**Indicators**
Critical thinking MC-A	Ability to question the structure of the proposed H-TS-N model - A1	Questioning the structure of the H-TS-N model - A1a
	Ability to complete the model with critical thinking - A2	Process for questioning the information collected to complete the H-TS-N model - A2a
	Ability to step back and detach oneself from the H-TS-N model - A3	Approach the H-TS-N model differently. The model remains a possible form of representation. - A3a
Working in an interdisciplinary group MC-B	Ability to interact in an interdisciplinary context - B1	Check the diversity of profiles - B1a
		Effectiveness of interactions between students in a project group - B1b
		Frequency of interaction between students from different project groups - B1c
	Ability to exchange with empathy with people who are not from the same academic background - B2	Conflict resolution/empathy - B2a
		Quality of interactions (between members of the same group) - B2b
	Ability to organize effectively with people from different backgrounds - B3	Ability to identify the skills of group members - B3a
		Quality of collective productions - B3b
		Organization within the group - B3c
Systemic thinking MC - C	Ability to identify and represent the complexity of one or more H-TS-N interactions - C1	The process of understanding the elements that compose a technical system and its interaction with other technical systems. - C1a
	Ability to identify an interaction as a whole - C2	Understand an interaction in its context with all of the following elements: social, cultural, environmental, commercial, legal and political. - C2a

		Understand the definition of an interaction (reciprocal reaction of two phenomena on each other) - C2b
	Ability to link different parts of the model (e.g., between scales or between interactions) - C3	Links between the different elements of the model - C3a

4 SURVEY AND RESULTS

The survey was conducted after the final project was submitted by students. There was 1 questionnaire of 28 questions and 1 group interview. 30 students answered the questionnaire of 28 questions (20 students answered during the group interview, 10 students answered the following week). During the group interview, the pedagogical team (1 associated professor and 3 PhD students) and 20 students (out of 57) were present. The goal of the group interview was presented like this to the students: a discussion to find out the major difficulties they had experienced during the semester.
To give a general overview, students' groups worked on very different socio-technical objects: a bottle of champagne, a car wheel, a battery for electric cars or robot for agricultural activities.

Table 2. Results of each macro competence

Macro competence	Results
Critical thinking	The students became critical of the technical system they were studying but did not criticize the H-TS-N model as such. No real change in the H-TS-N model structure was implemented.
Working in an interdisciplinary group	Only 5 out of 12 project groups are made up of students with different profiles, which limits the development of this skill. Moreover, interactions between the different groups were generally weak and did not allow for the creation of other interdisciplinary situations. It was found that the students had a medium ability to interact in an interdisciplinary context. We can add that the lockdown situation may have had an effect on the quality of student interaction.
Systemic Thinking	Systemic thinking competence is partially acquired: most of the project groups described interactions, sometimes quite complex, but no group was able to describe a global vision of the technical system.
Normative competence	Most of the students did not explain the current standards they were expected to.
Self-knowledge	The majority of the students did not integrate the role of the engineer in their model and did not question this role in the interactions described.
Contextualization and vision of the future	More than half the students who answered the survey acquired a broader vision of a technical system (see the current impacts of technical systems on humans and the biosphere) but did not project this vision into their future activity of design.

5 DISCUSSIONS

5.1 Model's contribution

The H-TS-N model enabled students to acquire 2 major competencies from the Quelhas model [4]: systems thinking and contextualization (the latter being included in the competency "contextualization and vision of the future", the vision of the future not being developed in this pedagogical module).
Three competences which are critical thinking, normative competence, self-knowledge, could be acquired thanks to this model but have not been developed by the students because a specific pedagogical integration would have been necessary (for instance having a "vision of the future", some specific pedagogical sessions should have been implemented).
27 students answered the question, "Why do you think you made this model? Why did you get out of it?" and all the answers were similar in their meaning "This makes it possible to realize that our actions have an important role to play, whether on the environment or on mankind. The use of a technical system, its manufacture and recycling not only have an impact on our own scale but also on a global scale." (answer of 1 student). Thus, this model encourages systemic thinking and an ability to

contextualize, but not critical thinking. Also, the normative competence was usually forgotten and no real thought on the nature of engineering work could be seen in the final deliverables.
We can thus conclude overall that this model is a good way to improve engineering students' competences on sustainability but that several changes would increase its pedagogical efficiency.

5.2 Future perspectives: modification of the pedagogical module

5.2.1 Path to a better acquisition of competences

The development of critical thinking could be achieved by better linking the impacts of technical systems on the biosphere and human organizations at different scales, thanks to the different modules of the course. Some students described all the different deleterious consequences of a technical system on the biosphere and humans but finally concluded on the very positive aspect of the technical system. The gap between what they described, and the conclusion was substantial and might be a sign of a lack of critical thinking or cognitive dissonance.
Normative competence and self-knowledge could be developed by clearly asking student more clearly to integrate the role of the engineer in the design of a technical system. This could be integrated into the rating scale. Also, integrating the status of engineers in the model, would force students to question their future role in society, and might help their critical thinking.
Competences around the issue of interdisciplinarity could also be improved by integrating engineers from the curricula in computer science, networks, telecommunications and logistics. However, this interdisciplinarity will remain limited by the fact that students are in engineering training. Also, we could improve the evaluation of this competence by carrying out a cross-evaluation to measure the personal investment of each individual within the groups and thus confirm if they have efficiently contributed, as done by [15].

5.2.2 Exploring graphic representation

At first, the H-TS-N modelling as a table seemed to be a valuable representation (because it allows a real holistic view of the causes and consequences of a technical system at different levels of scales and stages). However, this graphic representation becomes a complex and hard table to summarize when filled. This is the reason why students offered alternative representations: (1) *"Concerning the representation, I would have liked the [H-TS-N] table to be presented in a pie chart form with a stage of the life cycle on each sub-section, subdivided according to interactions (in a way derived from the climate collage[1] presented at the beginning of the course)"*. (2) *"The graphic representation is interesting to organize the different ideas in place, I found that once filled out the model is quite unreadable. A more pictorial or mind map representation would be more visual."*
However, this table remains a valid tool for appropriating the different levels of impact, as it clearly displays the interactions between the technical system, human organizations and the biosphere. It allows a greater understanding of those phenomena and therefore a better quality of knowledge acquisition on the technical system studied as well as a better systemic vision.
Also, one of the limitations of the model is the absence of time dimension.

5.2.3 Modification of skills assessment

According to Quelhas' article [4], critical thinking is reflected in our own values, precepts and actions and allows us to take a stand on the discourse of sustainability. In the course, it is an aspect of critical thinking that we have not evaluated (by omission) and that we will include in the next session.

5.2.4 Data collection

In the questionnaire to assess students' skills at the end of the semester, several aspects were present in the same question and only partial answers were given. Also, we poorly anticipated the lack of precision in the answers that forced us to set aside some questions from the analysis. For the next session, we will improve our questionnaire which will allow us to integrate all the answers in our assessment.

6 CONCLUSIONS

Overall, the students developed a global vision of the interactions between the technical system, human organizations and the biosphere. The didactic aspect of the course (and the H-TS-N model) seems to be

[1] https://climatecollage.org/

relevant, but a better pedagogical integration will be necessary during the second iteration of the course. Indeed, modifications planned in the 5.2 section will be integrated to the course. Also, integrating the status of engineers in the model, would force students to question their future role in society, and might help their critical thinking.

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THE GIFT OF UNCERTAINTY

How can design education bring complexity and unpredictability into a positive framework for designers?

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ABSTRACT
This paper follows Krippendorff's recommendation "to think and do things differently." In particular, we explore the potential of his reformulation of a product as an "interface" to substitute "the meaninglessness of physical properties" [1] while exploring the "deceptive notion of THE user" as "stakeholder networks" [1]. The three stepping stones of the exploration of "What is?" [2], the journey "Where can we go?" [2], and the challenge of transitioning to "the turning point" [2] to increase flow in designing with uncertainty are examined in relation to Krippendorff's reformulations of products and users, here by cases from design education on a master's level. The students in this case have worked within a grid of a more traditional design processes, but system theory was introduced, forcing the students to evolve with the discovery of open systems and their interrelations and contradictions. The aim of this paper is to explore a design approach for progress and transition and, thus, designers' future ability to meet future uncertainty and complex challenges with both humbleness and boldness. We argue how such a change of perspective may involve the exploration of new networks, relations, and experiences that support regenerative ripple effects and sustainability to handle uncertainty.

Keywords: System-oriented design education, cybernetics, designer's framework, uncertainty, diversity, sustainability, game dynamics

1 INTRODUCTION

Systems are reluctant to change, and the praxis (behavior and thinking) of the people who constitute the structure is influenced by the systems. To change these systems, it is efficient to make changes at a systems level [2]. Hence, the paradigm of design research is concerned with structural change, which means designers are educated within the perspective of approaching complex situations by using structural change.

In the current article, we discuss the pain of letting go of this existing illusion of the designers' ability to predict the future and alter it through structural change. The illusion typically exists in the designers' analysis of a company confined to the products or services isolated where the uncertainties are easy to recognize and resolve. Uncertainty may appear in many scales and types, as well as layers and importance of impact. Donella Meadows [9] explains how the knowledge of how systems work really shows us how much we *cannot* predict and how much uncertainty we actually must be prepared to meet.

Therefore, we have oriented the discussion about the assumption that the ability to handle uncertainty on a systemic level may orient designers into a new role in society and business practice. We further discuss how this may lead to a design perspective building on systems theory and cybernetics, hence emphasizing the design of new systems or changing old systems; thus, this creates the emergence of subsystems and structures that produce new types of growth and systems goals.

1.1 Challenging design education to be relevant for future designers

We modeled this discussion around the following research question: How can design education play a role in future designers' development in the complexity of the uncertain? Design education is slowly bringing in systems thinking to design for complex uncertainty. However, our teaching methods and design methodology, which is rooted in the making of things, cannot meet the needs for future service

and product designers that will operate in exceedingly complex contexts [3]. The systems goal of existing design practice, which is industrial growth, perhaps needs new measures of success.

1.2 Our need to tame the wild produce uncertainty

Humanity's need to gain control over nature as a way to feel secure is an anthropocentric tendency that influences the epistemology of most disciplines. The control that we strive for has a strong impact on how we design our things and surroundings and has been destructive for the environment. This represents a paradox because our need for control has made our future less predictable. Rewilding is now one important method in restoring and healing nature, as well as striving to stop and restore climate change. The design epistemology represents a system that is reluctant to change; therefore, these forms of education do not provide designers with the methods needed to handle the uncertainty that produces such destructive changes. We see examples of trying to reconnect with nature that are romantic and fictional. The story of convenience, safety, and comfort [4] hides the story of decreased flexibility and manifold [5]. Our systems of industrial growth represent a paradigm that lacks consideration of the limited natural resources and intrinsic value of species other than the humans that destroy their own basis of life. Therefore, we need a change in epistemology or paradigm that can lead to a new awareness. A paradigm change is regarded by Meadows as the second most influential leverage point for transforming or changing systems [3]. Such a shift in paradigm can be exemplified by an awareness about the uncertainty that caused the destruction and exploitation of nature. Such a major shift will influence create a major turn in humans' conception of their own place and role in the world, as well as understanding of the systems of Gaia. In this context, Macy mentions this change of awareness as the "Great Turning" [4].

2 CHANGE OF DESIGN PERSPECTIVE THROUGH SYSTEMS THEORY

Krippendorff [6] points toward the importance of a turn in designers' approaches in design, from the traditional proposal of drawings, models, and written words to a participatory approach designing together with a range of stakeholders, leaving behind "THE user" as a simplified factor. He states that "human centered design creates possibilities of others." This view aligns with the functioning of flexibility and resilience. Designing flexibly for people and nature advocates a low entropy [7], which strengthens the sustainability of the system; it calls for simplicity, a few simple principles creating robustness that serve the options for complexity [3]. The design will serve a diversity of people, time span, and change in context. The increase in the number of choices for solutions brings uncertainty of context as an inspiring element for creativity and mastering.

2.1 Theory bringing uncertainty to the table of benefits

Joanna Macy [4] presents the five gifts or rewards of uncertainty: 1) The present moment, or discover this living life, one where the individual does not have to check their hope—this takes one out of the present moment; 2) the power of intention; 3) become whole by befriending pain; 4) solidarity with all relations; and 5) time, the immensity of time. Macy's dimensions emerged from cybernetics and are typically oriented toward the study of the now and a praxis that can be understood as behavior and thinking [8]. Based on this, we can discuss how the managing of a design project would function differently if there existed an individual and common toolbox for understanding, monitoring, and evolving, along with adapting the phases of the design process. This would come in addition to the ability to communicate the gained insight, dialogues, and decision making, facilitating the progress of a development process.

2.2 From perfectionism to plasticity

The search for the perfection of a malfunctioning system is a dead end when the system is about to go through a transition of change; when there are relationships between elements as part of a structure, it is of crucial to create change. The solution is a continuous movement from one state to a new desired level, rather than a new permanent and perfected state. Perfection is most often not possible when people, animals, nature, or living systems are involved. Hence, design is moving from a more static goal to a service or experience in an overarching system or a physical product that may be repaired, reused, remanufactured, recycled, or just being used in different ways, here depending on context and relations. This calls for solutions with simple and robust structures. We may need to move from complicated

specializations to archetypes and the basic principles of solutions that can be understood and interpreted in many ways.

2.3 System dynamics from numbers and computer simulations to qualitative design tools

Meadows [2, 9] explains how researchers in system dynamics have been surprised by the findings of how mathematical models are important to demonstrate how systems actually work. However, as designers, we usually do not have the skills or ambitions to compute and simulate feedback loops and relations. In systems theory, we may reach for the qualitative descriptions of phenomena made by scientists such as Meadows and Bateson. "*Modern systems theory, bound up with computers and equations, hides the fact that it traffics in truth known at some level in everyone. It is often possible, therefore, to make translation from systems jargon to traditional wisdom*." Meadows p3 [9]. We introduce for the students the description of leverage points, as well as the traps and opportunities of troublesome systems, and the lessons, or lenses for recognizing the behavior and dynamics in systems.

The eight traps of troublesome systems

Even though the design approach mentioned here is not pinpointing a problem at first, there are certain characteristics to recognize in unsustainable systems. Systems will break down at some point. We will not go deeply into this area, but we will mention three behavior archetypes that represent troublesome structures: addiction, drift-to-flow performance, and escalation. When evaluating the sustainability performance of a system, it is important to detect the roots of these behaviors.

The fifteen lenses of transition

How do we design with numerous stakeholders? Donella Meadows invites us into the entanglement of stakeholders and uncertainty with her lenses of transition. As we gain deeper insights into the systems, they end up as energies and relations that we would never be able to intuitively predict. She describes fifteen lessons, or lenses, that are key encountering systems; these are brought into design teaching and proposed as important when stepping into the uncertainty of complexity. Building on the above theoretical framework, we have synthesized the below method for designers that supports a process of modeling possible futures and perhaps coping with how to work with the uncertain.

3 FROM SYSTEM THEORY TO PRACTICE, EXPECTING THE UNEXPECTED

3.1 A draft—framework monitoring uncertainty in systems design

For a future designer to handle such processes, we have developed a rough framework (Table 1) for leading and monitoring a flexible design process based on experiences from systemic design, cybernetics, and system theory [2]. The framework is based on a net of system lenses and guidelines based on her grounded theory, and the framework builds on three phases: the twelve leverage points, the fifteen lenses of transition and living in systems, and the eight traps from the three archetypes of troublesome systems. The framework consists of three main stepping stones. These stepping stones have emerged as a draft, based on experiences from interdisciplinary students teams as well as design practice:

The Exploration "What is?" Stepping stone 1 relates to Joanna Macy's first gift of uncertainty: the importance of the present moment. The process and leadership of a transition starts entering a messy system, detecting the relations, structures, elements, and behavior of stakeholders in the system, as well as the system itself. Accepting painful parts, challenges, and destruction is important to discover how the system may be structured in ways that are troublesome. Evaluating feedback loops, for example, may help in detecting the root causes for dysfunctional behavior.

The journey "Where can we go?" Stepping stone 2 relates to the empathy with all living things, or "solidarity with all our relations" with the planet as such, as well as with the diversity of people, species, and the intrinsic value of these. Time is an important dimension. There is very often a call for quick action, whereas this stepping stone should be explored over time and allow for some reflection. Traditionally, this is a phase where design strategies are discussed, as well as the strategic use of design comes into play. This stepping stone is powered by leverage points theory from systems theory

that utilizes discussions about where to intervene in a system and how.

The challenge of transition "The turning point." Stepping stone 3 relates to the power of intention. Early exploration of a minimum viable product (MVP) and early testing of interventions are done at a minimum scale and costs. Real people, context, and experiences are part of the development. Systems are always coupling and uncoupling the large and small, the fast and slow. Testing and evaluating consists of practice and theory, and the results are carried further into foresight and future scenarios. The method helps us see what is important to keep and simplify and the actions needed to start today for upscaling, such as a business model with different levels of complexity, from the fine details to the distribution system.

Table 1. The systemic framework for design in uncertainty

Stepping stones	Dominating approaches
Stepping Stone 1 The exploration of "What is?"	**The eight traps of troublesome systems, and their behavior archetypes** • The discovering of addiction, escalation or drift to low performance, show traps for opportunities for change. Some are; the tragedy of the commons, policy resistance, success to the successful. **Some lenses of transition** • Get the beat of the system. "Before you disturb a system in any way, watch how it behaves." Focus on facts, not theories. Timeline, observations, and data. • Locate responsibility in the system that generates action and feedback loops reflecting the consequences to those responsible.
Stepping Stone 2 The journey "Where can we go?"	**Some lenses of transition** • Expose your mental models to the light of day—words, pictures, arrows. . . . Find uncertainties and mistakes—invite others to challenge your assumptions. Defy the disciplines. • Listen to the wisdom of the system . . . don't destroy the system's own self-maintenance capacities. Talking to people, observing, and searching for values to bring further. How can these be strengthened through system development/interventions? • Pay attention to what is important, not just what is quantifiable, e.g., trust among people in a system—or to the system. Care, freedom, democracy, truth, love, and meaning. Social sustainability. • Expand the time horizon, 1000 years back and forth . . . the forest—the building. • Celebrate complexity. Systems are nonlinear . . . But a few simple principles make complexity. • Expand the boundary of caring. **The twelve leverage points** The most leverage lays in change of values of paradigm or goal and purpose of the system, changing • the mind-set out of which the system arises • the purpose of the "game", ex from competition to cooperation. Leverage points for information flow and control are important, and typical here to intervene is by • adding new rules, feedback loops, or structures that breed continuity, regeneration and then self-organizing structure. • redesigning the relations in a system. "Win-win" solutions that create interconnection—stakeholders might have different purposes in the system, but they support an overarching goal. • balancing feedback-loops Physical structures are crucial, but are rarely leverage points. They should be designed well in the first place and used within their potentials and constrains.
Stepping Stone 3 The challenge of transition "the turning point"	**The fifteen lenses of transition** • Don't erode the goodness. Never leave the goals of the "standard" or compromise on what you know is important in your system. • Systems are always coupling and uncoupling the large and small, the fast and slow. • Testing and evaluating consists of practice and theory—the results are carried further into foresight and future scenarios. The method helps us see what is important to keep and simplify and the actions that are needed to start today for upscaling (e.g., business model with different levels of complexity—from detail to distribution system). • Use language with care, and enrich it with systems concepts. We see what we talk about—try to express the concrete and meaningful important principles of the system. • Honor, respect, and distribute information. Information holds systems together—wrong, delayed, or missing information can make feedback loops malfunction—this can drive a system crazy. • Go for the good of the whole. Don't maximize subsystems; aim for total system properties growth (regenerative types), diversity, stability, resilience, and sustainability. • Stay humble—stay a learner. What happened with your systems meeting COVID-19? Error-embracing is the condition of learning. • Make feedback policies for feedback systems. Feedback structures for learning and monitoring the system.

4 CASES FROM DESIGN TEACHING

4.1 Intersystem analysis, an introduction to uncertainty, stepping stone 1

Students are usually trained in searching for a problem, researching the people affected by it, the situation causing it, and then continuing with criteria for new idea generation for solutions and so on. In many institutions, the design thinking methodology has replaced the more engineering detailed approach; however, convergent and divergent thinking and working methods are characteristic for a designer's approach. This approach works well with rather domestic problems. When working with "wicked problems" [10], however, this methodology is not suitable. The problem we see is usually just a consequence of systemic errors on deeper levels.

To introduce this thinking to master's students in product design, we have proposed an intersystem analysis that is presented as an open approach to analyze an activity or experience. The students would then need to study the sectors and stakeholders interacting that make the foundation for the activity to happen. We further motivate the students to visualize a synthesis map, and based on this, we can explore the context in a frame that is as wide as possible. Furthermore, the heart or intension of the system is described, which may convey the most interesting activities happening in the system. The map is then mirrored with the eight principles of sustainability to describe where and how the sectors misalign with the principles. This first stepping stone—"What is?"—leaves the student with a range of challenges that can be explored further and evaluated as tasks that are suitable for a designer's toolkit for further development and change or even deeper system transition.

4.2 Game dynamics in design, feedback loops for change, stepping stone 2

Play and playfulness concerns exploration, risk taking, search for new sensations, engagement, and testing out ideas, here consisting mainly of communication by messaging between people or people and phenomenon. Thus, play involves seeking change and designing or *framing* [11] for play. This involves the design of allopoietic systems, that is, systems that produce something other than themselves [12]. A game design can then be oriented about the designing of reactions, quarrels, social interactions, deceiving, teaming up for a victory, and tuning of techniques, all of which can be understood as various descriptions of feedback loops caused by the thing, not the thing itself. Thus, the play activity is invented and sustained by feedback loops, and the oscillating variations of these loops are strengthened or balanced by the rules. This second step stone introduces the possibility of experimentation with the effects of feedback loops because the designing of a game itself demands thinking about the dynamics caused by communication sequences. These can be understood as drives, and in play theory, "the purpose of a drive is not to reach its goal (a final destination) but to circle around it, which brings about achievement of its aim" [Lacan in; 13], and that aim is about a mission. To exemplify this, Lacan explains that "when you entrust someone with a mission, the aim is not what he brings back, but the itinerary [journey] he must take…the aim is the way taken" [in; 13]. That is, experimenting with game dynamics in design is a process that involves experimenting with the question of "where can we go?" thus broadening the understanding of designing praxes and behavior by play elicited by such journeys.

4.3 Experiencing the real thing (working in the fields), a taste of stepping stone 3

"We see what we talk about"—it is usually difficult in a pedagogical context to bring in real testing with the right stakeholders and in a proper time span. Testing design concepts for system change most often requires a certain number of frequencies and maturing to see the evolvement and effect of the activities performed. A delay is always present to some degree. An activity may be experienced as fun and exciting for the first three days but after that may become tiresome, so the partakers will go back to their old routines. At the master's level, the three levels of learning by Bateson were introduced through a working day at a community supported farm [8]. The students worked with physical labor for half a day, performing practical tasks. Their contact with the soil, plants, and pigs and smelling the area made the experience real, giving them a surprising notion of joy. The work was explained and thought of as a basic activity with a clear goal (level 1). The students were verbally introduced to the circular thinking and interconnection between the plants, the soil, animals, and people. Choices of plants and animals may change in great variety; however, there are principles of interconnections that must be followed as important values. Then, there is the service system of the participants from the surrounding community

working weekly on the farm and harvesting vegetables from the spring to late fall. Finally, the farm is being transformed from conventional food production to an organic farm, relating to the local and global ecology to a regenerative system in relation to nature. The metalevel of learning is brought into the conversation with the farmers. Questions emerge about the farmers' choice of lifestyle, their background, and path into this new way of living and establishing their local-based value chains. The third stepping stone is the beginning of transition in real life, and for these challenges, the interventions and new designs for change must usually be cared for and nurtured as long as they are in their original state. The goal of the intervention is often a self-organized system that will overtake the role of care and develop in an autopoietic way.

