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WHAT HAVE WE LEARNT: REFLECTIONS PRE AND POST PANDEMIC ON THE TRANSITION TO ENGINEERING DESIGN EDUCATION ONLINE

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ABSTRACT
The COVID-19 pandemic had a significant impact on engineering design education and its delivery. In response to the pandemic, many universities changed to online teaching and learning, in order to reduce the spread of the virus and protect the health and safety of students and staff. The shift to online learning has presented a number of challenges for engineering design education, particularly in terms of providing students with the resources and support they need to continue their studies effectively. In July 2020, with a new online semester approaching, the Design Education (DE) Special Interest Group (SIG) of the Design Society prepared workshops with members of the Engineering and Product Design Education (E&PDE) conference and DE SIG communities to determine the challenges of moving online for the engineering design education community, and how to overcome these challenges. The workshop resulted in 12 challenges, and 5 solutions. A second workshop was conducted in September 2021 following the beginning of the return to on campus working. 19 challenges were identified and 16 solutions. Thematic analysis was used to identify relationships in the outcomes. By comparing the outcomes of the workshops, the community can better understand the gaps in knowledge of engineering design educators before and after the first full year of online learning and can learn from the innovative solutions created to overcome these challenges. This paper will share the engineering design practice changes reported by the participants of the workshops, and recommendations that will be useful to others who are similar transition in the future.

Keywords: Teaching online, online learning, digital, hybrid, COVID-19

1 INTRODUCTION
Engineering design education has experienced a recent paradigm shift. Online learning was once a novel concept where fully online courses were offered by a limited number of universities. A consequence of the global COVID-19 pandemic was a shift to online learning as the default for most universities during the period of self-isolation. For many, pre-pandemic on-campus education considered technologies to support distributed learning as a novel concept, as secondary to in-person education. The engineering design education community must consider if online learning is equal to in-person learning.
This extends to the demands of industry and students' skills development. Computer-Supported Collaborative Design (CSCD) skills are desirable to companies who operate across boundaries of location, discipline, time zone and other factors [1]. The ability of an employee to operate globally requires them to understand and utilise technology as the situation demands. In addition, it is becoming acceptable to collaborate online even when located nearby [2].
There remain challenges to overcome. Many students have struggled with the lack of access to physical studios and workshops, as well as the difficulty of collaborating with their peers and educators remotely, and the economic disruption caused by the pandemic has made it harder for some students to afford the resources and equipment needed to participate in online classes [3]. As educators, we should be aware of the challenges our students face to better support them. Design educators have been collaborating in their schools, departments, universities, communities and beyond to adapt to the new circumstances and find ways to support their students and continue delivering high-quality engineering design education. This has included a range of innovative approaches, such as using tools and online platforms to support

engineering design education and collaboration [4] and feedback [5], novel methods of teaching [5] and designing [6], as well as providing additional resources and support for students who are facing financial or technological barriers [3].
This paper discusses the outcomes of workshops held with the engineering design education community. The purpose of these workshops was to better understand the experiences of the community before and after the first online year of the COVID-19 pandemic. Section 2 will detail the methodology of the study and the workshop setup. Section 3 and 4 will detail the results of the workshops and discussion of each workshop before comparing the pre and post COVID workshops. The workshops represent a snapshot in time and the gaps in knowledge of educators who were moving into an unfamiliar teaching experience. By understanding and recording this, we as a community can be better prepared to face these or similar challenges in the future. Recommendations for future research are made.

2 WORKSHOP METHODOLOGY

In this section the methodological considerations for the workshops and study as a whole are shared. The workshops took place using a video conference with 39 participants attending workshop 1 and 31 participants attending workshop 2. Mural.co was used as an online shared whiteboard allowing all to participate in sharing ideas recorded on digital sticky notes. This paper goes beyond the workshop by analysing the pre and post pandemic experiences of educators. The outcomes can only represent the knowledge of the engineering and design communities who attended the workshop and further research is required to generalise the results.

2.1 Workshop 1 – Engineering design education: Transition to online

In 2020 the first wave of the pandemic hit, and many countries deemed it necessary to request or demand that those, who could, work or study from home. Before the first full term online, a workshop was proposed with members of the Engineering and Product Design Education (E&PDE) conference and Design Education (DE) Special Interest Group (SIG) communities. The workshop was advertised as the Design Society Chat Room to the Design Society community including those who attended E&PDE 2020 through the online webpage and newsletter shared with this community. The first workshop aimed to identify two things:

- What are the challenges of teaching online?
- How can we overcome these challenges?