5 REFLECTION AND DISCUSSION

The intention of the current research was to supplement design thinking in design educations with an understanding of designed products and services as *interfaces* that can produce meaning above the "meaninglessness of physical properties" [14] and an orientation toward understanding design as communication or *interfaces* [14], thus moving away from *THE user* toward the notion of *stakeholder networks,* which can lead to processes that open up for understanding design as *effects produced by something or someone* that are shaped by systems dynamics. All of these may stimulate experimentation and coping with uncertainty in design. An introduction of the epistemological view of cybernetics and Bateson, which is oriented about the relations and communications and what it produces rather than an emphasis on the thing as a facet of designing in uncertainty, may open up for new design perspectives. If the student is released from an understanding of the influence of *THE product* and begins to explore the influence of communication systems formed by interaction and feedback loops, this may, for example, orient the design process away from the goal of controlling people's progression in a service to creating concepts of emergence. The concept of working with uncertainty may involve giving power to the interaction that happens through the interface (product or service) to the elicited communication that the interface produces.

The pedagogical toolbox may become much richer in this field, and the use of play in systems thinking and learning is valuable. It gives the students the opportunity to actually experience uncertainty, as well as the very exciting relations discovered in the different types of structures and feedback loops. The experience of discovering errors and delays that cause an unexpected mess in the "corner" of a system might be stronger and more direct when it is experienced with one's own senses.

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RE-SIGNIFY THE DOMESTIC SPACE IN TIMES OF CONFINEMENT FROM THE APPLICATION OF ETHNOGRAPHIC TOOLS AND PERSONAL CENTERED DESIGN

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ABSTRACT
The Covid-19 crisis has been described as the "greatest challenge that humankind has faced since the 2nd World War," having an impact on health, society, and the global economy. Houses and domestic spaces are key sites through which COVID-19 is experienced, thus, an interdisciplinary approach is needed. The goal of this research project is to forge an analytical approach while experimenting with micro-ethnography and auto-ethnography tools to analyse how we inhabit the domestic spaces in complex situations of confinement imposition in order to arrive at an outward reflection from within. The project reflects on an innovative social experiment that opens up new paths of design provoking to help us rethink the domestic space. This paper has the objective to compile, compare and explain the processes and results around the characterization of the domestic space, centring on the person in times of confinement through an ethnographic approach.

Keywords: Domestic space, confinement, COVID-19, ethnography

1 INTRODUCTION

The Covid-19 is impacting not only our health but society and economy globally [1]. In this context, protocols have been proposed such as self-isolation, social distancing, complete lockdown [2], border closures, travel restrictions, school and business closures, and quarantine [3] amongst others.
Social isolation has posed a serious threat to people's physical and mental health [4], causing a decrease in the general well-being [5], experienced by a large part of the population [6]. Emotional fluctuations and psychological discomfort are detected as quarantine duration elongates [7], reducing social connection [4]. Confinement endangers domestic coexistence [8]. Younger adults and women report higher distress during the COVID-19 [4]. For children, isolation entails a substantial risk [9] with direct consequences regarding health, safety, and well-being [10].

1.1 Domestic space and housing

The subsequent measures have had implications on how we occupy our habitat and how we relate to the open environment and nature, observing the effects on our physical, mental, and emotional well-being [11]. This global crisis is an opportunity to question the role of designers as to rethink possible alternatives [12].
Houses are key sites through which COVID-19 is experienced [13]. In confinement, houses became the only place we slept, ate, worked, practiced sports, and socialized [14]. The characteristics of the built environment within houses are directly associated with health [15], and well-being [16]. Domestic space designs play a fundamental role in this health crisis [17].
As aforementioned, an interdisciplinary approach is needed [18], and in the school of Architecture, Art and Design of Tec de Monterrey in Mexico the idea of analysing our domestic spaces during confinement seemed a way to look at and re-signify our habitat while in confinement, but also to rethink for the new normal.
The research project "Re-signify the Domestic Space in Times of Confinement," hopes to be a guide for professionals in Design, from an analytical approach, while experimenting with micro-ethnography as

well as auto-ethnography to analyse how to inhabit domestic spaces inf confinement to arrive at a global reflection. The project reflects on a social innovation experiment that opens new paths to design, provoking the rethinking of the domestic space.
This paper has the objective to compile, compare and explain the processes and results around the characterization of the domestic space, centring on the person in times of confinement through an ethnographic approach.

2 METHODOLOGY

This project was developed during short research stays where the background was established to analyse the current situation to question the inhabitants, while at the same time contrasting against the self-experience.

2.1 Micro-Ethnography and Auto-Ethnography

Confinement implies new socio-spatial relations: of the subject with him or herself and with his or her family, as well as the subject with the domestic space. Ethnographies are used as a complex self-analysis that must be profound and critical to turn research into proposal and action.
A micro-ethnography was carried out through social cartographies and an auto-ethnography was developed through cognitive-body mapping and experience mapping to get a closer relationship to the people and their domestic situations [19]. The micro-ethnography focuses on particular aspects in a short period [20] and it allows to add a spatial dimension to discover the particularities within a full immersion [21], while visualizing an added value based on personal motivations [19], to find particular needs [22]. The auto-ethnography allows to prospect a qualitative research strategy [23] suitable for confinement, to approach the context from a subjective perspective of the researchers -actors themselves [24]. There is a capitalization on the affective and cognitive "experiences" of the person who developed knowledge based on reality due to his or her direct participation [23]. Here, the researcher is subject and object, an active participant capable of narrating the scene in which he or she works, having particular access to the observation [23], between the personal and the other interpretations [24].

2.2 Social Cognitive Mapping

Social cognitive maps are a way of telling stories where events are organized through visual, textual, or other means [25], and a way of communicating spatial information [26]. The narrative is fundamental, it is a way of finding the relationships between place, person, and time [27]. This includes narrated events, expressions, and interpretations of maps [28], critical reflections [29], dissemination of findings, data visualization, communication of information, and the exchange of stories [30]. This was used to approach family dynamics regarding shared spaces in specific time frames. The objective is to form socio-spatial cartography including different domestic spaces around the relations of the people who live there. The maps show the representation of conditions before and during confinement.

2.3 Body Cognitive Mapping

To represent new inhabited spaces through relations in confinement signifies working with the body. The body is the first territory on which to experience affective and emotional fluctuations and the first interphase in-between the subject and space [31]. The elaboration of a body cognitive mapping is based on the idea that when there is conflict in the lived spaces, there are pains that materialize directly on the body [31]. The researcher participants are prompted to develop their cognitive mapping where they play with the space and the emotions in direct relation to their bodies.

2.4 Experience Mapping

Mapping the experiences allows creating a relation between domestic spaces, the activities, and emotions, as its objective is to describe an effective method to understand and improve the user experience. This technique facilitates collaboration between stakeholders and designers, giving way to co-creation processes [32]. In this research, the experience maps were used to reach a deeper understanding of the mood of each family member regarding their family activities and relationships.
The tools aforementioned were applied within two months in confinement, with a total number of 17 people. The group was made up of undergraduate students (Industrial Design and Architecture students) and graduate students of Architecture. Most of them belong to a medium-high socioeconomic group,

and they live in medium to large size houses which allow for open spaces such as patios or terraces. Seven of them live by themselves, and the rest of the students shared inhabited spaces with their families.

3 RESULTS AND DISCUSSION

The used tools provide the identification of patterns that emerge from the phenomenon itself, from the individual analysis. The first finding refers to a progressive awareness around the issues of uses of space (before and during Covid-19). This is when clear socio-spatial dynamics around the definition of new personal and collective envision opportunities for change. Understanding the experience of each of the family members enables agreements, considerations and in many cases, through reflection on the proximity/privacy or inside/outside dualities, actions that lead to the resignification of spaces.

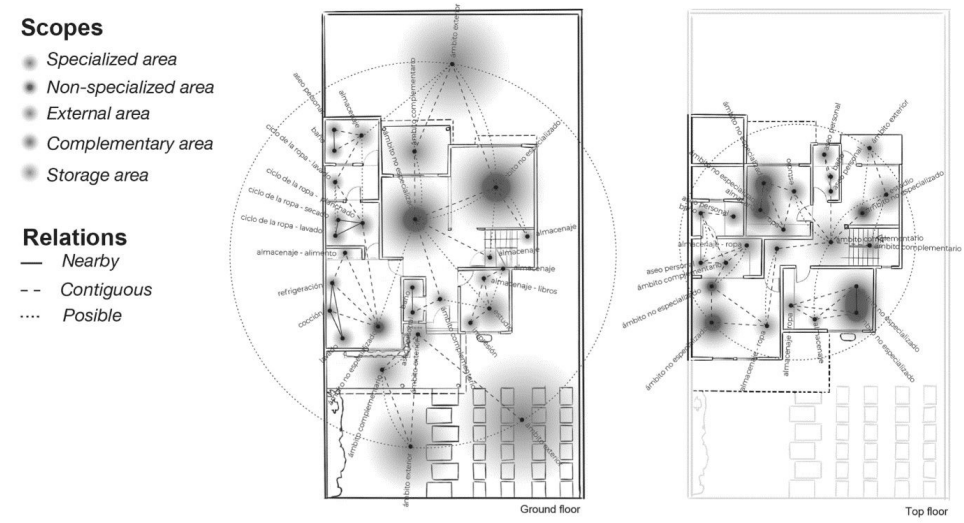

Figure 1. Example of Socio-Spatial Cartography (A). Relationships between housing areas

Unravelling the emotions, from the mapping of the body, allows for changes not only in the relationship with the inhabited space but with the body itself, establishing and increasing self-love.

These processes show the transition from an initial condition of bewilderment (at the beginning of the confinement), to a moment of empowerment and improvement based on creativity that allows the space to be adapted to new demands, to reappropriate it, and to regain security and serenity. The feeling of bewilderment and anxiety, in some cases, is accompanied by a greater concern for "the other," in a more socially conscious approach with attention to common spaces that are no longer usable. The repetition of domestic and work actions in a single space becomes an obsessive condition that transcends the limits of its inhabited space and overflows into an external space marked by the absurd, oppressive and monotonous, due to housing model conditions.

Figure 2. Example of Body Cognitive Mapping (B)

For some students, there was an awakening of a gender consciousness linked to spatial appropriation: before confinement, the individual room was essential for privacy and autonomy. During the confinement, leaving the room and expanding to other more public spaces in the house created a feeling of emancipation and liberation. The domestic space is analysed as the place of the process of role attribution, as was found by reviewing the conditions imposed by confinement.
Using experience mapping helped researcher students to understand the importance of self-e insights. They discovered that spaces could improve by allowing for self-awareness tools, which lead to redesign the domestic space improving their daily interaction with others.

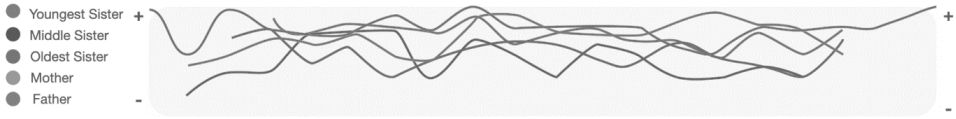

Figure 3. Example of Experience Mapping (C) of a common day in confinement

4 CONCLUSIONS

Family relationships were affected by space, and space was affected by the type of relationships. The confinement implies new socio-spatial relationships: that of the subject with himself or herself, and that of the subject with their family, also of the individual with the house itself. Analysing the above is possible with the use of auto-ethnography tools and micro ethnography: the first allows self-reflection in the confinement and reflection with the other in the same space, while the second allows the reflection on the specific problem of coexistence in the confinement (from the self to the we-family). Both tools, when used in a spatial context, can have a high value of "truth" and authenticity by eliminating the interpretation of others and judgment value. In addition, self-experimentation produces a greater understanding of the tools that will undoubtedly lead to a more empathetic attitude when collaboratively returning to fieldwork or when designing new domestic spaces.
The results obtained contribute to rethinking the domestic space beyond confinement. From academic experience, the use of autoethnographic and micro-ethnographic tools helped student researchers to understand how they experienced the theory of spaces first-hand. There was no need for interpretations, but self-knowledge and self-awareness. In addition, focusing on the specific topic of micro-ethnography allows one to reach a detailed and deep understanding of where new questions arise regarding the conception and categorization of spaces to satisfy new needs and desires. The application of the aforementioned tools within the family domestic space allowed researchers to articulate possible solutions based on an analysis that was not only experienced first-hand but also helped understand the terms of other relatives through their interactions and the space they share. For both students' researchers and teachers, new questions were triggered regarding the role assigned to the designer in confinement and beyond confinement, where roles are exchanged and assumed in new ways. Where spaces are transformed through self-awareness and observation.

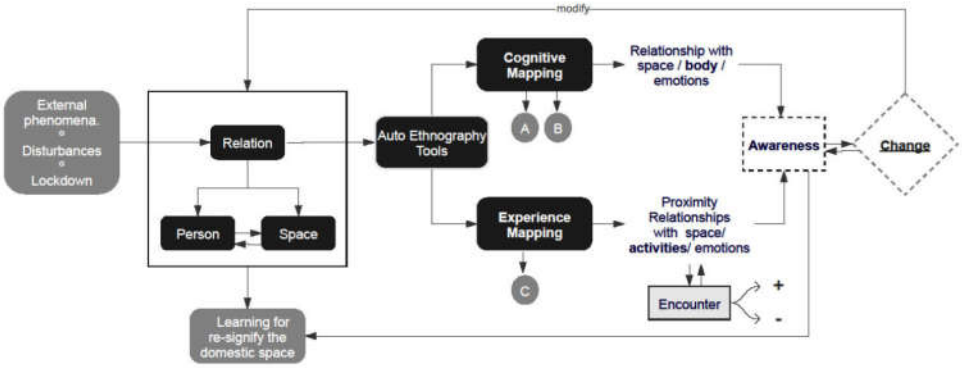

Figure 4. Autoethnographic analysis model and re-signification of space

As a final conclusion, as explained graphically according to the model in Figure 4, it can be observed how the ethnographic tools of cognitive and experience mapping, self-applied by the same research subject, facilitate reflection on the body/space relationships mediated by emotions, and close relationships with other people, in the same space, mediated by activities and other emotions. Also, some encounters can represent positive or negative experiences, thereby generating self-awareness leading to change. This, in turn, has repercussions on the initial space/person relationship in the form of learning that implies the resignification of the domestic space.

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THE DESIGN STUDIO AS A NETWORK – APPLICATION OF CONNECTIVISM IN THE PLANNING OF AN ONLINE LEARNING SPACE

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ABSTRACT
The design studio is the core element in the design curriculum where students gain key knowledge and skills. When the traditional classroom course had to be transferred to an online modality enforced by covid-19 pandemics, re-conceptualization of the structure and contents was required in order to ensure the quality of the teaching and students' satisfaction. Based on the premise that the contents should not be simply adapted to an online version, but an entirely new learning experience should be created, the redesign of the class was inspired by the principles of connectivism (Siemens, 2005). Connectivism as an alternative learning theory recognizes the societal shifts and the inevitable impact of technology on the learning processes. This new framework for understanding learning, states that knowledge is derived externally of the individual through a process of connecting nodes and patterns recognition. These abilities are considered especially important to prepare design students for the challenges of the profession within the context of the fourth industrial revolution.
The paper explores the potential of connectivism as a holistic approach to the planning of the contents of an online design studio. It describes the process of designing the course structure and discusses the challenges encountered in the creation of a connectivist learning environment. The advantages of the networked design studio were verified in a survey on the perceptions of the students in regard to their satisfaction and the effectiveness of their knowledge acquisition.

Keywords: Connectivism, design studio, online education

1 INTRODUCTION

Design education has undergone significant development in the past decades to respond to the technological and social changes and to adequately prepare students for their future professional practice. Digital technology has been extensively embraced by the educational system to facilitate the learning process and to improve the quality and effectiveness of the teaching. Enabled by Web 2.0 online learning brought a radical change in the educational context with its accessibility, independence of time and space and the ability to promote varied interactions with the content, the instructor and the other learners. However, the giant leap to online learning was not a natural result of its advantages but was externally imposed by the covid-19 global pandemic when it proved to be the only possible way for the educational process to continue. University educators were faced with the fact that in the changed setting learning occurs in a different way. They had to rapidly adapt and discover the new opportunities for teaching and learning afforded by the online environment. I also had to re-evaluate the content of the studio classes I teach and to plan how to present and transform the information in a relevant way. I was aware that to ensure the quality of my teaching and to respond to the needs and expectations of my students, the contents cannot be simply transferred to the online version of the class. Instead, I had to fundamentally rethink my teaching approach and to devise entirely new experience for the students. Guided by the principle summarized by Laurillard that "[k]nowledge technologies shape what is learned by changing how it is learned,"[1] I aimed to provide a systematic organization of the content and to plan the class interaction by combining the best pedagogical practices of the traditional face-to-face class with the emerging possibilities provided by the virtual environment.

2 TOWARDS A VIRTUAL DESIGN STUDIO

The design studio is the core element in the design curriculum where students gain key knowledge and explore their creative skills [2]. By implementing a project-based approach, the studio is where students "express and explore ideas, generate and evaluate alternatives, and ultimately make decisions and take action" [3]. Students learn how to communicate their concepts through representation, how to master the visual design language, or generally said they learn how to design [4]. The pedagogical approach is focused on the following three educational aspects – new skills, new language and the development of student's thinking [5]. However, central characteristic of the studio is not pedagogy but the interactions that take place and which form the exemplary atmosphere or the *studio culture*. Wang describes it as "a vital complex of material representation, social collaboration, creativity, emotionality and a tolerance for uncertainty – if not outright confusion – balanced with a faith that meaningful designs eventually will emerge." [6]. Through the critical dialogue that is established and the provided feedback, students tests the validity of their ideas, and constantly revise and improve them. In this way knowledge acquisition occurs – in the experiential creative process defined by Schön as "reflection-in-action" [7].
The traditional notion is that the social and cultural domain of the studio has a counterpart in the physical environment where students spend long hours, create their own community of practice, and identify with it as individuals and as a group [8]. However, with the pervasion of information and communication technologies both in the design practice and the educational process, the design studio was inevitably transferred to the digital realm. Driven by the growing complexity of the design problems and the higher demand for collaboration between all participants involved in the design process, in the early 1990s the virtual design studio emerged [9]. The new studio typology offers a computer-mediated collaboration, often between geographically distributed and multicultural teams which is space and time independent [10]. Though considerably different from the physical space, the virtual studio has the same function as a shared learning and practice space where students interact, develop and present their projects. Furthermore, an important fact is that a sense of place can be fostered [11] and hence the identity and the community typical for the face-to-face studios can be successfully retained. A major benefit of the experience in a virtual design studio is that students are exposed to a simulation of the real working environment where expertise in digital media and collaboration in multidisciplinary teams are prerequisites. In the virtual studio students master the new digital tools and develop competences which help in bridging the gap between academia and the professional practice.

3 THEORETICAL FRAMEWORKS FOR LEARNING IN THE DIGITAL AGE

To understand the effects of the technological context on education and to support the planning of the online design studio a relevant theory is needed. Determinant factor to be considered is the changing nature of the design process. The commonly accepted notion of its structure consists of two situations – an identified problem that needs to be resolved and a solution which fulfils a certain goal. The transformation from one state to the other, or the causal link between the two situations, is the act of design [12]. From the perspective of systems and complexity theories, Findeli suggests that instead of a problem and a solution, two end states of the system should be considered – its present state and its desired future state which is never a specific solution but a transitory state in a dynamic process. In this new structure the designer and the user are also considered parts of the system that undergo changes during the transformation process. The awareness of the systematic nature of design requires attention to be paid to the invisible relations that exist between the actors within the system and not on the artifact as an outcome of the design project. This new understanding might be the radical change needed in design education and the design studio in particular which are in a state of crisis [6].
Our students, the future designers need to be trained how to deal with the increasing complexity of both the design problems they have to resolve and the design process which often requires a multidisciplinary approach to the design project. To support the acquisitions of skills and prepare them for the challenges of the profession within the context of the fourth industrial revolution, learning should not be focused on the accumulation of knowledge but on the ability to seek for the most up-to-date information, to filter it and to apply it when making decisions. Again, the importance of the relations within the highly abundant and rapidly changing information network and the ability to explore them is prioritized. Hence, the application of systems and complexity theory in learning can provide the demanded framework and foster the required change in education.
In his seminal work "Connectivism: A Learning Theory for the Digital Age" Siemens questioned the viability of behaviourism, cognitivism and constructivism as theories adequately addressing the learning

processes in the digital age [13]. He advanced connectivism as an alternative learning theory recognizing the societal shifts and the inevitable impact of technology on learning processes. He reconsidered the relationships between knowledge and the learners in the current social environment and proposed a novel understanding that knowledge is derived externally of the individual through a process of connecting nodes and patterns recognition. According to connectivism, knowledge is a network phenomenon, composed of networked entities and their connections [14]. A major tenet is that knowledge is considered as a function of elements distributed across a system; it is decentralized and may exist outside of a person, which implies that "know where" becomes more important than to "know what" and to "know how." Learning is considered as a continual network-forming process in which knowledge is created through the construction of new connections between fields, ideas and concepts. It evolves from knowledge consumption to a knowledge creation process [15].
Though the status of connectivism of a theory has been criticized [16], [17], its conceptualization of learning accurately reflects the context defined by the online learning environment and the changed student demographics, so I consider its application as a pedagogical approach in the design studio pertinent.

4 CONNECTIVIST LEARNING IN THE ONLINE DESIGN STUDIO

The studio takes a central place in the four-year undergraduate programme of Interior Design at the University of Monterrey, Mexico. From the very beginning of the course of study, students are exposed to studio work which each subsequent semester features a changing focus of the subject and increasing complexity. Successful completion of the previous studio is required for the students to enrol in the next studio and to continue their studies. The class in consideration which had to be transformed from a traditional studio into a fully online mode in the autumn semester in 2020 is "Studio Integral." This is the last and most advanced studio which allows students to apply progressive theoretical approaches in the development of a comprehensive large-scale project.
The major questions considered in the planning process of the online studio were:

- How to plan for effective communication and collaboration in the online learning environment?
- How to engage students and how to encourage a more autonomous and self-directed learning?
- How to ensure meaningful knowledge acquisition in the online learning environment?
- How to support new types of interaction so that the authentic culture and practice of the design studio is preserved in the online learning environment?

The first aspect taken into account was the profile of the students. The impact of technology on millennial students' behaviour, beliefs, attitudes and educational requirements has long been recognized and researched with the intention to implement learning activities which are meaningful and conform to their learning needs [18]. However, in 2020 a new digital native generation is in the classroom and though sharing some characteristics with their predecessors, they certainly have their differences. To understand the characteristics and the learning preferences of the cohort it is imperative to support the students through their learning journey and to maximize their engagement in the educational process. Generation Z students are described as observers with a preference for visual and video-based content. They identify themselves as intrapersonal learners who are used to learning in their own setting before sharing their knowledge with others. They focus on acquiring the skills needed for their future career and expect to immediately apply them in real life. Moreover, they feel highly motivated when they are engaged with their passions and when they are involved in social change initiatives [19].
A main goal of the design of the teaching strategy was not to focus on the content but to align the learning outcomes with the proposed activities so that each student is enabled to master competencies while comprehending the value they add for his professional development.
The expected learning outcomes were formulated as follows:

- Ability to implement systematic design approach to solving problems
- Skills to develop and structure a design narrative as a prerequisite for a successful design solution
- Ability to translate conceptual ideas into tangible forms and spaces
- Analytical and critical thinking skills for generalization, evaluation and selection of structures, constructions and materials
- Mindset to apply integrative design approach for sustainable solutions
- Presentation skills and ability to defend concepts and ideas with well-grounded arguments
- Interdisciplinary and heuristic thinking

Contrary to the departmental requirement that the course content should be well-defined and preliminary structured, I proposed a flexible programme which could easily adapt to changes and self-organize according to the needs of the students.
Following connectivist principles I tried to offer a variety of perspectives and opportunities for students to connect and to establish dialogue. I relied on the interactions which would be naturally formed and the spontaneous emergence of learning through these interactions. The didactic content was not hierarchically structured but instead was split into small segments which could be easily re-arranged and personalized according to the prior knowledge and individual interest of the students. The theoretical lectures and videos supporting the concepts which were to be explored in the design process were uploaded on the learning management system for students to review at their own pace. At the same time, students were encouraged to research these concepts further, to collect reference materials and through reflexion and self-critique to move from observation to interpretation.
A major premise in this teaching strategy is that the students are responsible for their own learning. However, in general, they are accustomed to receiving precise instructions and prefer to be guided in the development of the assignments. To prevent them from getting lost in the massively abundant information and to create a feeling of security, the synchronous sessions in the beginning of the semester were devoted to creating an atmosphere of trust and confidence. The provided nodes of theoretical content served as guidelines for the initial building of a personal knowledge base while the online discussion forums resolved doubts and supported students in the process of self-directed autonomous learning (Figure 1). The formation of this knowledge base is critical for the acquisition of skills to recognize which information is valuable and authentic.

Figure 1. Mind-maps representing student's understanding of the theoretical concepts

When understanding of the basic concepts has been developed, students could move on to the next level where through interactions with a new content they could form new connections. The formation of new and unexpected connections between existing ideas and the most up-to-date concepts results in new forms of knowledge and this is the essence of the creative process. Not only analytical and critical thinking but also interaction and discussion are crucial for students to be able to "see" these new connections (Figure 2).
The feedback provided by peers and the instructor aided in distinguishing the valuable inputs. Another important aspect is that students are expected to contribute to the knowledge network by sharing insights and disseminating their own knowledge. Engagement and active participation of each student is expected. In this knowledge co-creation process the main role of the teacher is to curate and sustain the learning environment, to monitor and control its effective functioning, to motivate the self-directed learning and to create opportunities for knowledge sharing. One such opportunity was provided with the implementation of a collaborative online international learning (COIL). This virtual mobility experience made possible the interaction with students from another country (Ecuador in this case), gave a new contextual meaning to the explored ideas, encouraged cross-national dialogue and additionally expanded the created networks in a culturally diversified environment.

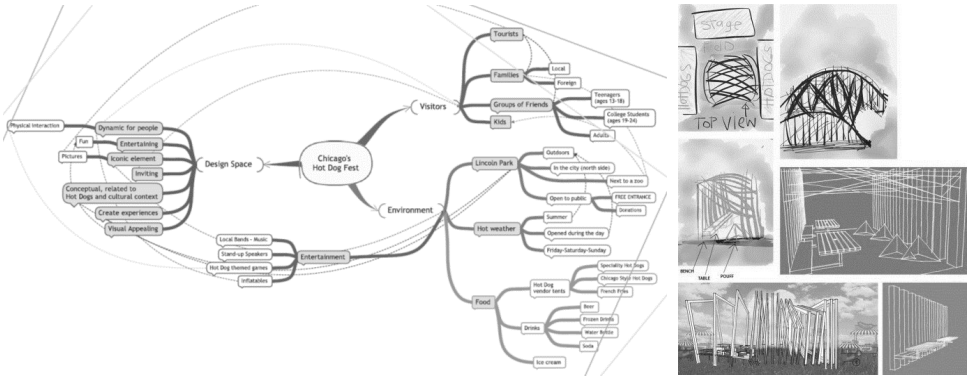

Figure 2. Mind-map exploring the existing relationships between the major aspects considered in a pavilion design and the resulting concept sketches

5 LESSONS LEARNED

The perceptions of the students and their own estimation about the achieved outcomes of the class were examined with several surveys which were carried out before, during and at the end of the semester. In this way I could verify the effectiveness of the teaching strategy but also gain valuable recommendations and critical feedback on what to change and how to improve the online learning environment. One of the most satisfying results was that all 15 students found the class to be very well planned and would not change anything in the future. Also, all students replied positively to the question "Did you find the learning in the studio meaningful?" Another survey question addressed the perception of the level at which the class prepares students for their professional practice. 53% indicated a "very high" level, and the other 47% evaluated the level as "high." Likewise, all students considered that their personal achievements in the class as "very high" which was also confirmed with my direct observations.

However, in the answers to the question whether the online studio can replace the face-to-face classes prevail the opinion that traditional classes are indispensable as 67% preferred them. Among the reasons were pointed out that communication is better in person than talking to a camera, because working in front of the computer for long hours has been very tiring, and distractions occur more often at home. Still, students found a lot of advantages of the online studio. A respondent commented, "I liked the class very much, I think that the teacher understands that the online class is harder for us, but she makes it very interesting and useful, also not that difficult and always supports us." Another student shared, "Yes, I think the proposed type of learning made us more responsible. We, as individuals, are responsible of our own learning. Learning goes way further than connecting to the class, we have to be present and have the best attitude in order to be able to learn". Another opinion which summarizes the advantages of the teaching strategy is, "This class has helped me improve my level of organization and my design process."

I consider an indicator of the success of the proposed teaching strategy to be the changed attitude of the students towards the responsibility for their own learning. While at the beginning of the semester 80% responded that they prefer to receive precise instructions how to develop the assignments and only 30% were willing to search additional references and readings not assigned by the teacher, at the end of the semester 14 of the students defined themselves as self-directed learners and only one was uncertain. The feeling of belonging to the community was also confirmed by 93% of the students.

One of the findings which require some changes to be implemented in the future is that 73% of the students think that the overload of the online class is higher than the traditional face-to-face class and all of them felt very tired at the end of the semester.

I was surprised by a comment from one of the students who shared, "Thank you for caring about our experience with online classes. This is the first time a professor takes the time to ask important questions about this type of learning." I find this a big shortcoming because educators should always be aware of the effectiveness of their classes as there is a direct relation between the selected method of teaching and the learning outcomes. And this is especially important to be identified in the online environment which most likely is completely new for the majority of the teachers.

6 CONCLUSIONS

The creative transformation of the traditional studio class into a highly interactive and meaningful online environment was considered a major prerequisite for ensuring students' satisfaction and valuable learning experience. Through the implementation of the connectivist learning strategy I was not only able to adapt to the new circumstances but to offer a space with added value where students were able to fully unfold their creative potential. Though still being highly controversial and criticized, connectivism answered my need to translate the content of the face-to-face studio class and to convert it into an advanced knowledge network. My major objective was to encourage students to be critical, to search for problems in the world around us, to learn from other fields and cultures, to create narratives which merge poetry and advanced technology and to aid them in the process of becoming visioners of a better future. The positive results of the survey unambiguously showed that the initial frustration created by the lack of rigid structure and higher uncertainty of the studio organization was overcome and to a certain extent students learned how to deal with complexity.

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TAKING RISKS-ADAPTING THE AALBORG PROBLEM BASED LEARNING MODEL IN A NEW FIRST YEAR ENGINEERING DESIGN CURRICULUM

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ABSTRACT
An introduction to design for first year engineering students contains many facets. Students are expected to learn and demonstrate their knowledge of design processes, drawing, and computer-aided-design. In a new interdisciplinary design unit, students were given an ongoing individual design project which assessed their understanding of design, as well as competencies and skills in using their drawing, computer-aided design (CAD) and programming skills - they were also introduced to design through a design challenge that enhanced their individual and collective learning run in partnership with Engineers without Borders. This paper discusses the challenges of not only delivering such an ambitious model to first year engineering students from multiple disciplines-but the online and face-to-face teaching delivery that had to be implemented under Covid-19 restrictions. This paper documents a challenging year for all design educators, with significant uncertainty and rapidly changing circumstances. The conclusions of the paper are that Problem-Based Learning alone may not be suitable for engineering teaching in the first year of study, and with students who are getting to grips with blended learning and self-directed study. A hybrid model of problem and project-based learning may be more adaptable to different learning styles. If Problem-Based Learning is solely to be used it should place more emphasis on team work rather than individual competencies. Further work is to be explored in hybrid or hyflex online and in-class teaching to make the most out of activities linked with Project and Problem-Based Learning.

Keywords: Multi-disciplinary, Problem-Based Learning, Project-Based Learning, hybrid delivery, inter-disciplinary, engineering systems, Covid-19

1 INTRODUCTION

The impact of Covid-19 has proved to be a significant and ongoing challenge for Higher Education providers in the UK in 2020. There was a rapid transition from face-to-face teaching to online and blended delivery, with significant restrictions on the capacity of teaching spaces and safety measures in place. Some problem focused subjects such as Maths and Engineering Science subjects, typically delivered via lectures and problem classes, seemed to have adapted well to this transition, however, the move to blended learning has proved challenging and difficult for practical aspects of engineering and design education-in particular, studio-based design classes, labs, and workshop-based activities. For many design educators, a new approach was required - and this was the case for a 20-credit first year Design & Computing unit; originally delivered to Civil Engineering students the previous year to give them a foundation on sketching, design process and computer-aided design (CAD), as well as basic mathematical modelling and programming skills. As a conjoined unit, which focused on both design and computing as well as for the purposes and scope of the paper, the design element of the conjoined unit will be the primary focus of this study. The unit intended learning outcomes remained the same for 2020 delivery, however there was a significant reduction in face-to-face synchronous teaching, with many aspects of the unit delivered online. The unit was also not only delivered to Civil Engineering students, but to the entire first year of the School of Engineering-including Engineering Design, Mechanical and Aerospace Engineering students, effectively growing the cohort size fivefold to almost

600 students. This required a broader approach to teaching design, which was not discipline specific. Another challenge was that the unit had many aspects that had to be delivered via a combination of online asynchronous (self-study, pre-recorded lectures, reading and activities) and online synchronous (online meetings, webinars, and workshops) as well as live synchronous (labs and studio-based work) sessions; of which the latter was restricted in limited sessions per week with significant capacity restrictions in the teaching space. This was also coupled with a demand to significantly reduce assessments across each engineering programme.

2 PROBLEM BASED LEARNING AALBORG MODEL AND INTERDISCIPLINARY APPROACH

With significant changes to the scope and delivery of the unit, the teaching material had to be redesigned from scratch. For a first-year unit, it was important to balance the new knowledge, competencies, and skills that students would be learning and assessing their ability to apply knowledge, competency, and skill in their project work, which would adequately prepare them for development and integration of first year content in the second year of study. It was important that each student is assessed individually on these competencies, to ensure a successful progression into the second year. A Problem-Based Learning approach, rather than project-based learning, was considered as an effective means of delivering new, ambitious content to an entire school of first-year engineering students to give them a wider appreciation and scope of engineering, as well are harmonizing the two components of the unit into a consolidated project. During Problem-Based Learning students learn about a subject through the solving of problems which do not have a single correct answer, usually working in groups. This approach 'empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem,'[1]. In project-based learning students learn by investigating more complex problems or challenges. This approach promotes active learning, engages students, and allows for higher order thinking through the exploration of real-world problems [1]. The main difference between Problem-Based and Project-Based Learning is the outcome. The focus of Project-Based Learning is the development of an artefact or system in response to a complex and ill-defined problem, in contrast to Problem-Based Learning where the outcome is simply a solution to a clearly defined problem. Problem-Based Learning could be considered a subset of Project-Based Learning in that the problem at hand is simple enough not to require a project to solve it. Project-Based Learning is often multidisciplinary, over longer timescales, and involves undertaking authentic tasks to solve real-world problems, whereas Problem-Based Learning is more likely to focus on a single topic over shorter timescales and may rely on less realistic scenarios. There is an argument that Problem-Based Learning is more reliant on group work and Project-Based Learning is more appropriate for individual self-direction. However, on this basis, what Problem-Based Learning allows students to achieve is the *acquisition* of knowledge rather than just the *application.* It also fits within project activities with a degree of complication and systems thinking, such as computing, hydraulic or water engineering related to Civil Engineering or Mechatronics projects in Australian institutions [2]. However, these case studies were delivered at more senior levels (second, third and fourth) year in the halcyon days of in-class teaching (pre-2020). The risk of adapting Problem-Based Learning in this context is that it will be delivered to an inexperienced first-year cohort getting to grips with blended learning for the first time. Problem-Based Learning has also been explored in the teaching of sustainable development to promote education innovation in student-centred learning [3]. However, this was explored as broad, complex themes which would integrate into a hybrid problem and project-based model and delivered at too high a level for first year students. However, the approach explored four learning principles that were desirable outcomes for the new unit [4]. These were:

-*Constructive learning*: where students learn by **constructing their knowledge base**, connecting new information with existing knowledge (e.g., through discussion)
-*Collaborative learning*: where students learn **collaborating with each other** to maximise their learning through peer-to-peer teaching (e.g., in small group work)
-*Contextual learning*: where students learn to consider **relevant context of a cases** in order to transfer and apply insight and knowledge to different cases (e.g., through real-world/authentic problems)
-*Self-directed learning*: where students learn to **regulate their learning** by playing an active role in planning, monitoring, and evaluating their learning process (e.g., through self-interest and formative exercises)

These four principles would come to define the overall strategy and goals for the Design & Computing unit; however, it still needed a framework. The Aalborg Problem Based Learning (PBL) model [5] is well-established and lends itself well to integrating knowledge and practical based elements into project work. Aalborg's unique project-organised problem-solving approach allows students to work collectively on a common project, whilst enabling individual assessment of skills and competencies. Instead of literature, lectures, and experiments; the inputs to the problem-solving activity would be competencies linked to the student's ability to design, draw, model in CAD and use programming software. See Fig 1.

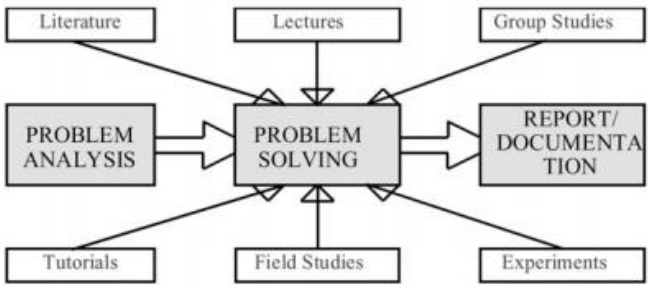

Figure 1. Principles of project-organised problem solving [5]

The Design & Computing unit contained technical drawing, CAD, and programming elements that students required competency in before applying this in their project work. These elements would normally be traditionally taught through lectures and studio-based teaching or computing labs. However, due to the constraints of teaching spaces and limitations of live synchronous sessions, it was deemed that the project elements were of the most priority for face-to-face classes, therefore all drawing, CAD and programming activities were delivered online. These practical elements were formatively assessed to allow students to obtain feedback throughout the unit. It also offered some contingency in the new delivery of the unit that was affected by external factors, such as students not having the right equipment or internet issues. Another important element was to allow students to obtain formative feedback on their report/documentation halfway through the unit. Not only was this an important stage gate to monitor and check on student progress, but also help regulate their learning. A major theme in the unit is design, and students were asked to undertake a 5-week group project in collaboration with Engineers without Borders. The Engineering for People Design Challenge provided an opportunity for students to work together to solve a global design problem, learning core design skills and tools through collective learning. The intention of this project was not only to allow students to meet and work with new course mates, but to introduce design in a fun yet challenging project.. The adapted PBL model-which shows the structure and approach for the unit, combining practical elements as well as design and systematic thinking-is shown in Fig 2.

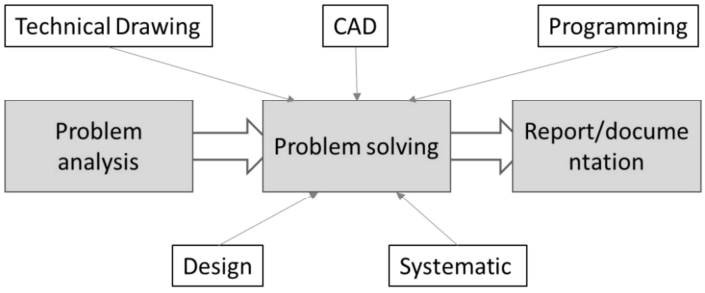

Figure 2. An adapted PBL model and framework for the unit

3 MULTI-DISCIPLINARY PROJECT THEME & PROBLEM

With the unit now containing a mix of engineering disciplines, the project theme had to be sufficiently broad but with some disciplinary nuances to help students transition well into their second year. Given a major learning outcome was to demonstrate an appreciation of the environmental, economic, social, professional, and interdisciplinary contexts, as well as understand the purpose of engineering in delivering sustainable development; a wind turbine farm context was devised. Each student, depending on their discipline, focused on a sub-system aligned with their discipline. The problem-solving aspects of the project took on two major themes, firstly it was important for students to understand the complexities of sustainable development and secondly to start appreciating systems engineering/integrated approaches as part of foundational design competencies [6]. A fictional Scottish island and context was devised based on the controversial Viking Wind Farm development on the Shetland Islands. Not only did this give the project authenticity and relevance but was also a project context that many UK-based students could connect with. To adhere to the problem-based nature of the exercise, students were presented with a collection of data, which included information on the islands, costs and detailed proposals and technical annexes They were also presented with weather and geographic data of the island, as well as a set of equations to work from. This was not presented in a sequential order, nor was there a step-by-step instruction list of how to tackle each stage of the problem. The only way students could successfully progress with the project was to make the most of in-class discussion and learn from their peers. Project phases were communicated to students using a broad design process; an adapted V-model [7] was developed to help students understand the project phases.

4 HYBRID ONLINE & STUDIO-BASED DELIVERY

The design studio had to conform to Covid-19 restrictions, which included vastly reduced capacity in a session (approximately 90 students) as well as safe spacing between desks and seats; in addition, all students and staff had to wear personal protective equipment. To work around the capacity restrictions, the cohort was broken up into multi-disciplinary teaching groups of approximately 30 students: with three groups working in the studio space during a single session. Each teaching group room had dedicated audio-visual (AV) equipment with teaching assistants to provide support. A minority of students were unable to attend classes in person, for example those who were unable to travel to the UK or were required to shield or self-isolate. Rather than create a separate online session, it was deemed more inclusive to run both in-person and online classes in parallel. The intention was to allow all students to feel part of the class; and get a better appreciation of activities and interactions happening in the rooms. The online collaboration room was accessible by all students in their respective teaching group- and a live feed was visible on the projector screen in each section of the studio. Teaching assistants could interact with both students in class and in the online room simultaneously. See Fig 3.

Figure 3. A design project team working collaboratively online and in-class

This hybrid method of delivery proved highly effective for the Engineers without Borders activity in which the larger teaching group was broken down into smaller groups of 4 students. Each group had their own online group space in which to collaborate, share files and complete a collaborative learning journal week-by-week to reflect on their understanding of the design process as an essential part of the PBL process. [8]. This delivery method was intended to be supplementary to on-campus teaching, with a contingency in place to run the class entirely online if required.

5 BEST LAID PLANS

The first five weeks of the unit were intended to be a great opportunity for students to socialize and work on an introductory design project, but with a spike in Covid-19 infections and students self-isolating, more and more students became reliant on accessing their learning through online collaboration rather than attending class in person. Class sizes dwindled until the fifth week, when groups were to present their work in class. The AV system in each class could allow students to able to present their work in class with some of their team members online; some groups presented their work entirely online-with students in and out of class sharing the same collective experience. Over time students who were self-isolating returned to class; but the onset of a second national lockdown made students return to their home domicile for the remainder of term. The engineering drawing content in the first few weeks of term proved particularly difficult to deliver online, not only as some students had not received their equipment in time for the start of class but also due to the constraints of online delivery. It was difficult for teachers and students to show their work onscreen and only a small minority of teachers had access to a visualizer. The start of the individual project required some reinforcement, as it was not clear to some students that the tools and techniques, they had learned in both their drawing practical and group design activities were meant to be directly applied in their project work. This highlights the key differences between Problem-Based Learning and traditional project-based learning. Many students demanded clearer instructions and wanted to be told exactly what to do from teachers, rather than discuss activities and learn, on a collective level, from their peers. The last two weeks of the term had to be delivered online as remaining students on campus returned to their homes before the Christmas break. The online delivery of CAD was somewhat more successful than drawing, as teachers and students had the ability to easily share their screens. Teachers could also take control of student's computers to access tools and features as also observed in the programming delivery in the second term. At the start of second term, and with the UK under another national lockdown, all classes had to be delivered online. This shift of in-class PBL delivery to online proved difficult. Each class had to be far more structured to promote discussion and it was difficult for students to interact in small groups. It was clear from student feedback that students did not enjoy the use of breakout rooms for online group discussions.

6 DISCUSSION

It is difficult to determine whether Problem-Based Learning was too much of a challenge for a first-year cohort under unprecedented circumstances. For Aalborg, the PBL approach is implemented throughout every year of study, albeit in a group context. Rather than individual projects, where students would have more reluctance to discuss and share their work with peers it is more likely a small group project, for example a team of 3 students in each discipline working on their own sub-system, would have been more appropriate-and more in line with the project-oriented approach. This is more difficult to achieve in practice, as there are not an equal number of students within each discipline to create balanced team-an alternative could have been to keep students in their small groups from the Engineers without Borders exercise. Had the unit been delivered asynchronously, there is a risk that students may have worked in isolation with limited class engagement or collaboration and the four learning principles as a strategy of the unit would remain unfulfilled. This may be an issue with aspects of hyflex teaching methods [9] which allow students to engage with content in an asynchronous online capacity-and thus does not facilitate collaborative learning in the same way. It was observed that some students who approached the project in this individualistic way made little progress, failed to attend class, or engage with formative exercises. They soon got very lost in what was going on and where they needed to be in the project. It was also evident that a significant number of students struggled, not only with the unit content but also external factors, but they struggled together. It is also evident that sketching and engineering drawing would have been more effective if delivered in class, as the introductory group design task could have been delivered completely online and achieved most of the same outcomes. It is another good example that some topics can be very difficult, if not impossible, to deliver effectively online, and

with drawing requiring the most physical interaction and observation, it should have taken priority for in-class teaching in the first 5 weeks. CAD and programming, being in the digital domain and operated solely via computers, naturally lend themselves to online delivery. The hybrid approach to online and in-class teaching proved to be successful-and has been noted in literature as a way of working in virtual teams with other universities [10]. In the context of this unit, it was a vital tool for students who were not on campus to engage in collaborative learning with their peers on campus-and be part of the collective learning experience.