The purpose of answering these two questions was to better support the engineering design education community by sharing our knowledge and experiences.

2.2 Workshop 2 – Transition to Online: What have we learnt?

In 2021 restrictions were beginning to ease and many countries were returning to in person teaching once again. For some this was a full return, and for others this was a staged return with hybrid teaching or reduced time on campus. Again, the second workshop was proposed with members of the E&PDE and DE SIG communities. This workshop was advertised as part of the schedule of the E&PDE 2021 conference where delegates of the conference and member of the Design Society community were invited to participate. The second workshop asked the same questions as the first, these were:

- What were the challenges you faced in teaching online?
- How can we overcome these challenges?

By answering these questions, the community could share their experiences of the transition to online.

3 OUTCOMES OF THE WORKSHOPS

Outcomes of the workshops are presented in *Figure **1***. Yellow and blue have been used to demonstrate connections within and between Workshop 1 and Workshop 2. Where no connection exists, this has been highlighted. The first workshop identified 12 challenges in the transition to online and five solutions to overcome these challenges. Solutions were not proposed to three of the 12 challenges. The second workshop identified 19 challenges experienced during the transition to online and 16 solutions to overcome these challenges of which one solution was proposed that did not relate to a challenge.

3.1 Comparison between workshop 1 and 2 – Gaps in knowledge

The expected challenges and experienced challenges were thematically linked to help to identify: (i) The challenges expected that were not experienced, and (ii) the experienced challenges that were not