7 CONCLUSION AND RECOMMENDATIONS

Delivering design and computing competencies via Problem-Based Learning may have been too high an expectation to be understood by all first-year engineering students, and it may be that a hybrid model of project and Problem-Based Learning may be more suitable to different learning styles-and offer a little more structure to students who need more instruction and self-direction. Two project contexts may also work-allowing students to experience both learning formats (e.g., a typical engineering product design project) rather than define the overall structure of a module or unit. Another outcome is not to see online and in-class teaching as two separate entities, and that a hybrid approach may be a vital component in making PBL a success in a blended learning environment that requires a high level of adaptability, such as collaborations between Universities or distance-learning modules. The student feedback from the unit was polarized, for some students it "*was the only unit to offer a form of socializing, created an environment to develop project skills and technical analysis"* and "*gain valuable learning experience by collaborating with others…"* Some students were also able to appreciate the context and scope of the unit, appreciating that "*the skills which are taught in these units are really intellectually stimulating and crucial for anyone wanting to pursue a career in engineering"* and understand the "*steps needed to create, design and test a system but in an educative way. Instead of just teaching us the steps, we got to apply the knowledge we were learning to a project*". However, it was clear that some students did not adapt well to this delivery model and needed to *"make it more clear what needs to be done"* with *" clearer and set instructions"* Whilst not suited to everyone, for some "*one good thing about this project is that it shows student[s] the steps needed to create, design and test a system but in an educative way. Instead of just teaching us the steps, we got to apply the knowledge we were learning to a project. Also, during the year, this project showed me how to go search, by myself, information needed for my project"*

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DESIGNING FOR EQUITY, ACCESSIBILITY, DIVERSITY AND INCLUSION IN AN UNDERGRAD INDUSTRIAL DESIGN COURSE

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ABSTRACT
Centred on Inclusive Pedagogy, a third year undergraduate course in 'Design for Health', at OCAD University has approached the pandemic as a problem-based learning opportunity. Through the implementation of a layered approach that included Critical Design pedagogy, students were encouraged to acknowledge their own position in the design process, challenge biases in health care, and examine the technical layers that surround products, services, and systems. The course implemented outcomes, activities and assessments that supported students to become critical, responsible, and inclusive industrial designers. At the same time, similar inclusive principles and a Universal Design for Learning approach became the pedagogical basis for this online course, where curricular barriers were removed to provide accessible learning opportunities to all students. Combining ethnography and observational methods to guide the work, students were encouraged to engage in diverse design applications that drive innovation, decrease systemic barriers, and increase access to health and wellness.

Keywords: Industrial design, design for health, responsible design, universal design for learning, intersectionality, oppression, AEIOU, Micro-Meso-Macro, design interactions and experiences

1 INTRODUCTION

Recent social and economic stressors have emphasized the need for new ways of thinking, questioning, and problem-framing through interconnectivity, interdependence, adaptation, and resilience, while creating awareness of socio-technical and cultural structures, bias, and barriers. This paper describes a course that implemented critical design pedagogical methods to achieve adaptability and empathy, promote resilience, and include diverse learners through the application of Universal Design for Learning principles - resulting in a layered approach to accessible curriculum design. This course aimed to analyse and reframe the questions: How would a more equitable, diverse, and sustainable post COVID-19 world look like? How can we teach in a more accessible way that values, celebrates and embraces diversity in the class?

The "Design for Health" studio course, is offered during the third of a four-year BDes Industrial Design programme at OCAD University, the largest Art & Design Institution in Canada. It is a studio format where students learn multiple theories, methods, and tools, and apply their knowledge and skills to the design of physical and digital products and services based on human factors and human-centred design. Offered during the pandemic, comprised of three sections with 25 students each, this course was facilitated fully online - a novel approach for studio learning in our institution.

The content was closely aligned with socially responsible design practice: "Design students work to provide a useful, enabling, and desirable product or service to those who are largely ignored by the market and /or other socio-cultural structures" [1]. Responsible design focuses its practices on those in need, who are overlooked, ignored, or otherwise underserved. This foundational knowledge is introduced, practiced and assessed while building up the formal, interactive, and aesthetic skills of undergraduate students in a university-level design education.

2 COURSE FRAMEWORKS

The "Design for Health" studio course materials were constructed around the following four frameworks to build students' understanding and analysing of 'socio-technical determinants of health'.

2.1 Social determinants of health model

Students were introduced to the social determinants of health through readings, lectures and data visualizations. Health is more than medical care. Research shows that medical care, genetics and biology account for only 33% of variance in factors that contribute to our health [2]. The biggest contributors are individual behaviours, social circumstances, environment, all of which include multiple variables that, the authors would argue, can be positively influenced through critical design method and interaction designs that foster accessibility, inclusion, behavioural, social and systemic changes.

2.2 Intersectionality and oppression

The present course based its work on the 'Theory of Oppression' developed by black female lawyer and activist Kimberley Crenshaw in 1998, and intersectionality, which refers to the social, economic, and political ways in which identity-based systems of oppression and privilege overlap and influence one another [3].

2.3 Micro-Meso-Macro framework

This ethnographic analysis tool from the social sciences allows for observation and dissemination of how everyday experiences affect people differently, based on the intersection of their gender, ethnicity, and economic status. This framework also facilitates the analysis of the three layers that surround and impact individuals, including experiencing systems of privilege and/or oppression- on the individual (micro)- social (meso) and cultural & institutional layers of our societies (macro) [4].

2.4 Activities, environments, interactions, objects, and users (AEIOU)

AEIOU [5] is an organizational framework that provides ethnographic analysis and synthesis methods for observational research. This framework prompts students /researchers to attend to, document, and code information under a guiding taxonomy to interpret results and apply to interaction design.

These four key frameworks were integrated into the teaching of product and industrial design methods, including human-centred design, human factors & affordances, and interaction & experience design. Frameworks and design theories were embedded in every aspect of the course including assignments, critique, in-class discussions and evaluation with the goal of increasing awareness and analysing the inherent biases and barriers that surround the way health care systems are constructed and experienced.

3 COURSE ASSIGNMENTS

The first assignments of the course built the basis of theories and methods that bridged into applied design approaches. Theories were integrated into activities that encouraged students to consider multiples perspectives during their design process. For the first half of the course, project assignments were completed in small groups to ensure students had the opportunity to practice their knowledge and skills with their peers in different contexts. This strategy was also part of an overall scaffolded approach to prepare students for the self-directed work completed at the end of the term.

One of the group assignments invited the class to describe and share selected experiences living in the pandemic. Students described several interactions such as getting a COVID-19 test, self-isolating in a family setting, grieving, or remote learning. This exercise aimed to centre the pandemic as the main context for the course, start to build community within the online studio classroom, and focus on individual lived experiences as the starting point of the learning process. Given the diversity of the classroom, students faced multiple identities, which in turn shaped their experiences with health care and the educational system. These reflections were further described and analysed using the AEIOU observational research framework, which helped students to identify different pain points, including systemic social-technical issues, and to frame opportunities for user-centred design interventions.

In addition, students individually plotted their intersectional identities into a Wheel of Oppression diagram [6]. A voluntary and anonymous class poll identified at least 10 dimensions on the chart where students self-identified as oppressed. These series of exercises meant to highlight the impact of socio-technical factors on different contexts and scenarios.

One more example is the bandage assignment. This group project asked students to analyse and visualize the interactions and touchpoints between two users during the process of applying a bandage to a cut wound. The users within the scenarios were purposefully selected with diverse gender and ethnic power imbalances to emphasize potential of different experiences. In this assignment, students were introduced to the Micro-Meso-Macro framework to map the interactions between people and assess their perceived barriers and pain points. Figure 1 shows how students integrated these three layers and combined them with the AEIOU framework to map out a user journey and visualize systems of oppression. Through this exercise, students further uncovered that a seemingly simple product such as a bandage is not neutral but holds systems of oppression in its design and materiality. Most bandages are matched to a white person's colour tone and visually represent how white supremacy looks when placed on the wound of a person of colour - acting as a double injury for the user: the accident itself (physical) as well as racism and oppression at large (emotional and mental factors). This critical and analytical approach shifted the design framework of problem solving to enquiring about the surrounding social, cultural and political mechanisms first [7].

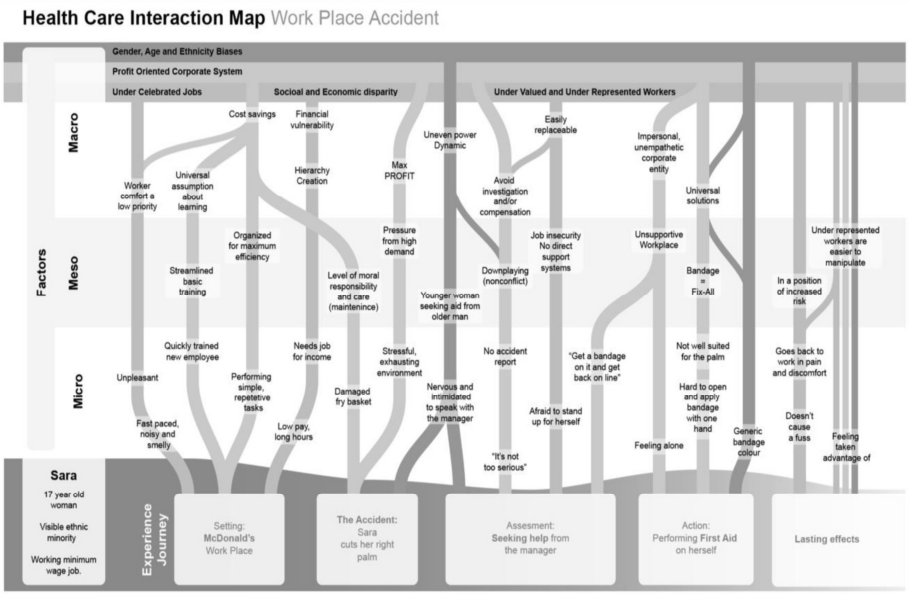

Figure 1. Student example of Bandage assignment. Interactions while integrating Micro-Meso & Macro layers

In the second half of the course, students embarked on a self-directed six-week project, themed around COVID-19, in which they applied all learned knowledge and skills to design a physical or digital product, service or system that found new opportunities to enhance health care for diverse communities during and after the pandemic. Although the work was independent, students were encouraged to continue consultations with their peers to bring different perspectives and considerations. Final projects were inclusive, accessible, and innovative with products to support intimacy at home, apps and connecting services to enhance access to mental health resources, systems to improve safety COVID-19 measures in airports, or communication platforms for food sharing initiatives, to name a few.

At the end of the course, to optimize authenticity and engagement, the course instructor invited students to self-organize a public online showcase as part of an international design event "Design TO Festival", in January 2021. The opportunity to participate in this exhibition brought higher value and relevance to students' work as they had the chance to share their projects, learn from other designers and familiarize themselves with the international "design scene". Students proposed and discussed award winning products and app solutions that contribute, through design, to a more diverse and equitable approach to health, mental health and beyond – demonstrating that we can get there.

4 UNIVERSAL DESIGN FOR LEARNING (UDL)

This studio course aimed to bring awareness of the impact of diversity and oppression into the design process through relevant theories and methods, but also with the implementation of an inclusive pedagogy that values diversity and creates a respectful and collaborative space. Since the initial design of the course, principles from UDL were incorporated into the syllabus. The UDL framework [8] acknowledges and values the vast differences in learners' interests as well as the way in which they perceive and process information, relate to the learning environment and show new knowledge. UDL supports all students to become purposeful and motivated, resourceful and knowledgeable, strategic and goal directed. UDL has three main principles that guide its application: multiple means of (a) engagement, (b) representation, and (c) action and expression. Table 1 lists how the UDL framework was applied.

Table 1. Examples of the application of UDL in the current course

UDL Principles	Description	Applications in the course
Multiple means of engagement	Multiple means to engage students and sustain their motivation and interest in the curriculum	● Integration of lived experiences into the learning process ● Choices on presentation dates and assignment topics ● Visual maps to structure the course ● Opportunities to build community through weekly group work and voluntary peer studio spaces ● Participation in international design event 'Design TO Festival'
Multiple means of representation	Multiple means to present information that supports and values diversity in the classroom, such as different language skills, cultures, learning preferences, abilities, or previous knowledge	● Presentation of content in diverse ways (e.g., videos, text, graphics) ● Diverse guest speakers bringing in multiple perspectives of health/ medical/ anthropological approaches ● Synchronous lectures recorded ● Connections with other disciplines ● Translation of theories, methods, and tools into the product design context ● Guidelines to support respectful peer critiques, and collaborative group work
Multiple means of action and expression	Multiple opportunities for students to navigate the course and demonstrate their knowledge	● Student demonstration of knowledge in multiple ways (e.g., choice of written documents, mind maps, oral and visual presentations, or videos to meet outcomes) ● Video to share the course structure, clarify roles and responsibilities, and provide suggestions to navigate the course ● Discussions about metacognition (to help students know themselves as learners, acquire new learning skills, and plan, monitor and assess their own learning strategies)

5 STUDENT FEEDBACK

Student feedback was gathered through a survey that students completed at the end of the course, which included questions on students' self-perceived acquisition of critical thinking and creativity skills, identification of the most helpful assignment, the most effective learning strategies, and challenges

within the course. This questionnaire encouraged students to reflect on their own learning journey, and it helped the instructor identify successes and challenges in the course. The questionnaire was completed by approximately 80% of the students. Since this activity was not designed as a research tool, it was not possible to complete a comprehensive qualitative data analysis in the current pilot. However, in the upcoming second iteration of the course, the authors are planning to incorporate qualitative and quantitative methods to critically assess the different components of the course.

When asked to identify the most helpful assignment, several students mentioned the Bandage project. Students described it as "impactful" as it helped them identify how social constructs and theories influence different scenarios. Students also appreciated many aspects of the final assignment (i.e., COVID-19 individual design project), in particular the appreciation of intersectionality, oppression, and accessibility during the prototyping phase. With regards to pedagogy, several students valued the inclusion of visualization tools to communicate information in more direct and accessible ways. Many students mentioned that they will be adopting these tools into their future practice. Finally, students explicitly highlighted how much they appreciated and learned through group work and peer studio spaces. They specifically mentioned how collaboration helped them navigate the course (especially in an online format), engage in critical analysis, learn from peers and stay accountable for the progress.

6 LAYERED APPROACHES TO ACCESSIBLE COURSE DESIGN

Figure 2 showcases our recommendations to create an accessible course that combines Critical Design, UDL and online teaching and learning best practices. The upper four layers in blue can be considered when designing an accessible learning environment for students, regardless of course content. The green layer at the bottom describes the course content, which can be adapted to multiple design courses. The red layer indicates access to physical facilities that were not possible during the pandemic but remain crucial for design studio practices.

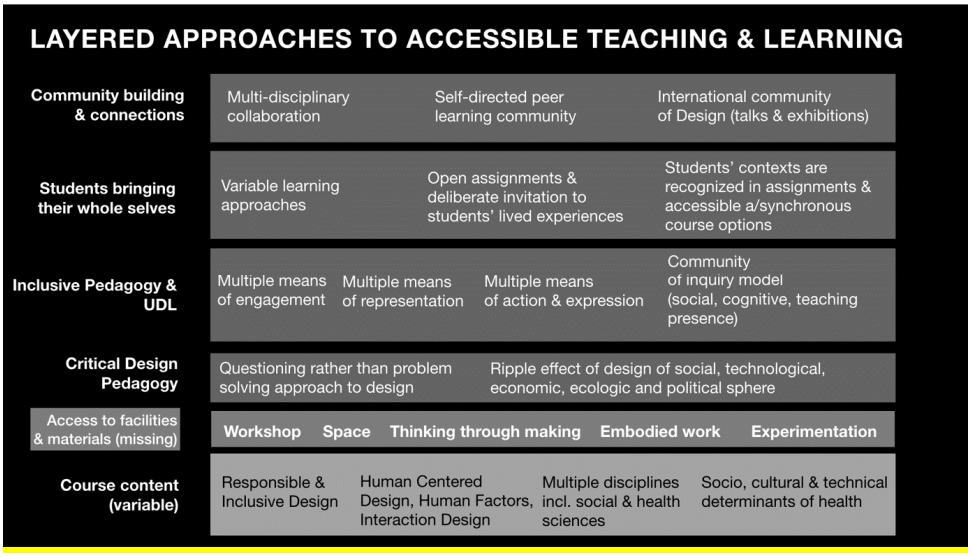

Figure 2. Diagram showing the layered approach to accessible teaching & learning

7 REFLECTION/CONCLUSION

Situating this course content within the COVID-19 pandemic provided the context for the Design for Health course and allowed students to reflect on their own experiences. This approach helped students and faculty recognize the diversity of desirable interactions and outcomes through the understanding of socio-technical and cultural systems. This course applied critical design pedagogy to mentor responsible designers to become aware of systems of oppression when they design products, services and systems. Equally as important, the same principles were used to facilitate the course and provide accessibility and opportunities to all learners. We hope that these approaches helped students design a more equitable,

diverse, and sustainable post COVID-19 world, in a classroom where they felt respected, valued and empowered to continue their long-life learning. We aspire to contribute to a broad design curriculum that develops students' critical skills to become self-directed learners and responsible designers while opening the practice to new mindsets.

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TAKE BACK CONTROL OF YOUR TIME: DESIGN ACTIVITY FOR REFLECTING ON TIME AND TIMEKEEPING PRACTICES

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ABSTRACT
This paper reports on the procedure and the results of a design activity carried out to reflect on time and timekeeping practices. The design activity involved a diary study followed by an idea generation workshop in the scope of a graduate level course with the participation of 12 graduate level industrial design students. The paper first explains the procedure of the design activity. Then, it presents the outcomes under two themes: i) timekeeping related insights: the students' reflections on their timekeeping practices and ideas on how to improve these practices to support wellbeing; ii) pedagogical insights: students' thoughts and instructors' reflections on the online diary-keeping and conducting the workshop remotely. The findings are believed to be beneficial for inspiring designers interested in designing interventions to support better time management practices; and for design educators interested in conducting remote diary study and/or workshop in distance education settings.

Keywords: Product design, timekeeping, online diary, wellbeing

1 INTRODUCTION

Time is precious and one of the most valuable resources we have. It is often perceived as a resource that should be utilized or managed. How we plan and spend our time has a direct impact on our wellbeing. Challenging the traditional definitions of time [1] (e.g., time as a measure for productivity), rethinking chronobiological knowledge [2], devising new representations of time (e.g., using cycles of moon to illustrate time [3], and redefining time as a social coordination tool [4] are required to better understand time as a concept that we inherently experience in our daily lives, and to support better time management practices. The impact of time management practices on wellbeing is prevalent in educational contexts. For university students, time-related demands such as high workload, time pressure, and the challenge of self-organized learning are associated with elevated stress levels [5], but better time management practices are known to decrease the perceived stress [6]. The pressure put by such demands on students' wellbeing has been recently increased by the COVID-19 pandemic, as it led to a 'forced' transition towards engaging in remote learning practices. Hence, understanding students' experiences with their time management is crucial to create possible interventions that would support their wellbeing during and post-pandemic times.

This paper reports on the procedure and the results of a design activity to reflect on time and timekeeping practices of university students with the following objectives: i) to explore how students' relationship with time has changed during the pandemic, and ii) to identify design opportunities and to ideate on potential routes for supporting 'good' time keeping practices that would bring positive impact on students' wellbeing. The design activity involved a diary study followed by an idea generation workshop in the scope of a graduate-level course at Middle East Technical University with the participation of 12 graduate level industrial design students, who all had industrial design background but completed their undergraduate studies at various universities. In the diary study, the students individually reflected on their time management and timekeeping habits during COVID-19 by filling in an online diary. They were asked to answer the following questions: 'Where does the work-life end, where does private life begin? How can we manage the boundaries between work time/non-work time in which the way we work, relax, and socialize have drastically changed due to the COVID-19 pandemic? Do we have control over our time? To which conflicts and tensions do our lack of control of our time lead?' Then, in the

idea generation workshop, the students reflected on their perceptions of time and time management practices in groups and generated initial design proposals for supporting good practices.
Accordingly, the paper first explains the procedure of the design activity. Then, it presents the outcomes under two themes: i) timekeeping related insights: the students' reflections on their timekeeping practices and their ideas on how to improve these practices to support wellbeing; ii) pedagogical insights: students' thoughts and instructors' reflections on the methodological approach of conducting the diary study and the workshop remotely. The findings are believed to be beneficial for inspiring designers interested in designing interventions to support better time management practices; and for design educators interested in conducting remote diary study and/or workshop in distance education settings.

2 DESIGN ACTIVITY

The design activity was conducted in the context of a graduate-level course titled "Design for Sports, Health and Wellbeing". All students, who enrolled into the course, participated in design activity. The design activity was to enhance the students' understanding of wellbeing and to provide a starting point for the following phase of the course, in which students were asked to develop design concepts that improve wellbeing. The activity was carried out synchronously in two four-hour-sessions over Zoom. The sessions ran with a week apart. A general class discussion about time, time-management practices, and how COVID-19 impacted such practices, is carried out in the first session. Then, the students were introduced to the aim of the design activity. This was followed by a detailed presentation of the templates prepared for the students to fill in online. In the following six days, each student was asked to fill in their online diaries individually and asynchronously. In the second session, working in groups, the students generated proposals for supporting good timekeeping practices based on their input in the online diary. The following sections elaborate on both sessions.

2.1 Diary-Keeping

A six-day-long diary was devised to reflect on students' current understanding of time, and each day of the diary was specifically designed to challenge a unique concept of time (e.g., control of schedules, negotiation of time, right moments). The students were provided with an online Miro board space to individually fill in their diaries on the pre-prepared templates for six consecutive days. They filled in the templates by responding to set task(s). They were encouraged to take photos, videos, write notes, doodle etc. while reflecting on the certain aspects of 'time'. As a general approach, each day, the students were asked to record their timekeeping practices (any window throughout the day) and then to reflect on the recorded information (at the end of the day). For example, in day four, they were asked to reflect on their weekly schedules by visualizing the mismatches between "expected" and "real" durations of the calendar activities (e.g., meetings, shopping, online classes, etc.) that they allocated as time slots. The tasks in the templates were purposefully designed for quick reflections expected to take no more than 15 minutes a day. For example, in day one of the diary, one of the starting tasks was "name a favourite moment" followed up with a question asking, "what makes it a favourite moment?". Breakdown of the six days of the diary with their specific aims, tasks to be completed and a representative image from template(s) can be seen in Figure 1.

2.2 Idea Generation Workshop

In the idea generation workshop, students were divided into four groups of three. Groups were assigned to a new Miro board consisting of templates to facilitate the process (see Figure 2 for an example). To carry out the group activity, they were assigned to a Zoom Breakout Room (i.e., a feature in Zoom to help group of people to have a private chat), and regularly visited by the course instructors. The workshop was carried out in three steps: i) problem identification, ii) ideation, iii) discussion and reflection. In the first step, students were asked to share their diary entries with other group members. After all group members studied and briefly discussed each other's diaries, their collective reflections and problems identified in the diary study served as trigger to formulate a design problem. In the second step, they created a "How Might We" (HMW) question regarding this problem and generated multiple ideas. Then, they were asked to reduce the ideas into one and develop a user scenario of the selected idea. In the final step, all groups were invited to the Zoom main room to present their ideas. The groups also gave feedback to others' ideas and offered reflections on the workshop process.

3 INSIGHTS DERIVED FROM THE DESIGN ACTIVITY

The design activity was analysed to reveal insights for solutions that support future timekeeping practices, as well as carrying out similar future activities in an educational setting. Quantitative analysis was not considered appropriate or necessary for the objectives at hand. The outcomes of the design activity (i.e., online diary entries and the design proposals) reviewed with an eye to find out whether there were any repeating themes across time checking practices, intersections, and ways of experiencing time. Diary activities also uncovered several issues pertaining to students' timekeeping practices which provided both students and instructors with insights into the topic. Course instructors reflected on their observations during the design activity and gathered them as insights on using online collaboration tools, online diary keeping and time management of the activity. Two themes were identified as a result: timekeeping related insights and pedagogical insights.

3.1 Timekeeping-related Insights

Timekeeping related insights were grouped under three sub-themes: fractured time checking practices, intersections of the schedules and activities, and ways of experiencing the progression of time.

3.1.1 Fractured Time Checking Practices

Student diaries revealed that current digital and/or app-based timekeeping technologies such as digital clocks and calendars, do not fully cover the richness of subjective perception of time. Some students expressed that checking time may sometimes cause stress, anxiety and even trigger negative feelings whilst interacting with such technologies. Besides, they mentioned that clocks/watches that represent time in numbers, minutes, and hours do not reflect on how and when to check time. The numerical representations of time often fail to capture the notion of "experiencing time as a whole" resulting in fractured time checking practices (e.g., looking at a clock but not perceiving anything meaningful or abandoning the digital calendars due to their overloaded content). Therefore, new ways of representing the concept of time are necessary to better grasp the notion of time checking, and to activate positive thoughts while checking time. In this respect, timekeeping technologies can make use of (personalized) "things" that are meaningful for that user. For example, several design proposals mentioned 'daily life activities' as new means of representing time (e.g., using coffee preparation process to visualize time). Accordingly, the students proposed that seeing upcoming events on a clock represented through new interactions (e.g., audial feedback, smell of something pleasurable) would be less stressful and enjoyable than just seeing the numbers on a clock.

3.1.2 Intersections of the Schedules and Activities

The main findings in this category can be summarized as: distinction between work and leisure time has been getting fuzzy; work time has been transforming into something that is extensively long and overwhelming; and leisure time is gradually disappearing that results in accumulation of negative emotions towards time. For example, while some students mentioned the problems, they face due to overwhelming work time (e.g., going into "depression sleep"), others raised the importance of equally valuing the leisure time with work time. Overall, students emphasized that current work time allocations are slot-based and that experiencing time through these slots (e.g., work time between 9:00-5:00 or meeting in 1:30 hours) causes negative emotions towards their perception of time. To address this problem, the students suggested rethinking timekeeping tools as smart agents. The calendar was given as an example to take an initiative and better communicate with its user, for example by indicating: "Hey John, you were checking out ... and I see an open slot, maybe you can book for this slot?". They indicated that such a solution would help them take back the control of time, which they have lost due to intersections between work and leisure related activities.

3.1.3 Ways of Experiencing the Progression of Time

As expressed in the students' diaries, timekeeping technologies (e.g., mobile phone apps that track task efficiencies based on timers) are not fully integrated into our lives. The students mentioned the necessity of experiencing the progression of time through new ways. Several students argued that technologies do not follow a natural cycle (e.g., waking up with the sunrise), for example they may need to wake up before the sunrise (to go to work or to attend a class). This makes them feel like they are no longer in control of their time. Natural cycles (e.g., growth of a plant) and daily life practices (e.g., going into a meeting) can be merged for better experiencing the progression of time. For example, several students

mentioned using 'light' as a way of experiencing this progression, by emphasizing the concepts such as a clock that gets darker when the day and the night is approaching. Also, the progression of time can be represented through non-circular and non-repetitive clock designs. For example, "Tetris" can be an example for using it as a metaphor for illustrating the progression in activities. Lastly, students focused on "having an ability to be in the conversation" with timekeeping technologies as a way for better grasping the notion of progression.

3.1.4 Students' Initial Design Proposals for Supporting Time Management Practices

In the idea generation workshop, all four groups focused on different aspects of timekeeping related problems, and generated ideas responding to improved ways of spending time, meaningful representations for timekeeping achieved through the use technologies, and better ways of keeping control of the time. A brief description of the groups' proposals are as follows:

- Group 1: An activity-based calendar app that learns and adapts itself according to users' preferences. The app prioritizes the sequential activities and offers new ones based on the user's busyness level so that a more natural and uninterrupted schedule can be achieved.
- Group 2: A wellness assistant that aims to raise awareness for spending time more consciously. Whilst performing long tasks, the assistant tries to catch the user's attention by probing them with pop-up messages, and encourage them to give a break, then provides feedback on their use of time.
- Group 3: A smart watch coupled with a phone app to support better sleep times. The system learns the user's music taste and play songs in the right moments to signal the time to sleep/wake up.
- Group 4: A journal that contains several digital components to nudge its users to start a task. This was aimed to trigger the user's motivation to initiate a task with a reward system.

3.2 Pedagogical Insights

On the completion of the idea generation workshop, a questionnaire, consisting of several open-ended questions, were distributed to the students to gather their feedback regarding the design activity. They were specifically asked the usefulness of the diary-keeping; how they made use of their diary entries during the idea generation workshop; and whether they would like to advice any improvements. Their answers show that diary activities enabled them to better realize their time perception, the mismatches between what they might have planned and what they ended up doing during the day. Most students mentioned that diary-keeping was useful to identify problems relevant to idea generation workshop. However, some students mentioned their struggle to fill in the diary using an online platform, as it required carrying a device such as a laptop with them. Consequently, some students took their notes on paper sheets to be transferred into Miro later in the day. Finally, expressing themselves through photos and drawings found to be enjoyable and facilitated to convey students' thoughts and ideas regarding their conceptualization of time and time-related daily practices.

3.2.1 Simultaneous Use of Zoom and Miro Programmes

The idea generation session was conducted over Miro, partly synchronously (together with Zoom) and partly asynchronously (filling in diaries outside the class hours). However, during the class hours, Zoom and Miro were used simultaneously and collaboratively, which enabled group members to carry out their discussions on Zoom, while visualizing their ideas on Miro boards. Moreover, allocating breakout rooms for each group during the session helped students to keep their focus on their own task since they did not get distracted by other groups' conversations and shared their screen without interrupting the others. In summary, combining Zoom and Miro in the design activity was useful in terms of engaging students in idea generation tasks while maintaining the communication between different groups and instructors.

3.2.2 Online vs Paper Based Diary-Keeping

From the instructors' point of view, the main advantage of an online diary was to monitor students' progress on diary entries, which would otherwise have been difficult in paper-based ones. It was observed that some students preferred to make daily entries to their diaries, while some preferred to fill in every 2-3 days. This was due to some students' preference of taking notes on paper throughout the day and transfer them onto the Miro boards later in the day. Besides, the online diary gave the students a chance to express themselves in various ways using a combination of digital media including photos, clipart, and drawings (see Figure 3). Only diary-keeping through Miro supported the integration of sound, videos and gifs which otherwise can be difficult in paper-based versions. In the context of idea

generation workshop, completing the diary entries online supported students to transfer their ideas and thoughts quickly (using the copy-paste feature), onto the group idea generation boards and templates without having a need to reproduce the same content. Miro allowed the content to be managed and presented through a single platform, which enabled students to use their time efficiently.

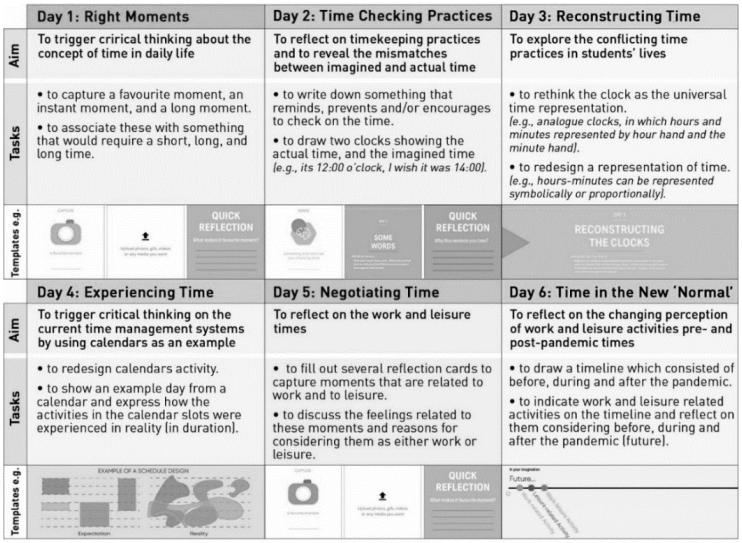

Figure 1. Aims, tasks to be completed, and example visuals from templates across the six diary days

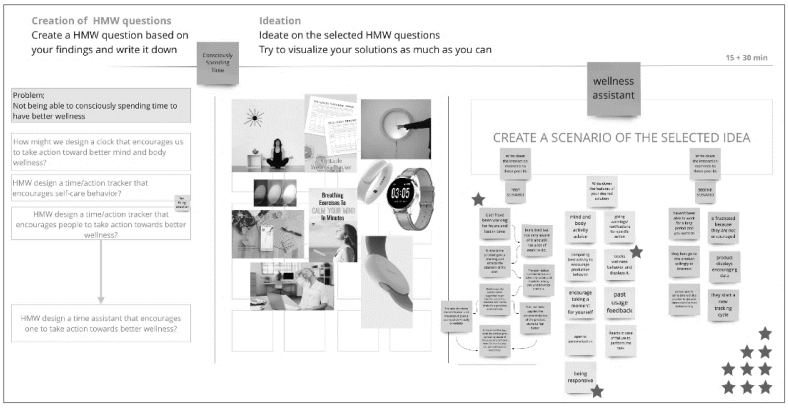

Figure 2. An example from a Miro board template filled in during the idea generation workshop

3.2.3 Time Management of the Idea Generation Workshop

The idea generation workshop was structured to provide flexibility to students and to balance online and offline activities. For example, the diary activities were designed to create an offline free time-space for students, and in-class activities (e.g., idea generation session) were designed to compile and have focused sessions. During in-class activities, apart from when it was necessary to brief the entire class, the students were provided with flexible time arrangement by means of dividing class hours with group activities, creating break-out rooms in Zoom, and having multiple breaks. This was thought to be necessary during an online education setting, where everybody stays in front of a computer screen for long hours even without noticing. The instructors observed that balancing online and offline activities and giving regular breaks in Zoom helped to keep the students' engagement high. This was confirmed

by the questionnaire, administered to the students at the end of the semester to evaluate (anonymously) the different aspects of the course, including workshop. They were asked to rate (over 3-point Likert scale) whether they found the time and effort allocated for the workshop activities 'too much', 'just right' or 'too little'. Apart from one student, who commented that the time spent for diary-keeping in preparation for the workshop was 'too much', the remainder found it 'just right'.

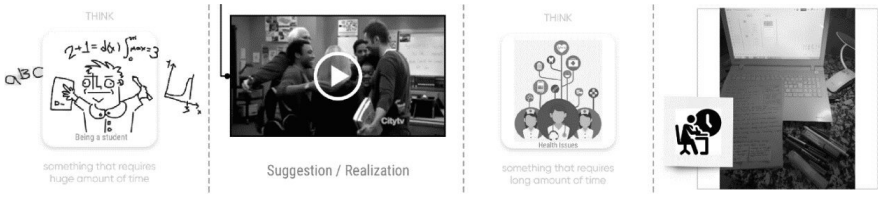

Figure 3. Examples of a drawing, a video, a stock image, and a captured image

4 CONCLUSIONS

This paper examined students' timekeeping and time management practices, and ways of supporting these practices with the help of a design activity (i.e., the combination of an online diary-keeping and a collaborative idea generation workshop) carried out with 12 graduate industrial design students. Insights gained to uncover: i) existing timekeeping tools fail to address fractured timekeeping practices as well as help understand the progressive nature of time, and ii) the intersections between work and leisure time blur the boundaries between the two and create a pressure on wellbeing through triggering negative emotions like anxiety. Furthermore, an activity organized in an educational setting integrating the dynamics of working individually/in a group, online/offline, and synchronously/ asynchronously together, helped to make useful observations for future set-ups. This diversity in task structures observed to be helpful for students to perform the tasks in their own pace (e.g., filling in the diaries outside the focused sessions) and stay focused on the task at hand while collaborating with others. Time and wellbeing are intertwined. This paper provided initial problem spaces that are related with timekeeping practices, we plan to further explore insights that are gained from graduate students. Besides, design activities showed the necessity of reflecting to the existing design course curricula for online education. We will utilize the insights related to this issue and will integrate in the future courses. In times of uncertainty, as the recent pandemic showed, the significance of better time-management practices for increased wellbeing becomes even more prominent. This paper was an effort to contribute to understand this relation from the perspective of university students and in an educational setting. The ideas generated during the design activity were also found be inspirational and diverse, helping to define ways to support timekeeping practices.

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INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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PROTOTYPING REMOTELY TOGETHER WITH 2D, 3D AND IMMERSIVE VIRTUAL REALITY DESIGN TOOLS

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ABSTRACT
The 2020 pandemic demanded changes to design education from in-person to distant and hybrid learning and accelerated the use of new technologies in both design education and professional working methods. In this new paradigm, how do we re-engage studio-like interactions, collaborative making and co-design strategies? This preliminary study, with 25 midwestern US industrial design students, adds to previous research on designing with 2D and 3D digital desktop tools versus immersive virtual reality when co-designing prototypes. The results showed a measurable difference in the quantity of prototypes favouring digital desktop design tools, but a negligible difference in the quality of prototypes even with little experience with immersive virtual reality tools. This study suggests a need to integrate immersive virtual reality in earlier design education as more experience may lead to further advantages and design results.

Keywords: Prototyping, immersive virtual reality, distant learning

1 INTRODUCTION

The COVID-19 pandemic has accelerated trends that were anticipated to take years to mere months. Directly, this is on top of the exponential trends in digital technology transformation already identified around workforce [1] and learning [2]. Due to the pandemic, online teaching and learning had to rapidly develop in different contexts, often situated at different locations at a distance which impacted studio-like in-person learning. There are studies that distance diminishes engagement between peers, instructors and also the important corporeal material in design amongst others [3, 4, 5]. As a designer, the studio environment is considered to provide a rich multi-modal engagement for communication and the making process. Preparing students to thrive in these distant interactions and then their digital advancing professional domains becomes a cornerstone for today's pedagogy.

A previous pilot on immersive virtual reality (IVR) among design students indicates the potential for divergent thinking and creativity [6] when using IVR to design. We believe it is critical to include mediated embodied experience in distant design education. Our aim is to explore when students co-design prototypes in IVR compared to other distant desktop solutions. Co-design is a collaborative way of approaching the design process, including designers and/or other relevant actors that do not have design experience in the process [7]. In this article we approach co-design as design students collaborating in the early phase of the design process, during idea generation and early prototyping.

This research sets out to answer the question, what are the differences and similarities between 2D and 3D design tools when co-designing prototypes in an immersive virtual reality collaborative environment, compared to distant desktop solutions.

This preliminary study is conducted in a university setting with about 25 industrial design students. We surveyed students' pre-knowledge about 2D, 3D and virtual reality design tools, then evaluated their co-designed prototypes and analysed their reflections on these experiences.

2 RELATED RESEARCH

The related research was sparse when searching for "product design" or "industrial design" with "design pedagogy" and "VR" (Virtual Reality). The product design string returned (37) results and the industrial design string returned (44) results.

Reviewing these returns relevant to this study narrowed the references to seven. This points to a rich area of design research and advancement in the near term, as well as methods for understanding and evaluating design in IVR and related technologies. Recent advances in consumer IVR technologies have likely contributed to this lack of research. The Oculus Rift, the first generation of consumer IVR headsets on the market was released in 2016 and still required an attached computer with a capable video card to run the IVR software. And the Oculus Quest, the first consumer IVR headset without requiring a computer with adequate graphics capability to run IVR software for design, came out in 2019.

While the existing research is sparse, it is also inspiring to see work being done with this new capability. Price, et al. [8] highlight the paradigm shift from "seeing" (more visual approach) to "feeling" (holistic, embodied respecting the sensing body) with IVR as one of the driving technologies. Mitchell, et al. [9] conclude this type of experiential instruction enhances the construction of meaning and improves applications of touch across digital (virtual) and physical design. Camba, Soler, and Contero [10] bring forward IVR as being used as a catalyst for integrated collaborative student work. The studies by Ozgen, Afacan, and Surer [11], conclude that IVR was a valid tool where the enjoyability and intention could be indicating reduced cognitive load, increased student engagement, and made learning easy, concrete and enjoyable. Gero and Milovanovic [12] connect AR or IVR with design that can technically be accomplished through Eye tracking, electrodermal activity (EDA), ECG and emotion tracking and hand tracking. The reviewed article points more toward future work in design education. Cindioğlu's study [13] indicates beginning architecture students in mixed-reality (MR) are more responsive and less fixated in MR, where changes seemed less consequential, than in the real world. In addition to the driving pilot study by Lee, Sun, and Yang [14], these authors all connect emerging technologies such as IVR to an increased understanding in design and engineering disciplines, where students showed reduced cognitive loads and improved divergent thinking.

3 METHODS

The project goal is to explore the role of IVR in the early phase of the design process using consumer IVR headsets and software when co-designing prototypes.

The study began with an online survey Technology Familiarity Assessment (TFA). This gauged the students' general knowledge of 2D and 3D design tools and their exposure to IVR prior to the study.

Then, twenty-five university industrial design students were divided into two main teams, A and B. Teams are determined by most diverse partnerships as possible. On the first rotation, Team A was provided IVR headsets and Rumii software and Team B used general digital desktop equivalent software, Topia for audio/video communication and Google Jamboard for co-design collaboration. Both teams were assigned the same design challenge and ideated and prototyped designs over two class sessions (40 minutes each). Pictures were captured of Team A, the IVR group, while producing each design prototype session. Team B, the NonVR group submitted PDFs of their online work during each co-design prototyping session. Both teams also submitted self-reflection documents of their co-design prototyping session. Then the teams rotated roles. Then the study was repeated and both teams were assigned a similar but new design challenge and ideated and prototyped designs over two class sessions (40 minutes each). Both teams also submitted self-reflection documents of their co-design prototyping session.

The design assignments in this study were based on principles derived from Heidi Hayes Jacobs [15] who articulates embodied learning interactions actualized in practice by Rosan Bosch Studio (2018) around metaphors of mountain top, cave, campfire, watering hole, hands-on and movement [16]. For example, one assignment revolved around the metaphor "Mountain Top." This metaphor acted as the design brief for the students where they designed *a place to stand* and *a light*.

The prototypes made by the two teams were then evaluated. Each prototype was evaluated based on four primary aspects: 1) quantity of prototypes, 2) quality of prototypes, 3) co-design interaction and 4) novelty of solutions. Two of these aspects, the quality and novelty aspects were rated on a 10-point scale by four

expert raters–instructors/professionals in design including the teacher–and then analysed, modelled on the Consensual Assessment Technique (CAT) by T. M. Amabile in 1982 where expert raters independently evaluate aspects of a product's creativity [17] similar to a sporting judge panel reviewing their sporting event.

4 RESULTS

The initial online Technology Familiarity Assessment (TFA), completed at the beginning of the study, is shown in Figure 1. There were three primary areas of assessment: (1) Students' use of 2D design tools, their favourite top three and how they rated themselves as beginner, intermediate or advanced in their use of these 2D tools; (2) Students' use of 3D design tools, their favourite top three and how they rated themselves as beginner, intermediate or advanced in their use of these 3D tools; and (3) Students' experience with IVR, how many hours they had spent in IVR, and if they owned a consumer IVR headset.

AREA OF ASSESSMENT 1					
1ST 2D tool		2ND 2D tool		3RD 2D tool	
Photoshop	7	Illustrator	4	Indesign	2
Sketchbook	1	AutoCAD	1	Adobe XD	1
Indesign	7	Procreate	2	Illustrator	5
Adobe CC	1	AAE	1	Photoshop	3
Illustrator	2	Adobe Sketch	1	Sketchbook	1
Clip Studio	1	Indesign	3		
		Photoshop	2	Advanced	0
Advanced	5	FCP	1	Intermediate	8
Intermediate	14	Keyshot	1	Beginner	6
Beginner	0			N=	14
N=	19	Advanced	2		
		Intermediate	12		
		Beginner	4		
		N=	18		

AREA OF ASSESSMENT 2					
1ST 3D tool		2ND 3D tool		3RD 3D tool	
Solidworks	16	Keyshot	8	AutoCAD	1
Keyshot	3	Fusion360	1	Shapr3D	1
		Blender	2	Inventor	1
Advanced	4	Solidworks	3	Masterpiece VR	1
Intermediate	12	PhotoView 360	1	Minecraft	1
Beginner	3	Rhino	1	Fusion3D	2
N=	19	Inventor	1	Keyshot	1
		3DS Max	1	Blender	1
		Advanced	2	Advanced	0
		Intermediate	10	Intermediate	3
		Beginner	6	Beginner	6
		N=	18	N=	9

AREA OF ASSESSMENT AREA 3			
VR Experience			
A Great Deal	1		
A moderate amount	3		
A little	10		
None at all	6		
Ownership(N=20)	2		
		HRS	#
Sum	214	0	6
Avg	10.7	1 to 5	9
Min	0	10 to 15	1
Max	50	20	1
Count	20	50	3
		N=	20

Figure 1. Student responses to TFA survey showing their top 2D and 3D digital design tools and IVR experiences prior to study

Figure 2 compares student responses in the first two areas of assessment, (1) Students' use of 2D design tools and (2) Students' use of 3D design tools. The figure shows students indicated a lower knowledge and experience with 3D digital design tools as compared to their knowledge and experience with 2D digital design tools. Responses in the third area of assessment about VR experience which is not shown in Figure 2 but noted in Figure 1, indicates 80% responded with "None at all" or "A little" experience with IVR technology and only 10% responded that they own their own headset.