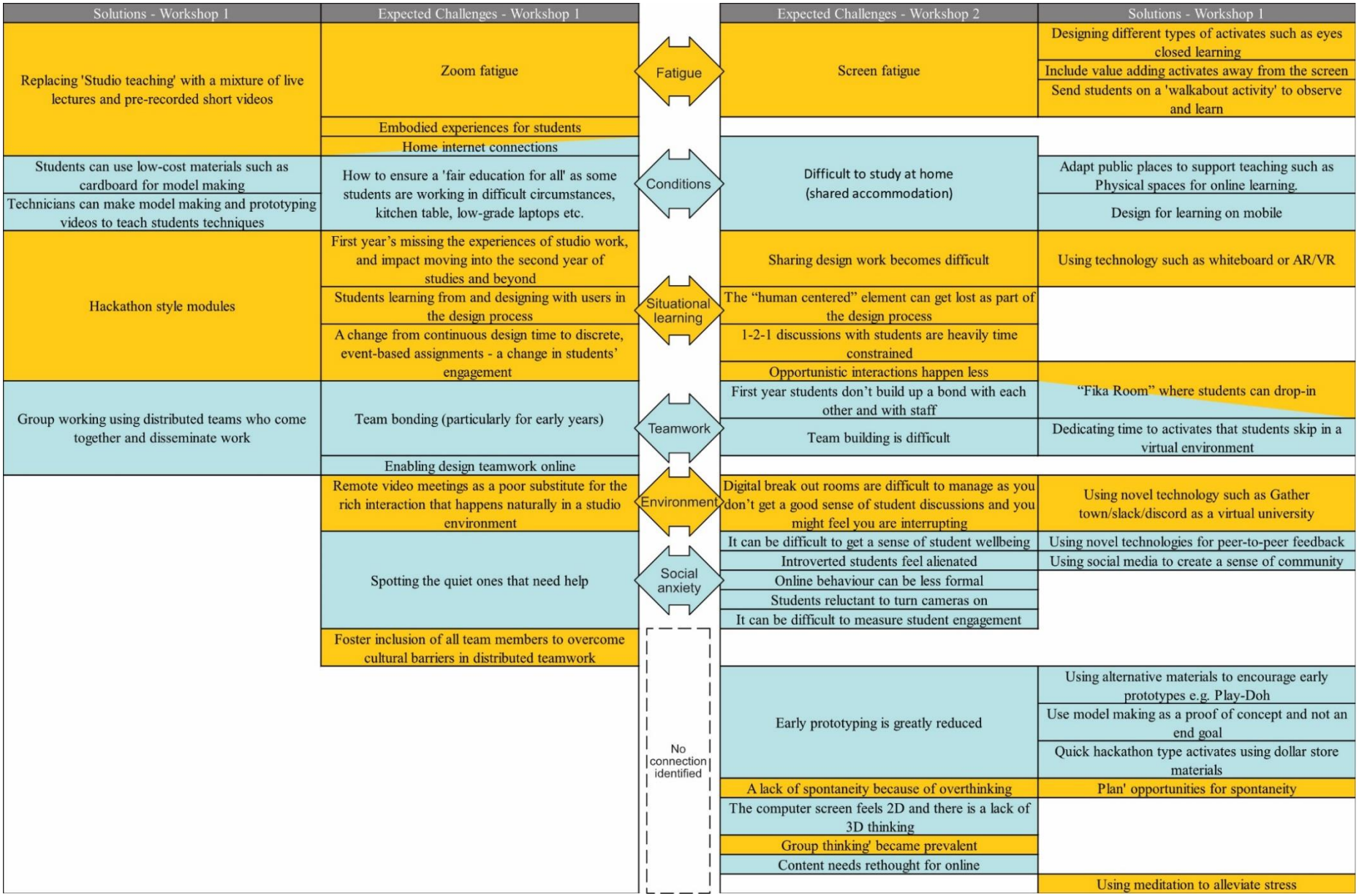

Figure 1. Outcomes of workshop 1 and workshop 2 mapped with thematic connections

expected. Comparing the expected challenges from workshop 1 and the experienced challenges from workshop 2, there were three expected challenges that were not experienced. These are:

- Remote video meetings as a poor substitute for the rich interaction that happens naturally in a studio environment.
- Spotting the quiet students that need help.
- Foster inclusion of all team members to overcome cultural barriers in distributed teamwork.

In addition, there were five experienced challenges that were not expected. These are:

- Early prototyping is greatly reduced.
- A lack of spontaneity because of overthinking.
- The computer screen feels 2D and there is a lack of 3D thinking.
- Group thinking became prevalent.
- Content needs rethought for online.

4 DISCUSSIONS

In the discussion section, the reasons for the challenges in the transition to online are discussed. The purpose of this section is to determine the research required to overcome these challenges that the engineering and product design education community can tackle in the future.

4.1 What we didn't know?

During workshop 1, two challenges were identified in which solutions were proposed in workshop 2, one challenge was identified in workshop 1 and 2 with no solution, and two challenges were identified in workshop 1 but not workshop 2.

The outcomes of workshop 1 were identified as: remote video meetings are a poor substitute for the rich interaction that happens naturally in a studio environment, it is difficult to identify quiet students that need help, and it can be difficult to encourage inclusion of all team members to overcome cultural barriers in distributed teamwork? Following the second workshop it was identified that remote video meetings remained a challenge specifically using break out rooms. Also, identifying quiet team members remained a challenge to evaluate student wellbeing, students feeling alienated, the sense that online can be less formal, students are reluctant to turn their cameras on and that it can be difficult to measure student engagement. Solutions were identified including the use of novel technology such as social media to support a sense of community and peer-to-peer feedback [7].

Fostering inclusion of all team members to overcome cultural barriers in distributed teamwork was identified as a challenge in workshop 1 which was not mapped to a challenge in workshop 2. This was suggested for reasons of: it is a perceived challenge but not a challenge that exists in reality, or the experiences observed by educators did not identify this as a problem through lack of aware ness or misidentifying the root cause of the problem. An example of this from distributed design literature is cultural attitudes towards organising and attending meetings. The behaviour of some cultures to organisation in a distributed group can be interpreted as laissez-faire. However, an educator may interpret this as the students being unprepared or busy with other classes. Therefore, the solutions they may suggest may not be appropriate [8]. Because inclusion of team members and overcoming of cultural barriers was not identified as a challenge in workshop 2 it indicates that further research is required.

Two challenges, enabling design teamwork online and embodied experiences for students, were identified in workshop 1 but not in workshop 2 which indicates that these expected challenges were not realised. These may have been identified as challenges in the moment but did not remain a challenge for a long time. Guidance from universities and the engineering design education community may have helped to overcome these challenges promptly.

4.2 What we still don't know?

Following workshop 2, five challenges were identified in workshop 2 that were identified in workshop 1, three challenges were identified in workshop 2 that were not identified in workshop 1 with no solutions, and two challenges were identified with no solution.