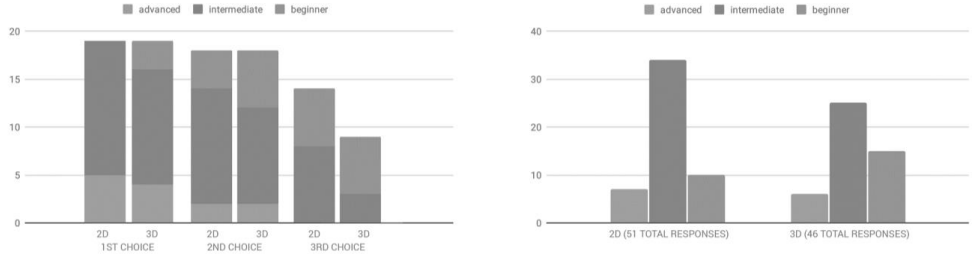

Figure 2. A comparison of the TFA data showing top 3 2D/3D digital design tools used by students (on left) and a comparison of total responses (on right). In both cases, students self-report their perceived ability with these tools

In evaluating the data, the quantity of prototypes showed a clear result favouring NonVR prototyping versus IVR prototyping. Out of a total of 50 prototypes, which were distinguished as unique ideas, 40 were NonVR prototypes. The prototypes were also evaluated to be one of four typologies: (1) low aesthetic, (2) high aesthetic, (3) low function, or (4) high function [18]. 60% of evaluations found the prototypes to be "low

aesthetic" out of all for typologies. Then when comparing the aesthetic categories to the functional categories, responses showed approximately 75% of evaluations rating the prototypes "aesthetic" versus "functional." This aligns with the students in this study coming from an industrial design background versus an engineering background where functional attributes might appear more often than in industrial design.
A more nuanced evaluation of four additional aspects of the prototypes included, (1) response to the design brief, (2) appropriate use of scale, shape, colour and form as an early phase design task, (3) technical quality of the prototype, and (4) novelty. These four aspects were rated 0-10 with 0 being "worst" and 10 being "best". Across all four questions, a composite (across teams) the NonVR prototypes average scored 1.1 higher than a composite (across teams) IVR prototype. Prototype results also evaluated better (within teams) in NonVR than they did in IVR (within teams) by an average of 1.1. However, it is notable that in a sum by totalling scores across the prototypes, the highest score was a prototype completed in IVR (127) with two NonVR prototypes very close behind (121, 123). These scores indicate both modes can perform well but also indicate a negligible difference between IVR and NonVR.
The reflections around the IVR and NonVR prototyping provided individual feedback for insights into the co-design aspects and perceived benefits and shortcomings for these prototyping methods. For the IVR prototyping, there were several student comments around the challenges of the initial orientation to Rumii as software, Rumii's unique interface challenges for co-designing prototypes, and generally getting used to a virtual environment. There were also comments noting the advantages IVR co-design provided early team-oriented design work. Notably, there were comments around a more perceived embodied co-design environment permitting a more direct understanding of a teammate's actions and intentions akin to "a natural design activity" and better than translating NonVR prototyping ideas to Jamboard documents. Looking at the IVR experience in Rumii, one student wrote, "... the VR space, it felt a lot more collaborative and realistic," and another, "… really easy to visualize what she was thinking once she began drawing." And "The fully immersive environment led me to think with my hands, and the space around me." Another comment noted, "we were able to see each other in the process." The student experiences with Rumii also brought important comments about prototyping shortcomings like, "quite primitive ideation," "one (shared) main menu," and an issue where, "creations being deleted if one teammate left." For the NonVR prototyping, there were comments that NonVR prototyping did not permit the level of co-design and collaboration as IVR prototyping and that the Jamboard drawing tools were not as articulate as digital drawing normally allows. Students noted it, "lacked the ability to really sketch and draw easily," even, "ineffective for ideating" and, "not as collaborative, as we couldn't sketch together as easily as we could build together."

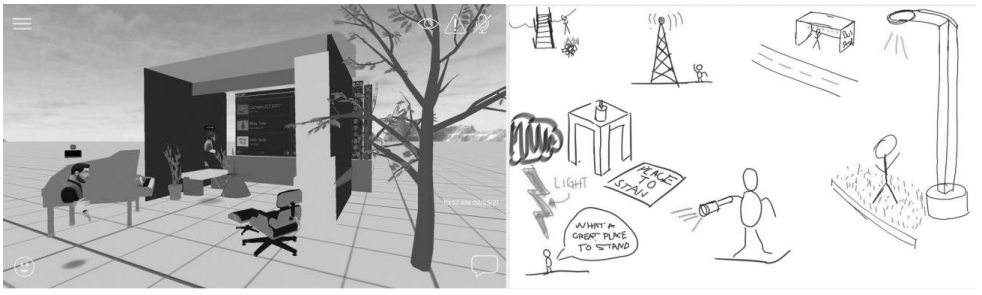

Figure 3. Examples of co-design prototyping in IVR using the collaborative virtual environment Rumii (on the left), and with NonVR using Google Jamboard (on the right). Students are prototyping around metaphors "CAVE - sit / shelter" and "MOUNTAIN TOP - stand / light"

5 DISCUSSIONS OF RESULTS

As noted in the related research, there were few empirical studies around how consumer IVR technology adds values or lends an important perspective to design education. This study builds on this related research. The results of this study showed a large difference in quantity favouring the NonVR co-design prototyping

approach but a similar potential when considering the quality of either IVR or NonVR co-design prototyping methods. Additionally, there were clear statements from the student reflections showing an enthusiasm and recognition for the potential of IVR co-design prototyping. A further discussion of the results and additional anecdotal reflections offer insights regarding the prototypes and the potentials in the processes that developed them.

It was noted that Rumii, the IVR software, limited smooth co-design interactions in this rapid prototyping mode of work. This may have also impacted quantities of IVR versus NonVR prototypes and the rest of the scoring for the quality of the prototyping around the use of scale, shape, colour and form, the technical quality of the prototype, and even the novelty where students struggled more in a less familiar medium (IVR) to complete the tasks. Students found, for example, that Rumii had two modelling approaches that seemed to limit one teammate to create using a 3D line tool and the other teammate to work with a different tool for pre-set 3D primitive shape creation or prefabricated 3D models. This likely required more team negotiation and slowed the process and translation of ideas between co-designers.

Student reflections also incorporate additional important perspectives of the technical and co-design experiences of the study. Student comments captured the important idea that an embodied perspective brings to a co-design challenge around a prototype (or similar) with spatial potentials. Other distant digital technologies do not permit this important concept that exists in the physical studio environment.

The student comments around shortcomings together with the quality of prototypes completed, showed that some teams excelled in Rumii when they matched one teammate with the 3D sketching tool complementing the other teammate working with 3D modelling tools. These frame important concepts that any IVR digital design software used for early concept ideation and prototyping requires a well-designed user interface for rapid ideation and even differentiated for each student or designer. This again would match in concept to a physical studio environment where each student can sketch, model and create according to their individual creative potentials and developed skills and where they can easily communicate those ideas with articulation, persistence and substance.

6 CONCLUSIONS AND FUTURE WORK

By this initial small study, it is not possible to conclude what the differences and similarities are between co-designing prototypes in IVR compared to desktop solutions. We tentatively suggest that there might not be a difference, or that IVR design tools may lead to higher quality prototypes when students are co-designing. The study shows a clear advantage to NonVR prototyping in quantity where students are generally more comfortable in 2D digital design than they are with IVR technology. Nevertheless, IVR prototypes were of a very similar quality to NonVR prototypes regardless of the students' prior experience. However, considering the students' lack of IVR technology experience, when the students have more exposure to IVR technology it may affect the results, since a larger difference is expected between the results to favour the media students are more experienced using. Design education has incorporated many design techniques, like drawing and modelling over the years as a proven part of the pedagogical foundations. It bears serious consideration to employ IVR in the early phases of design education so students can adequately communicate their intentions as with as other design tools they are familiar with. Future studies conducted longitudinally across time are relevant to capture more experienced results with these IVR tools. These studies need to look at student development and learning and different software for prototyping to better understand outcomes and potentials of NonVR compared to IVR design tools. Besides, it is relevant for future research to conduct similar studies in other design classes in order to make conclusions on co-designing prototypes in IVR compared to other desk top solutions. Studies also need to be conducted with well experienced professional designers which may give different results to impact future design education practices.

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A COMPARATIVE CASE STUDY OF BIO-BASED MATERIAL DEVELOPMENT BY DESIGNERS USING A DIY APPROACH IN A CIRCULAR CONTEXT

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ABSTRACT
There is an essential visionary element to design that affects how we experience and shape our environment. Reacting to our current reality with climate change and exceeding our planetary boundaries, designers are increasingly involved as catalysers of innovative and interdisciplinary material research by generating alternative proposals and scenarios for more sustainable futures. Recent academic literature on material practices within design has revealed a lack of strategies to support designers during the different stages of developing bio-based materials when using a DIY approach. Earlier studies have shown that the most successful material designers strategically gathered knowledge through literature, systematic material experiments and external expertise. The choice of strategy was related to prior experience and the material designers' level of education. This paper suggests a strategy based on a comparative case study combined with a contextual literature review. The bio-based materials in this study are produced by using local resources; they promote sustainability, are placed in a circular context and underlines the importance of the connection between a context, a community and the designer. Material-driven design practices, applying DIY approaches to material development processes combined with a theoretical framework from circular design and sustainable development can provide entry points to address parts of the complexity and envision new alternative solutions. Conclusions aim to encourage designers, researchers and tutors to respond to emerging needs by re-thinking material practices in design.

Keywords: DIY-materials, material-driven design practices, sustainability, design education, circular economy

1 INTRODUCTION

There is an essential visionary element to design that affects how we experience and shape our environment. Reacting to our current reality with climate change and exceeding our planetary boundaries, designers are increasingly involved as catalysers of innovative and interdisciplinary material research by generating alternative proposals and scenarios for more sustainable futures. Design is fundamental to all human activity, and at the nexus of values, attitudes, needs, and actions, designers can act as transdisciplinary integrators and facilitators [1]. Buchanan [2] stated that "designers deal with possible worlds and with opinions about what the parts and the whole of the human environment should be". Material designers have the opportunity for contributing to the societal change towards increased sustainability and circular economy. Materials are continuously developed, adapted and experimented with by material professionals (engineering, material science, biochemistry etc.) around the globe. In recent years, design has contributed to material development through Material-driven design practices, applying DIY approaches to material development processes or as a funded research collaboration with industry. The inspiration comes from various sources such as a specific problem that needs to be solved, an available waste stream, a bio-based building block, or an abundance of a renewable resource. Material-driven design practices and the DIY approach to developing materials find a significant source of creativity from transgressing norms concerning how materials are processed and used or what is considered a material source [3].
There is broad recognition that knowledge production in higher education is shifting from traditional disciplinary questions to cross-disciplinary investigations grounded in industry, society and the environment [4]. The challenge is to mix 'codified, discipline-based (explicit) knowledge' from outside

an applied field with 'intuitive (implicit) knowledge' from within it [5]. This challenge can be an issue in applied research projects conducted by designers and students experienced primarily in design practice [4]. Material-driven design and the DIY approach to developing materials have been applied in design education to support multiple perspectives on materials and support design students in developing reflective material practices, bridging theory and practice [6]. Earlier studies have shown that the most successful material designers strategically gathered and utilised knowledge both from literature, systematic material experiments and by using their network to find external expertise [7 & 8]. The choice of strategy was related to prior experience and the material designers' level of education. This study suggests a strategy supporting designers when applying DIY approaches to the material development processes of bio-based materials. The study is based on a contextual review combined with a comparative case study focusing on bio-based materials suitable for craft-based or small-scale manufacturing. The selected bio-based materials are produced by using local resources; they promote sustainability, are placed in a circular context and underlines the importance of the connection between a context, a community and the designer.

2 COMPARATIVE CASE STUDY

Comparative case studies embody a deep knowledge of a subject and lie at the crossroads of practise and theory. When selecting cases for the study, the following criteria were considered crucial; the bio-based materials should be produced using local resources; promote sustainability and be placed in a circular context. The six bio-based materials (Figure 1.) in the comparative case study are developed by 2nd and 3rd years BA Design students. The 2nd year students developed their bio-based materials in the course Material Driven Design 7.5 ECTS for 5 weeks. The 3rd year students developed their materials as part of their thesis work (30 ECTS). As it was considered important to study more mature bio-material concepts in-depth, these six projects were selected from a total of 49 projects.

Figure 1. Bio-based materials developed by 2nd and 3rd years B.A. level design students. Top row: Rose panels (Therese Rosén & Jonna Kytölä), Argenti Flex (Emma Thyni), Sea-Buckthorn composite (Peder Nilsson). Lower row: Pine needles (Jonas Hagberth & Neriman Arif), Argenti Flex & Coffee Chaff (Emma Thyni), Residue chair (Hanna Carlsson)

A comparative case study [9] of the project documentation was conducted. In the first step, commonalities of the collected cases were noted as well as distinct differences. The informants answered clarifying questions before coding the material. The material was then coded top-down and bottom-up and resulted in 7 main categories. See results in Table 1. Within each category, skills, activities and knowledge input and output were identified and summarised in short descriptions.

Table 1. Results from the comparative case study

Category	Description of findings
Explore & define a context	Allows for the designer to position the project, & thereby to in-depth explore & develop sustainable &/or circular solutions. A well-defined context contributes to an active framing & re-framing process during the material development process.
A Working Hypothesis	Facilitate active use of theoretical knowledge, especially the tinkering stage. Offers focus & allow for in-depth knowledge creation.
Theoretical knowledge	In-depth knowledge of specific raw materials pervades the projects, i.e., biochemistry, technical, botanical, historical & cultural aspects. Theoretical understanding of theories from sustainability, circular economy & the current system surrounding the raw material or waste stream played a key role throughout the process.
Practical skills	Material processing & tinkering skills with biobased components are connected to the ability to translate or adapt industrial-scale manufacturing techniques & cooking techniques to the lab environment. The ability to analyse & utilise the biochemical components of, e.g., an apple or pine needles are crucial when developing viable biomaterials.
Experiential & Aesthetical characterisation	User feedback allows for understanding, adjusting & fine-tuning the materials sensorial qualities & aesthetic expression. Contributes to define application area & position the final material in a system
Testing & Validation	Basic technical tests are performed continuously. More advanced & accurate testing is typically performed when scaling up the volume of the material. Initially, the testing is done by the designer & later on, external tests & validation are considered necessary.
Storytelling	Used as an ideation method in the concept development stage and when envisioning possible future circular scenarios. Translating complex information so non-experts "get it" at a glance, thereby bridging the knowledge barriers between stakeholders & society.

3 CONTEXTUAL LITERATURE REVIEW

A contextual review [4] was conducted to identify bio-based materials developed by designers using a DIY-materials approach and have been further developed to be made commercially available. The following selection criteria were applied in the review; bio-based materials produced by using local resources; promote sustainability and are placed in a circular context. In the next step, the list was reduced to contain only the materials where verified background information could be identified that described the development process. Academic sources were prioritised over articles in design magazines and forums, popular science, newspapers and commercial sources. Finally, 10 bio-based materials and their development processes were selected to be further studied to find common denominators, see Figure 2.

Figure 2. From top left to bottom right: Apple leather (Beyond Leather Materials ApS.), Mogu floor (Officina Corpuscoli), Malai (Malai Biomaterials Design Pvt.Ltd.), Pinatex (Ananas Anam), Sulapac Premium (Sulapac Oy.), Bioyarn (AlgiKnit Ltd.), Fruitleather Mango (Fruitleather Rotterdam), Mount Fuji (Ground Rule Studio), Neo Ionic (Blast Studio), Salt panels & LAAB lampshades (MIYUCA)

The common denominators of the materials found in the contextual review were collaboration across scientific, technological, social, ecological, academic and business fields. The materials had, in general, taken 4-8 years to develop from a concept stage to become upscaled commercially available. Designers had initially created the selected materials; however, two main categories could be identified:

- start-up design companies with designers controlling the material development through all stages, often acting as a project manager and company director with external partners/ expertise
- funded research collaboration with industry and inter- or transdisciplinary cooperation between design, material science and manufacturing process development

In the second category, most designers were doctoral students with previous experience of the DIY-material approaches and Material Driven Design. The selected materials were primarily represented by the first category, which was expected due to selection criteria.

4 FINDINGS

Working within a field of high complexity, in the cross-section between disciplines and with different expertise and skillsets required during the development process, requires a strategy that breaks down the complexity into manageable stages. The adequate combination of theoretical knowledge, skills, methods and approaches are unique for each specific bio-based material development process using a DIY approach. Yet a general strategy can be identified once the processes studied in the comparative case study has been broken down into stages. The model is based on the findings from the comparative case study and the contextual literature review. Each stage shown in the illustration (see Figure 2) needs to be adapted to fit the specific project. The model contains three circles, and they represent (1) required skills, (2) knowledge in- or output and (3) area of activities. The model illustrates how these relate to each other when developing a bio-based material using a DIY approach.

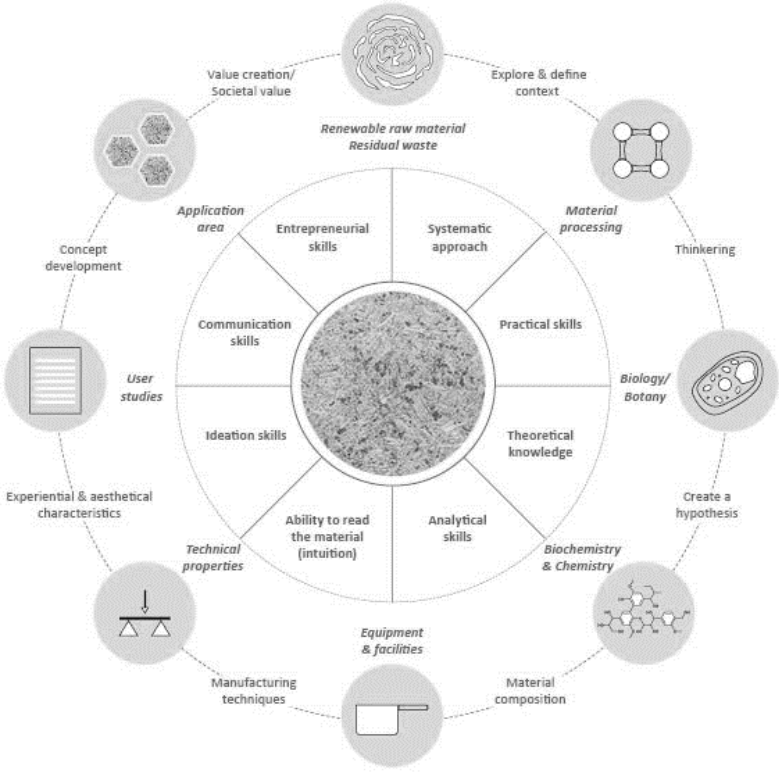

Figure32. The model contains three circles, and they represent (1) required skills, (2) knowledge in- or output and (3) area of activities in the project when developing a bio-based material, using a DIY approach

5 DISCUSSIONS

The biggest challenge for both students and designers was making the most out of many data types and mixing scientific with phenomenological methodology. The ability to continuously analyse and be "in dialogue" with or "read" the material proved crucial in the first development phase. Reflection became an integrated activity during the experimental stages. The ability to utilise theoretical knowledge, access to equipment and practical skills influenced the quality of the developed processing process or the cultivation of the material. Scaling up and formalising the manufacturing process of the material brings a new dimension to the relationship between designer, technologies, and the material. The process involves new stakeholders and competencies in a project. Communication skills and entrepreneurial skills become crucial factors for succeeding as it is no longer enough with tempting pictures of material samples in social media when developing a business. At this stage, storytelling becomes an efficient tool in communicating sensorial qualities and technical properties to non-designers and mastering technical language become essential when communicating with engineering.

Carmen Alvarez Hijosa [10] points out that by moving between the world of business and academia when developing Pinatex, it became perfectly acceptable to pose challenging questions, to doubt, ponder and follow thoughts that may lead nowhere today but somewhere tomorrow. The questions are becoming crossroads where crucial decisions can be made, building the foundations for a better and more in-depth way of thinking and doing. When analysing the student projects, it became clear that the complexity of working with the DIY approach in a material-driven design process improved their ability to frame and re-frame problems during the material development process. Ingold's theories [11] on framing and enskillment in how to frame, contextualise and re-frame a problem connect well with Simon's notion

[12] of how to develop intuitive expertise; both skills are needed when developing a reflective material practice. Intuitive expertise grows out of reflective practices as defined in Schön's theories [13&14]. Reflection-in-action, reflection-on-action and knowing-in-action is strongly connected to the practice of tinkering in an academic context and contributes to bridging the gap between theory and practice in current design education [6].

6 CONCLUSIONS

The model developed in the study underlines the importance of the connection between context, community and the designer when applying DIY approaches to material development processes. The result indicates that a synthesis between disciplinary and real-world knowledge production, including collaboration between academics and non-academics, led to the most successful results, both amongst students and professional designers. Transdisciplinary is highly recommended when scaling up the production from craft-based production to small-scale manufacturing, however challenging, as it crosses disciplinary and academic boundaries.

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EXPLORING THE GENDER STEREOTYPE THREAT THAT WOMEN EXPERIENCE IN TEAM-BASED EDUCATIONAL SETTINGS

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ABSTRACT
Solitary women students participating in male majority design and development teams often experience inadvertent stereotype threat. This paper explores the educational experience of undergraduate women participating in both majority male and majority female teams and how stereotype threat influences their educational experience. A 23-question survey distributed to thirty-eight female undergraduate students explores their experiences in both majority male and female group work. The results indicate women have an increased learning experience when participating in female majority teams. They experience increased decision-making and management responsibilities, experience more effective communication and influence, and feel ownership of projects and technical tasks. Participation on a majority female team amplifies positive emotional attributes and self-perception and increases courage, confidence, subject knowledge, and disciplinary cultural fit. To improve the learning experiences for all students, Design and Engineering educators should understand how to identify stereotype behaviour. This paper provides stereotype questions and topics to talk about with students and promotes a 60/40 gender composition when educators form project teams, thus improving students overall learning experiences.

Keywords: Women design teams, industrial design projects, project team creation, stereotype threat in education

1 INTRODUCTION

As an industrial design educator of 15 years, I have observed that women designers behave differently in majority female project teams than when they are the lone designer on a majority male team. I notice they are happier, highly engaged, produce better outcomes, and positively influence classroom dynamics. Many of these students also reported in their graduating exit interviews that their majority women team projects were "one of the most positive experiences" they had during their design education, indicating they experienced an increase in disciplinary growth and self-confidence and a decrease in the pressures and stresses associated with disciplinary learning.

In discussing this observation with the students, some explained that when they are in the minority on a majority male project team, they feel self-conscious, fearful and pressured to emulate or meet what they believe to be the expectations of their male peers' thoughts and actions. As a result, they also conceal their intrinsic values and thought processes to meet these perceived expectations. This behaviour is unfortunate and reflects a form of stereotype threat.

Steele (2011) discusses the role stereotypes play in day-to-day life and explains that 'stereotype threat' occurs when a person experiences a threatening situation where a negative stereotype of one of their identities exists [1]. Being in such a context elicits psychological arousal as the individual is wary of doing anything that may confirm the negative stereotype. Steele's other research collaborations indicate the effects of being in an environment where few women faculty or students, or where the curriculum marginalizes the experiences of women students, are enough to trigger a stereotype threat that undermines performance in math, science, and engineering fields [2].

While there is academic work addressing gender disparities facing women, the issue of stereotype threat deserves more attention within design and engineering education as it relates to group dynamics and specifically how educators form teams for group projects.

Research focusing on the female experience in design education is limited, with only a few papers published within the last fifty years [3]. Woodcock et al. [4] determined that stereotype-like threat experienced over an extended time tends to lead to individuals leaving their field of study and eventually dissociating from that area of study or profession. The number of professional women designers in the design field is unknown in the US, while in the UK, it is 22% of the total design workforce [5]. For engineering, The Society of Women Engineers reports that women currently make up 13% of the USA's professional workforce [6]. This gender disparity in the industry might reflect the stereotype threat experienced by women during their educational group experiences.

In recent years, governing bodies have begun to address these issues. For example, changes to standards for higher education institutions in the UK have emphasized equality, diversity, and inclusion (EDI) measures as requirements for receiving AHEP 4 accreditation [7]. Additionally, the USA and Japan have made legislative measures to ensure increasingly equal educational opportunities for all minorities, including the Strength and Diversity Act of the US and the MEXT initiative in Japan [8, 9]. While equality and diversity initiatives have emerged on the macro level, this study focuses on improving women's micro-interactions and learning experiences in design and engineering education courses.

To bridge the gap between legislation and the classroom, we first propose 23 stereotype focused questions educators could use to discuss or explore with all student's stereotype threat situations and experiences that could inadvertently be occurring in the classroom. Secondly, we propose eradicating the common practice of assigning the few women in a course equally across all project teams, which often isolates one woman on a majority male team.

2 METHODS

To explore the stereotype issues women in undergraduate design and engineering teams face in their educational experience, we interviewed three design students and one math student to gather insights on how their gender impacted their academic careers. Each interview was roughly an hour in duration, and the insights gathered formed much of the survey's framework and content.

A Qualtrics survey was administered to 58 undergraduate female students from Brigham Young University and Utah Valley University through a Facebook link. 54 respondents indicated enrolment in technology, engineering, or design. 57 of the respondents had participated in group projects in which they were in the minority as a woman, and 38 reported having experienced working in a predominantly female team for a group project in school.

We assessed data from the 38 respondents who reported experience with group projects under both majority male and majority female composition conditions for this study. Participation was voluntary; no students received compensation for participation.

The survey consisted of 23 'team participation' and 'self-perception' questions and 4 screening questions. Section 1 confirmed university enrolment, whether participants were studying in a technology, engineering or design field, and whether participants had experience participating in both male and female majority team projects. Section 2 evaluated the respondent's experiences to the 23 questions when participating on "male majority" teams, while Section 3 asked the same questions considering their experience on "female majority" teams.

3 RESULTS

The data was averaged for each survey question to expose potential trends and insights in participants' learning experiences. Participants ranked their experiences on a scale of 1-9, with 1 being 'strongly disagree' or the least favourable condition, and 9 being 'strongly agree' or the most favourable condition. For example, question 5 asks, "In groups with more men than women, I am included in decision making". The value '1' indicates participants' strongly disagree' they were included in decision making. In contrast, the value '9' indicates participants' strongly agree' they were included in decision making. A score of 5 represents neither a positive nor negative experience. Scores lower than 5 will be discussed as less favourable experiences, while scores above 5 will be addressed as more favourable experiences. In tables 1 and 2, the first column lists the 23 questions respondents were asked to rate. The second column lists average scores given by participants on a majority female team. The third column lists the average scores of participants on a majority male team. Finally, the fourth column indicates the difference in rating between the two gender majority conditions.

Table 1: Team Participation scores between majority female and male teams. Notably all scores are higher in the majority female column

	Majority Female	Majority Male	Difference
We Fairly Distribute Technical Tasks	7.21	5.10	2.11
I Have Opportunities for Leadership	6.59	4.50	2.09
Communication is Easy	7.05	5.05	2.00
We Share Project Ownership	7.69	6.08	1.62
I am Engaged with My Team	7.67	6.05	1.62
My Ideas are Considered	5.72	4.13	1.59
My Peers are Persuaded by my Input	5.26	3.75	1.51
I am Included in Decision-Making	6.49	5.08	1.41

Table 2: Self-Perception scores between majority female and male teams. Notably all scores are higher in the majority female column

	Majority Female	Majority Male	Difference
I Feel Confirmation that I Belong in this Major	7.36	4.50	2.86
I am Willing to Show Weaknesses	5.49	3.00	2.49
I Feel Included	8.00	5.7	2.30
I Don't Change the Way I Talk	6.77	4.55	2.22
I Feel Self-Assured	6.26	4.23	2.03
I Feel Secure Asking Others for Help	6.74	4.85	1.89
My Peers View me as Knowledgeable	6.54	4.80	1.74
My Peers Trust Me	7.63	6.00	1.63
I am Confident in my Technical Skills	6.77	5.15	1.62
My Peers View me as Competent	6.79	5.25	1.54
I Feel Confident	6.44	5.00	1.44
I Have an Absence of Anxiety	6.00	4.59	1.41
I am Not Intimidated	6.33	4.97	1.36
I Feel Adequate	6.92	5.87	1.05
I Do Not Feel I Have to Represent all Women	4.85	3.79	1.05

3.1 Favourability of Experiences between Majority Male and Majority Female Teams

Figure 1 indicates how strongly participants agreed or disagreed with the questions respective to their experiences on male majority teams compared to their experiences on female majority teams. The greater the rating number, the more positive the experience; the lower the rating number, the more negative the experience. Without exception, participants reported all questions more favourable when experienced on majority female teams.

- "I Feel Included" - the highest score in the survey suggests women experience some form of exclusion working with male majority teams. This rating could be explained by studies showing that males use communication to establish and increase their social status while females use communication to create relationships and establish equality with their peers [10].
- "I am willing to show weakness" – the lowest score under majority male teams; was the least favourable experience of all the questions indicating an extreme aversion to showing weakness. This situation reflects an unfortunate learning environment, as it is known that learning outcomes improve when students feel comfortable showing weakness and asking for help [11].
- "I do not feel I have to represent all women" – the lowest score under majority female teams; was less than favourable in both majority conditions. Follow-up conversations with women indicate participants feel this pressure because they are in male-dominated classes and majors. The micro-climate on all-female teams may have eased specific strains, but they continued to be affected by the broader context. However, more research is required to confirm this position.

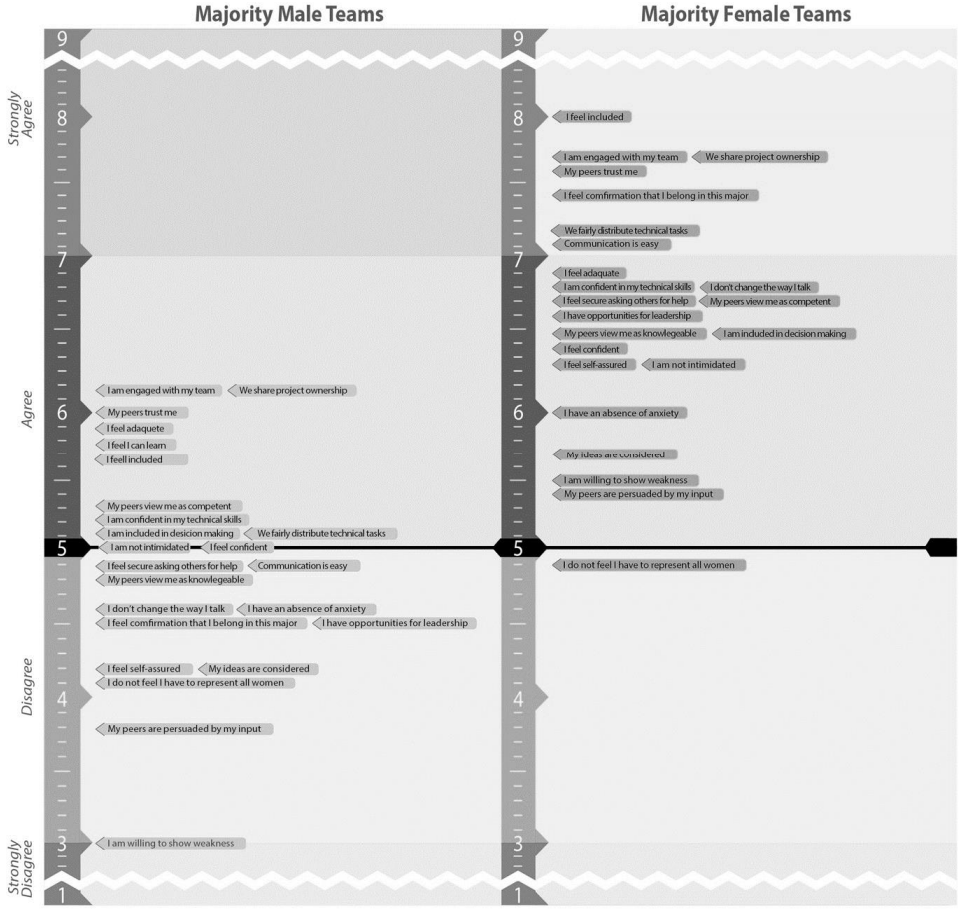


Figure 1. Favourability of experience between male and female majority teams. The greater the number, the more positive the experience and vice versa

3.2 Questions Re-ranked by Score Difference

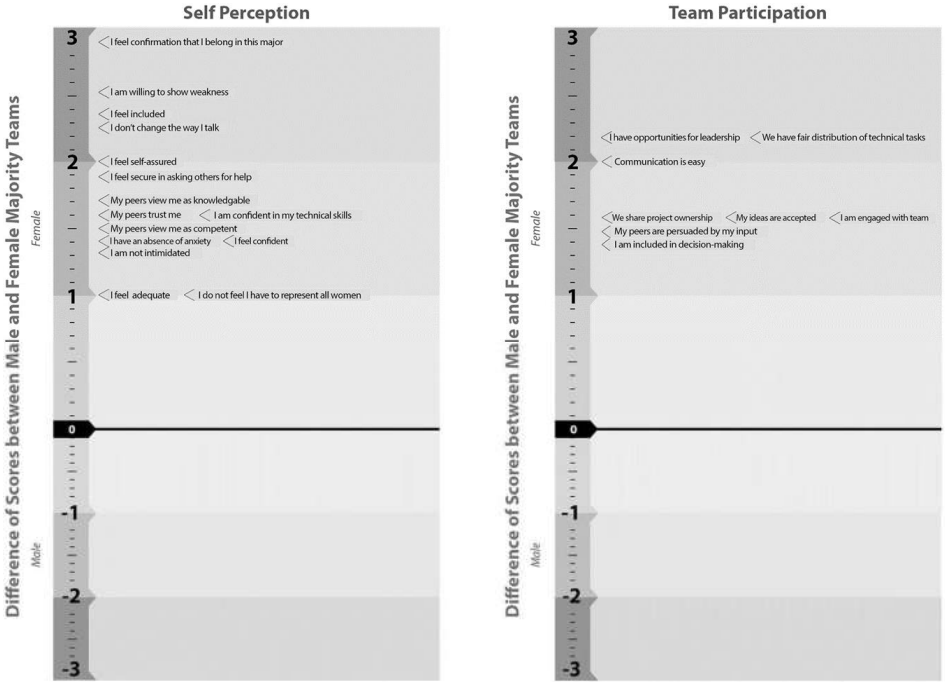
The graphs on the next page re-order the questions based on the score differences between the majority male and female team ratings in the "self-perception" category, Fig. 2 and in the "in-team participation" category, Fig. 3. Notably, none of the questions performed better in the majority male teams category.

- "I feel confirmation that I belong in this major" – the highest score in self-perception deserves further exploration but suggests women experience enjoyment, responsibility, engagement, and positive learning experiences in their chosen major primarily when stereotype threat is reduced in team projects. This result could have a direct impact on the number of women disengaging from the design and engineering disciplines early in their careers [4, 5].
- "I have opportunities for leadership" and "we have fair distribution of technical tasks" – the highest scores in team-participation indicate that women miss out on these learning experiences while participating in majority male teams. This condition could be explained by research that shows that females tend to problem solve as a group (we all share equally in leadership and task distributions), whereas men problem solve individually (I will do this, and he will do that) [12].

4 DISCUSSIONS

At Brigham Young University, the entering freshman class in engineering and technology (which includes design) has consisted of 20 - 21% women over the last eight years. When viewing those cohort's graduation rates five years later, statistics indicate that undergraduate degrees awarded consisted of 9-

10% women. During their educational experience, roughly 50% of the women entering our college decide it is no longer a "fit" for them and change majors. There is no data on why they are leaving. Still, this study suggests that women's ongoing exposure to the social threat they experience on male majority teams and programs could play a role in that decision.



Figures 2 and 3. These graphs re-order the 23 questions by the difference in scores. The higher the rating on this graph, the greater the disparity in educational experience between participation on a majority female team (yellow) and a majority male team (blue).

The majority of design and engineering programs at universities have higher male enrolments than their female counterparts [13, 6]. Additionally, these majors rely heavily on group work projects in their curriculum to prepare students to collaborate on teams during their careers. Casual observations and conversations on this topic indicate when there are fewer women students in a course, they are placed individually or in pairs on male majority teams. This scattering of women across the teams may appear to be the fairest and least discriminatory treatment of building teams. However, Steele found that for women to feel comfortable and involved in teams, their team should have a "critical mass" of no less than 40% female. The social threat these women experience being the sole woman on a team is neither reasonable nor appropriate and places them at a distinct educational disadvantage in those teams. This disadvantage may cause the gradual disassociation and dissatisfaction of women in engineering and design fields throughout their undergraduate experiences.

Fouad [14] found that two of the top three reasons women decide to leave engineering jobs are "unmet achievement needs that reflected a dissatisfaction with effective utilization of their math and science skills, and…unmet needs from a lack of recognition at work, and adequate opportunities for advancement". Seron [15] reports that effective strategies to improve women's "fit" in the culture of engineering are to address their experiences in college "coursework rituals and team projects".

To achieve positive educational experiences for all students in a classroom, educators should be aware of the effects and behavioural signs of stereotype threat and build teams with a critical mass reflecting the 60% - 40% gender balance male/female or female/male Steele recommends. This solution aims to increase the positive learning experiences of all students within their chosen programs, with the hope of improving women's education in the future.

We acknowledge that the survey could be improved and distributed to more extensive and diverse female students. Even so, there is an overwhelming sense of preference towards majority female groups in team educational settings. While this study has weaknesses, we believe it is worth pursuing further and should be a vital part of conversations regarding the future of equality in design and engineering education.

5 CONCLUSIONS

My recent experiences running majority female team projects have been overwhelmingly positive. They are not without their unique issues, and the women initially feel some gender discrimination when the teams are organized. However, those students who initially complained the loudest also returned 4-8 weeks later and thanked me for the wonderful learning experience. I will never again isolate a woman on a team project.

To enhance learning experiences for women and enable them to hold leadership roles on a team, perform technical tasks, be heard, and feel like they fit in, a 60/40% team gender composition should be the guideline for undergraduate group projects. It is also important to remember that stereotype threat is not limited to gender issues but can also include a student's nationality, age, religion, etc. Stereotype threat is real, and how the micro-climates educators manage, specifically how educators form teams for group projects, will affect the minority's positive or negative educational experiences.

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INNOVATION MANAGEMENT: A NEW SERIOUS GAME ALIGNED WITH ISO 56002:2019 - INNOVATION MANAGEMENT SYSTEM

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ABSTRACT
Innovation and Innovation Management are now common topics in the education field. However, the majority of the contents take the form of basic media: books, articles, courses, study cases and they are also taught in a linear way: lectures, tutorials. This does not consider new trends in terms of teaching, such as reverse pedagogy or pedagogy through games and does not seem appropriate when dealing with the teaching of complex topics such as innovation. The purpose of this article is therefore to present a new serious game which aim is to help students from engineering school, business school or master degree in innovation to acquire basic knowledge on building and assessing innovation management system using a playful way. The plus of the game: it is aligned with the standard ISO 56002: 2019 Innovation Management System [1]. In this paper, we will explain the methodological approach we used to design the game and in conclusion we will present some results issued from two experimentations we already have.

Keywords: Innovation Management System, innovation, engineering education, Serious Game, ISO 56002

1 INTRODUCTION

Innovation and Innovation Management are now an integral part of the entrepreneurial discourse. Training students in these fields has therefore become a must. However, it must be said that the desires and expectations of new generations of students in terms of training have changed: they are in demand for more flexible, more collaborative teaching methods in place of the traditional lectures, supervised work and practical work. They are asking us, as trainers, to be creative and innovative in order to capture their attention. The challenge is therefore to succeed in creating something that can both increase their competence in the field of creativity and management of innovation while meeting these new needs for less intrusive pedagogy.

In this article, we have chosen not to dwell on the justification of the relevance of using a serious game to teach innovation. Authors such as [2] have demonstrated this perfectly. Serious game approach makes it possible to acquire knowledge more easily compared to traditional training through engagement and motivation [3][4]. The main purpose of this article is to present a new educational game dedicated to student taking courses in innovation engineering or innovation management. Section 2 introduces the context of our work, the recent ISO standard in Innovation Management System that give new definition and directions to follow. Section 3 describes our methodological approach to design our serious game. Section 4 shows the visuals associated. A short discussion and perspectives are proposed in the concluding section.

2 ISO STANDARD IN INNOVATION MANAGEMENT SYSTEM FRAMEWORK

ISO Technical Committee on Innovation Management (ISO TC 279) was been created in 2013. It aims to describe terminology, tools and methods, and interactions between relevant parties to enable innovation within organizations. Published in July 2019, the ISO 56002:2019 - Innovation Management System standard aims to provide a framework to develop innovation management capabilities. This standard describes a set of processes by which an organization manages a set of activities to achieve its innovation objective. All Management System Standards are based on a common framework used to

describe management systems in general. It sets a table of content to follow and provide recommendations regarding the process of writing. It is clear that seeking to standardize innovation management may seem contradictory. This is why it is important to note that this standard is a guidance standard and not a requirement standard. It therefore aims to highlight good practices for steering innovation processes, commonly accepted by a pool of international experts.
We assume that training students in innovation cannot be done without taking as a reference this standard, which contains both definitions and explanations on how to steer an innovation process by considering the ecosystem in which it evolves.
Consequently, we will use the following definition provided by ISO 56000:2020 [5]:

- Innovation is "a new or changed entity, realizing or redistributing value" where:
  - Entity can refer to a product, service, process, model, or method;
  - Value can be financial or non-financial (for example image, strategic advantage, knowledge acquisition, intellectual property); and
  - Novelty (newness) and value are relative to, and determined by, the perception of the organization and interested parties.
- An Innovation Management System (IMS) includes all elements and their interactions that are needed for an organization to establish its innovation capabilities for the purpose of effectively and sustainably achieving innovations.

The IMS coordinates and directs the organization's innovation activities to ensure alignment to their customer and business requirements. It also provides mechanisms to measure and improve innovation effectiveness and efficiency on a continuous basis.
The objective of considering a systemic approach here is to move away from a vision exclusively centred on the development of an innovative project process (operational vision) by positioning innovation project processes within a broader organisational system.

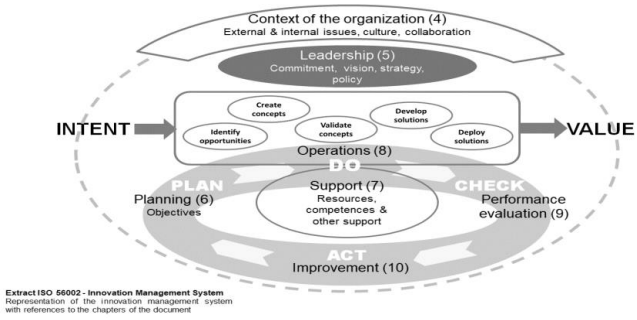

Figure 1. Innovation management system representation. Source: Extract ISO 56002

As any management system, the IMS can be continuously improved by using and Plan-Do-Check-Act (PDCA) approach.
As shown in Figure 1, the standard is a dense document, organised in 10 chapters containing definitions, methods and tools that any manager working in or wanting to work in the field of innovation should be familiar with. Nevertheless, the style of language and the imposed structure of the document do not make it easy to read and understand, especially for students.
As an expert from the French delegation, who participated in the drafting of the standard, we felt it would be appropriate to try to translate it into simpler terms and in a more entertaining format in order to attract more students to this subject.
Thus, for the construction of our game, we adopted the definitions and general framework of ISO 56002 (chapters 1 to 3 of the standard) as well as the model presented in figure 1 to formalize an innovation management system (chapters 4 to 10 of the standard).

3 METHODOLOGICAL APPROACH TO DESIGN THE SERIOUS GAME

The objective of the game is to give concrete expression to the notion of an Innovation Management System, to materialize the dynamics of such a system and to reveal the importance to balance idea generation, project development capabilities, value generation and resilience.

Serious games in general are created to train people in a more fun approach than classical training. They make it easier for users to get involved and to master the principles taught in the training materials more quickly [6]. However, the creation of serious games requires a greater effort than the construction of a classical training [7].
This is why we have chosen, for this article, to focus on the construction logic that was ours.
As stated by [8], the main purpose to create simulation games is to concentrate all the educational objectives that a teacher may seek, namely knowledge, understanding, application, analysis, synthesis and evaluation. Furthermore, as pointed out by [6], many factors need to be considered when developing the elements of the game, such as the complexity of the subject, the history of the game, the mechanics of evolution and the challenges to be faced. [2] have also tested a 6 items framework called SGDA (Serious Game Design Assessment, designed by [9] to help teacher or trainer in innovation to transform their traditional supports onto innovative ones, such as serious game. The 6 items are: Game purpose, Content & Information, Mechanics, Fiction & Narrative, Aesthetics & Graphics and Framing.
On the basis of these works, we have developed a specific approach for our complex subject: training students at Master's degree level in innovation by advocating a system vision of innovation aligned with the content of standard 56002. The result is a 4-step approach as follows:

- Step 1: Complexity and game purpose (objectives and Knowledge)
- Step 2: Content, Mechanics & and associated framing
- Step 3: Test, learn and adapt to better fit reality.
- Step 4: Aesthetics & Graphics

3.1 Step 1: Complexity and game purpose (objectives and Knowledge)

Objectives: Clearly define the objectives of the game and the challenges to be faced in order to reduce the complexity of the subject. Explain also the history of the game.
The development of this game stems from our experience as experts in drafting the Innovation Management Standards series. Innovation is an eminently complex process that takes different forms depending on whether you want to manage, steer or evaluate it. ISO 56002:2019 lays the foundations for understanding what an innovation process is and the ecosystem in which it evolves.
The use of an accessible vocabulary to link multiple notions related to the field of innovation was a major challenge for us. Indeed, concerning the knowledge gained from the game, we wanted students to:

- make the link between the implementation of activities in a company (system) and the impact on the flow of innovation (projects),
- Integrate the importance and the complexity to balance an innovation portfolio under development and to regularly produce innovation,
- Understand the value acquisition process and the fragility of an innovation under development.

3.2 Step 2: Content, Mechanics & and associated framing

Objectives: Select the content you want to reflect. Define the mechanics of the game and all the aspects related to the gaming process: time, period, cycle, …
In order to adhere as closely as possible to the standard in terms of content: definitions, methods and referenced tools, we have carried out two actions:

- "decoding" the standard, i.e. we translated the various paragraphs into the form of simple activity cards using business vocabulary. We defined 4 categories of cards associated with specific chapters of ISO 56002:2019:
    - Strategy cards are related to chapters 4 Context of the Organisation, 5 Leadership and 6 Planning),
    - Support cards describe activities related to chapter 7: Supports,
    - Project management cards describe activities related to chapter 8 Operations,
    - Continuous improvement card is related to chapter 9 Evaluation and 10 Improvement.
- Define game mechanics rules that would illustrate the principles of IMS development described in the standard:
    - each activity should have an impact on the system performance,
    - the system should be built over time and provide a level of efficiency corelated to the implemented activities,
    - the objective of the game would be to accumulate value by realizing innovations.