The six challenges identified in workshop 2 that were not identified in workshop 1 represent were unpredicted. These are: getting a sense of student wellbeing, the "human centred" aspect can get lost as part of the design process, 1-2-1 discussions with students are heavily time constrained, students are reluctant to turn cameras on and online behaviour can be less formal. Solutions remain as research

challenges. Technology can support awareness of student's progress if we identify suitable technologies and implement their use. In addition, educators need time to reflect and redesign courses improving the quality of lessons, as we typically do with in person courses based on student feedback. This could be solved by continuing hybrid teaching post pandemic. Hybrid will allow educators to continue to develop lessons online and in person for agility in the delivery method. Beyond the challenges identified, it is prudent to consider how learning can suit lifestyle and the role hybrid learning plays in this. With greater acceptance of online learning as a result of exposure during the pandemic, communities of learners have become more accepting of online learning. To support an excellent student experience, we must consider the appropriateness of learning experiences.

The three challenges, the computer screen feels 2D and there is a lack of 3D thinking, content needs rethought for online and "group thinking" became prevalent in teams, were identified in workshop 2 but were not identified in workshop 1 with no solution, represent challenges we did not foresee and areas for further research. There is extensive research into how designers think in the research field including [9, 10] and this may be extended to analyse the issue of thinking in 2D versus 3D when using digital tools. On the second challenge, rethinking content, the discussion hybrid is also relevant, and this may identify further challenges. On the third challenge, "group thinking", there is research in the wisdom of crowds [11], how people act in groups versus individually, and also in tools and techniques to support independent thinking [12]. This may be brought into the classroom where applicable.

Three challenges identified in workshop 2 with no proposed solutions were: early prototyping is greatly reduced, and a lack of spontaneity because of overthinking. Prototyping can be encouraged more. There was a solution to encouraging prototyping within workshop 1 by using low-cost materials. However, without encouragement there can be a different mindset when designing at home. Perhaps the reliance on the computer to communicate, and to progress the project puts the design student in the mindset that the project development should be digital. Educators perhaps need to rethink how to encourage a hybrid approach to design. Considering spontaneity, which was also identified in workshop 1, a solution may be to plan time spontaneity. 'Digital' can bring a logical approach which can lack creativity [13] depending on the designer and their approach. However, there is a lack of hybrid design methodologies to bridge the gap between online and offline working. There are some recommendations on how to best work in a distributed environment, but these are developed to support students, the next generation of designers. Further research is required to better understand the design processes of engineering designers in industry, understanding and highlighting that there can be co-located and distributed design activities throughout the design process.

4.3 How can future educators be prepared?

Next steps have been proposed to ensure educators are agile in their teaching pedagogy, no matter the global situation, and students are building the right knowledge and skills to be equipped to design whatever the future may bring. Recommendations are:

- Further research is required into novel ways of teaching and conducting design online. This may be the development of new software, new functionality of software or new processes and procedures to overcome technological challenges.
- Further solutions are required to better measure student welfare. It may be appropriate to bring functionality of social media to support this.
- Better prescriptive guidance from the global design, distributed design research community, and others, on how to overcome challenges of teaching and learning online; as well as an assessment of the research in this community to better understand which challenges still exist.
- Teaching hybrid classes will allow educators to improve the learning experience both online and in person. If there is a need to switch to fully online again, the quality of the learning experience can be guaranteed as there has been the opportunity to improve year on year.
- Finally, there is an opportunity to define the hybrid design process. How can a designer be agile when online or in-person? How can they easily switch between medium and ensure a robust product development.

5 CONCLUSIONS

This paper details the methodology and outcomes for a series of workshop to better understand the knowledge of engineering design educators pre and post pandemic. COVID-19 changed engineering design education and there is now an opportunity to learn from the collective experiences of the

community to ensure that educators and students are better prepared for future pandemic-like situations. The workshops have enabled a better understanding of the gaps in knowledge of educators post pandemic and an understanding of the challenges still faced in engineering design education. Recommendations have been shared to further the research field to develop solutions to problems still faced including the need to better understand novel ways of teaching and conducting design online, better measures of student welfare and to better hybrid design methodologies that are agile to external demands. Guidance should be shared from established research communities where appropriate e.g., from the global/distributed design communities. Hybrid education brings opportunities to ensure that both online and in person education remains high quality ready to change to online when required. The authors are excited to work with the community in addressing these challenges.

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