ISO 56002 precise that the elements of the system can be gradually adopted, according to the particular context and circumstances of the organization and that full benefits can be gained when all the elements of the innovation management system, are adopted by the organization. Thus, the order of implementation of the different innovation activities can vary. This is why we proposed a dynamic approach, non-linear, where player will be free to choose the order of implementation.
The game will be played over a 12-month period with each month representing a round. This will position us in a realistic framework where activities take time to be implemented and where the system will be monitored over a year. It is therefore a question of implementing the activities in the system, and allocating the resources and means to achieve this.
Considering that the objective of an IMS is to generate value, we have opted for a game by accumulation of resources. Player will make visible material gains in the form of multi-coloured diamonds that will illustrate the multiple forms that value may take.
At this stage of our work, we have a deck of cards representing innovation activities, some focusing on managing innovative projects and some others focusing on the ecosystem aspect in which a project evolves. We also have a currency (diamonds) as a resource and a correspondence between game rounds and time (1 game round representing 1 month, game round over a year).
An initial validation by a first expert committee was carried out. The committee was mainly composed of ISO TC 279 members. Although they appreciated the suggested contents and overall concept, they nevertheless raised the question of the impact of these activities on the performance of the system.
Working with the expert committee, we decided to:

- Define the variables to be retained as KPIs for the performance of the IMS, namely: ability to generate idea, ability to move projects forward, ability to generate value, and resilience of the organization,
- Define the impact of each activity (card) among the 4 defined KPIs,
- Differentiate two currencies or the game. In spite of the diamonds that will represent the value created threw innovation, we define another currency that will reflect the limited resources the player will have to implement innovation activities,
- Use the project process of the standard, and decide on the number of boxes a project will have to cross in each phase (e.g., it takes longer to do the development phase than to create a concept) and the potential value gain while progressing on the project process,
- Propose a calculation of the associated costs per activity (not all activities are so simple to deploy),
- Propose the calculation of a value/investment ratio revealing priority activities.

At the end of this stage, we have a first functional prototype of the game.

3.3 Step 3: Test, learn and adapt to better fit reality

Using the functional prototype, we realized a validation phase with a second experts committee mixing experts that were and were not directly linked to ISO TC 279.Their feedback noted that the game was very theoretical and lacked realism. Indeed, while developing innovation company has to face hazards, unforeseen events. Also, collaborating with external partners is also a common practice that we did not integrate in the game. We therefore introduced new cards, based on two principles:

- Illustration of the system agility: give an idea to the player of what and IMS can undergo and how it reacts. This will be illustrated by hazard cards that will be randomly drawn among the game,
- Consideration of using external resources to invite the player the ability to partner of specific projects. This will take the form of joker cards.

At the end of this stage, we have a complete game prototype, validated by the 2 experts committees.

3.4 Step 4: Aesthetics & Graphics

Objectives: Try to find the most accurate visual for the game. It must help to understand the all-purpose of the game in one look, support the flow of the game and must not create a barrier for the intended users.
At this stage of our research and considering feedback from experts, our aim was to make the system visible to users. We worked with two designers who made us several proposals, in order to put the graphics at the service of the objective. Two aspects were researched:

- Define the graphic universe that is consistent with the theme of innovation and that can be compatible with all types of organisations (private company, public service, etc.), we particularly

cared not to go towards an analogy to avoid cognitive dissonance,

- Integrate keys into the graphics and make sure that each element has sense (organization of the game board lengthwise for process projects, hide the difficulty of the development phase by presenting the pieces in columns, represent the diversity of people on the game board, represent a space for creativity, etc.). The aim is to initiate discussions and invite the player to interpret each graphic element of the game.

A third validation by an expert committee led to a warning: if the graphics accentuate comprehension but lead some of the testers to be too involved in the game and to stray from the desired learning experience. We will take this point into account in the future.
At the end of step 4, we have our final serious game, validated by the experts and with a visual done by a designer. Its presentation is the purpose of the next clause.

4 OUR PROPOSAL: « L'ANNÉE DE L'INNOVATION® »

The result of the approach previously presented lead to our serious game called "l'Année de l'Innovation®". The game will be available in French, English and Spanish.
Let us present the visuals selected for the game and summarize the rules:

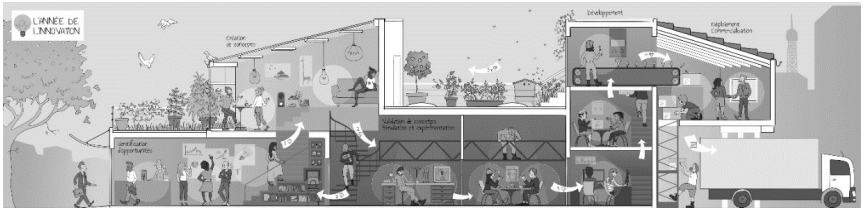

Figure 2. The game board that connects SMI with the development of innovative projects

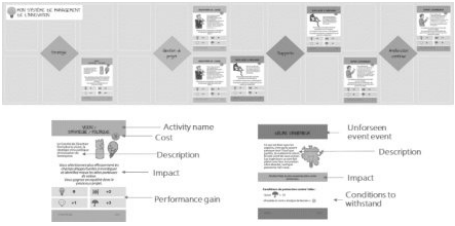

Figure 3. The tray and the cards simulating an IMS

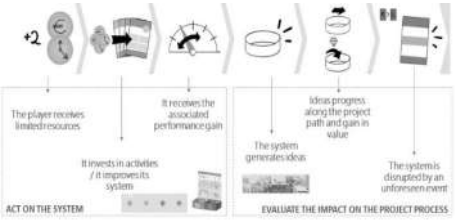

Figure 4. description of a game round

The serious game is the result of a co-design dynamic with industrial and academics. In order to validate is accuracy for training students, we tested our serious game with three types of students with different backgrounds and mindsets: entrepreneurship students, innovation management students and risk management students. The results obtained are interesting and will help to improve our serious game. This will be presented in a paper to come.

5 CONCLUSION AND PERSPECTIVES

In this article, we present a new game that allows to train students in an active and creative way based on the new Iso Standard dedicated to Innovation Management. Reading a standard is not a common purpose for students. Furthermore, the content of a standard is more for an expert of the domain. So, it usually requires an adaptation step to understand it. We facilitated that step by declining all the ISO 56002 chapters into a serious game. Thanks to the three rounds validation, we can say that the game meets most of its expectations: the innovation management best practices were understood and the students asked to play again in order to try another strategy to better perform. We were also satisfied because the game let see some concrete managerial implication: to work as a team, to negotiate, argue and find a consensus when several scenarios appeared.

In the future, a more normative evaluation of the learning process will be necessary and can be carried out in order to measure the efficiency of the serious game [10]. This evaluation will show which type of audience is the most receptive and which requires an adaptation of the game [8]. Consequently, we have already planned two new sessions with students coming from an engineering school and a business school.

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THE GATEWAY TO STUDENT LIFE EXPERIENCE A PRODUCT-SERVICE DESIGN APPROACH

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ABSTRACT
When thinking of attending a Higher Education Institution (HEI), a whole new experience comes to mind. Finding lodging, eating at the student restaurant, getting support during times where things get difficult, participating in fraternity life, and so much more, are all comprised in a term that we coin 'the student life experience' (SLX). This experience starts the moment you apply for an HEI and holds just as much value for your studies, as the actual studies themselves. At the University of Antwerp, auxiliary services provide necessary means for students and their experience in- and outside of the lecture hall. This wide range of services is essential to the quality of the university. Optimizing these services, makes a university stand out amongst others. Not only is it important to understand that balance and in particular to optimize the perception and interaction regarding the Student Information Point (STIP) that acts as a gateway to these services. The paper proposes a product-service design approach rooted in broad student involvement and open communication.

Keywords: Higher education, auxiliary services, student life experience, service design

1 INTRODUCTION

The University of Antwerp (UAntwerp) counts 21,133 students (including doctoral students) divided over four different campuses throughout Antwerp and its suburbs. Their SLX starts at the moment of enrolment when they embark on a new journey for the next couple of years [1]. They will eat, converse, party, and, obviously, do a lot of course work. SLX covers all of those experiences outside of the classroom or educational processes, such as cultural and sports activities, finding lodging, coaching, financial or emotional support, eating in the university's restaurants, etc. All these experiences are facilitated through the auxiliary services by the university's Student Oriented Services [2]. The Student Information Point (STIP) functions as a gateway between the students and the Student Oriented Services. However, a survey [3] has shown that only a small percentage of the students use the auxiliary services. In order to extend the services' appeal, interaction is encouraged with the auxiliary services and STIP, which should result in improving SLX. By focusing on both accessibility as well as service aftercare, innovative service performance should result from the input by students.

We can define two major stakeholders: the student population of UAntwerp as well as the university itself. Both can be broken up: on the one side, the students can be divided into three groups based on their motivation concerning supporting activities. First of all, there are students who are indifferent to these services. Often they do not know of their existence and will not interact with them unless it is absolutely necessary, for example, when a student has to request for special facilities (as in the case of dyslexia). Next, there are students who through STIP use these services occasionally or who will interact with them on a more regular basis. However, regularly these students do not know that all these services are interconnected, which can lead to misunderstandings and poor experiences. Finally, there are the student representatives. These students commit themselves to improve the inner workings of the university. These elected students can be grouped into smaller subcategories, but all of them are fairly up to very familiar with the operational side of UAntwerp.

On the other side, there is the university itself. Our focus rests firmly with the Department of Social, Cultural and Student Oriented Services. This department organises the auxiliary services which can be divided in seven groups (Figure 1); Culture, Sports, Student Associations/Coaching, Catering, Social & Housing Services, and the Study Advice & Student Counselling Service (DSSB). STIP functions as a gateway to each of these groups, although the students can approach the services directly (thus bypassing

STIP). STIP acts as a physical information desk on campus and directs the students to the right service solution. Students can come into contact with services such as Culture, Sports and Catering without the help of STIP. However, the Social and Housing Services and Student Advice and Student Counselling Service are less accessible, and access requires mediation through STIP. Specifically, STIP will process the students' requests and regularly schedules appointments. The current system is the result of organic growth within the university, which makes it less obvious to restructure and realign STIP to the needs of the students.

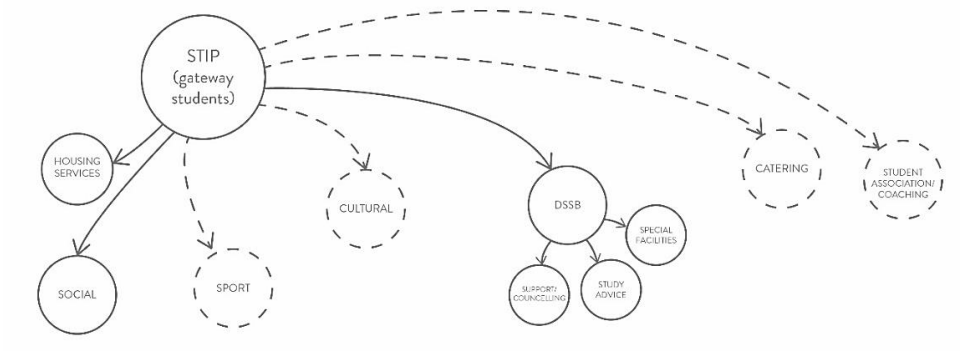

Figure 1. Simplified overview of the auxiliary services at the University of Antwerp

The head of the Department for Social, Cultural and Student Oriented Services suggests that 50 % of all student requests which are handled by STIP, are not related to their services. These requests are mainly course, faculty or another department related and should not be handled by STIP. This results in STIP employees having to refer students to other services on top of their own workload. This confusing situation affects the students' perception of the auxiliary services [4].

Bonnarens et al (2019) mapped out the different gaps that describe the unfamiliarity with and under/misuses of the auxiliary services (Figure 2). There are five gap types: listening, design and standards, service performance, communication and customer gaps. These types are placed on a timeline in four points of interaction with a service [5], the first one being pre-core service encounters. In this step, the two main gaps are listening and communication. Next, there is the initial encounter, with focus on the design and standards gap. Third, the core interaction step, which covers the listening, design and standards, service performance and customer gap. Finally, there is failure, recovery and feedback. This step contains a clear communication gap. The lack of communication and accessibility are at the root of dissatisfaction within these services [6] [7].

GAP MODEL	USER JOURNEY	Pre-Core Encounter	Initial Encounter	Core Interaction	Failure, Recovery and Feedback
	Catering	Communication*			
	Lodging	Communication*			Communication*
	Social	Communication** + physical aspects*			Communication*
	Student Advice and Student Counselling	Communication** + physical aspects**			Communication*
	Sport	Communication** + physical aspects*			Communication*
	Cultural	Communication** + physical aspects**	Responsiveness*		
	Student Association			Safety*	Safety*

* sig =< 0,05 ** sig =< 0,005

Figure 2. Gap Model (Bonnarens et al, 2019)

Why should the University of Antwerp invest in altering and adjusting their auxiliary services to its students' needs, aside from consumer happiness? Universities that provide solutions for their students, gain popularity among current and potential students [8]. By putting focus on the auxiliary services and enhancing that SLX, they can stand out among other universities. The article describes how qualitative and service design methods are used to improve these auxiliary services on campuses [9].

2 METHODOLOGIES

A student cannot judge the SLX as better if there is no commitment to improving the SLX. Therefore, it is important to understand the motivational drivers and students' current interactions with the existing services. We will specifically look for these motivational drivers by means of the following two methods.

2.1 In-Dept Interviews

First of all, in-depth interviews were conducted with six student representatives. As mentioned above, student representatives are highly engaged students who are committed to represent their peers in councils for a period of at least one year. There is an age range from nineteen to twenty-three years old, and all of the participants are from different faculties. Two of the participants are seated both in faculty student councils and in the Education Board, which is a central advisory body of the University of Antwerp. They are four female and two male participants (n=6). The duration of the interviews ranges from 28 to 64 minutes long. All participants were asked about their motivation, their engagement and their interactions with the auxiliary services. They were allowed to elaborate further on a subject matter where they deemed it necessary. The questions were devised so that the participants were forced to put everything they said in perspective. In these interviews, the focus was on the motivation, as specified above, and their extra interaction with the services of the University of Antwerp. By doing so, we focussed on an aspect that is not yet covered in the previously discussed context. However, this opened up a new avenue with regard to the transparency of the existing services and their operations.

2.2 Online Qualitative Workshop

Following the in-depth interviews, and due to the COVID pandemic, a workshop was held in MURAL, an online web application, that allows the users to write on Post-it Notes, to ideate and to brainstorm on a mutual online whiteboard. The workshop focussed on motivation and participation as well as the aforementioned terms "feedback" and "open communication". There were eight participants (n=8), two of whom are staff members of the Department of Social, Cultural and Student Oriented Services. The other participants are student representatives, two of whom were also part of the in-depth interviews. The participants' ages range from 19 to 23 for the students, and 32 to 35 for the staff members. Here we focus on three sections of the workshop. First of all, the ice-breaker aimed to link visual metaphors with the perception of STIP. This section had a duration of 20 minutes. This exercise was performed in two groups of three and one group of two participants. Within each group participants cooperated and debated their group logic. This was followed up with a debate between all eight participants. Next, a lotus blossom exercise [10] was done by the participants. After being asked about their motivational drivers, both intrinsic and extrinsic, the participants wrote these drivers down. Subsequently, the common denominators were looked into, and participants focussed on delving deeper into these drivers. At the end of this section, the participants had an open discussion about the collected answers. Finally, the last section was based on the previously gathered motivational drivers' "feedback" and "open communication". It comprises three stages. In the first stage, the participants were asked about their expectations regarding feedback within the university. The focus rested on the aspect of open communication between the services and the students. Then, the participants attempted to think outside the box following the prompt "How amazing would it be if…". After 5 minutes, both stages were discussed openly. The participants ended this section by elaborating on the Post-it Notes when they deemed it necessary.

3 RESULTS

3.1 In-depth Interviews

Each motivational driver is illustrated in Figure 3, indicated by the number of times they were mentioned during the different interviews shown in the grey and white boxes. The focus lies on feedback, open communication and witnessing progress since these were mentioned in all six interviews. Besides these drivers, there are also smaller factors in play that provide extra motivation, such as it being a learning experience or involving the sentiment of helping others. However, these are specifically linked to the representational aspect of their job description and not merely to being a student at the UAntwerp. We highlight one of the most prominent remarks from the interviews: ***"****I want to help others the way I expect to be helped, especially during my academic career".*

Figure 3. The resulting motivational drives

When looking at the positive experiences of interaction with the services of the University of Antwerp, as shown in Figure 4, a number of factors are also mentioned as motivators, such as feedback, open communication and witnessing progress. These factors are mentioned in five out of six interviews.

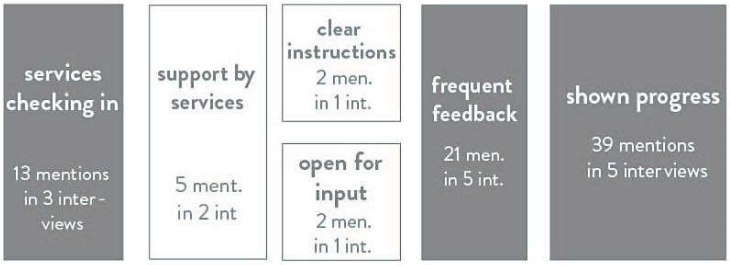

Figure 4. The factors contributing to a positive service experience

3.2 Online Qualitative Workshop

With regards to the perception of STIP, a clear pattern comes to the foreground. The four dominant metaphors are the headset (8 mentions), the pair of glasses (8), a glass of beer (5) and the hands (8). These metaphors were reported in all three group outcomes. In the open discussion, they are further explained. First of all, the headset is described as listening to the students and their necessities. Next, the pair of glasses represents the need for support and the sentiment of having STIP looking out for the students of the UAntwerp. Next, the glass of beer is described as down-to-earth and accessibility: i.e., the services and STIP must be at the level of the students. Lastly, the hands represent reaching out and supporting the students. Concluding this section, a general pattern regarding accessibility and support has arisen. In the section where we ask about the motivational drivers, similar results are reported. This can be observed in Figure 5, which maps the drivers in the grey and white boxes by the number of times they were mentioned during the different interviews.

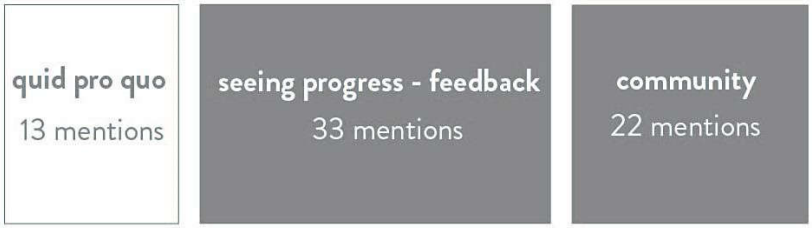

Figure 5. The resulting motivational drives - MURAL

Concluding the feedback section, six out of eight participants stated that in-house communication such as the student email and the electronic learning platform Blackboard are not efficient means of communication regarding the auxiliary services. These participants state that: *"Students perceive these messages as spam or advertisements, because they do not use their email account or Blackboard for non-course related subjects."* This leads to a communication gap between service and student.

4 DISCUSSIONS

After compiling the information from the context and the aforementioned methods, we can now focus on four insights. Firstly, many students are looking for a way to engage in the innovation of the auxiliary services and the university as a whole [11]. However, a year with an extra workload is the main reason why a majority of students do not pursue a roll as student representative. Yet, it is clear that interested students still want to participate in some manner.

Secondly, all results can be reframed as two loops: motivation-participation-synthesis-STIP-feedback [12] and awareness-contact-STIP-feedback. These loops are mutually reenforcing (Figure 6). Feedback anchors both loops [13]. It highlights STIP as the gateway to the services and generates word of mouth within the students' inner circles.

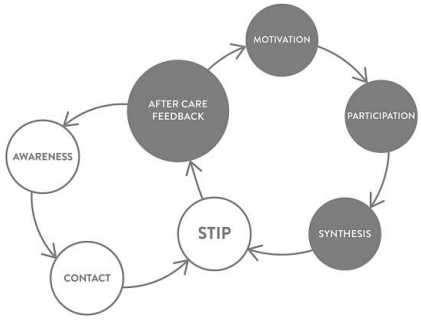

Figure 6. Two enforcing loops - Feedback as leverage point

Thirdly, we observe a matrix that encapsulates the four pillars of this interaction [12] (Figure 7). In this matrix, potential innovation ideas can be mapped. These pillars are placed in juxtaposition of each other. Horizontally, there is a difference between the intensity with which this pillar is executed. Both motivation and participation are on a student level, while the synthesis and feedback are on a service level. Vertically, the pillars are divided in emotional and physical, or passive and active. Motivation and feedback are experienced passively, while participating and synthesizing are active tasks. This matrix maps the innovative process to manage the gaps and find solutions that cover all four pillars.

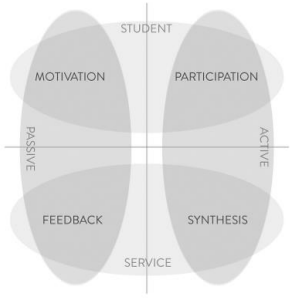

Figure 7. Four Pillar Matrix

Lastly, following our research, student life can be divided onto 6 different entry points for innovation (Figure 8). When looking at being a student at the UAntwerp, each of these entry points has their own respective potential for feedback, interaction and visibility, which are all essential to the quality of the SXL [12]. By utilizing these points, the auxiliary services are able to provide the necessary means for the student, while optimizing their inner workings to the fullest to receive the most efficient outcome.

Figure 8. Six Entry Points of Student Life

5 CONCLUSIONS

To conclude, this paper continues along the lines of previously performed research [14] and is based on an in-depth reflection by stakeholders. It is based on students' needs and serves as a guide to approach the service innovation bottom-up instead of top-down. In this paper, the students' drivers are brought into focus. The challenge is to translate their innovative potential into actual or improved auxiliary services. Our research shows a prominent presence of the need for feedback in all stages of the process, especially during aftercare [13]. Research also shows that the misuse of their work capacity prevents the current services to execute this advice properly. However, by introducing/inducing feedback, the students become more aware of the inner workings of the services. With this insight, the 50% under/misuses by students of the auxiliary services should decrease. By decreasing the work overload, there is a greater potential for innovation and meeting the actual needs of the students. Besides efficiency, the overall perception and image of the auxiliary services gets a needed boost. This can be provided by the same feedback and aftercare that is aforementioned [3]. This feedback and aftercare can take on many forms. However, we observe that the communication of the auxiliary services should be independent of course related communication. The feedback in itself should be short and concise and ideally personalized to the users. The aim is to have students propagating a renewed perception through word of mouth after having experienced positive results with the auxiliary services [15].

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