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NEW COLLABORATIVE WORKFLOWS - IMMERSIVE CO-DESIGN FROM SKETCHING TO 3D CAD AND PRODUCTION

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ABSTRACT
Digital technologies have enabled design sketching to expand into new applications and domains. Inevitably, these new forms of visualisation require re-evaluating how we use drawing to see, visualise, understand, and fabricate products and services in design education and the profession. This paper presents a selection of discoveries after the authors performed research, made presentations and mediated workshops when face-to-face collaborations and travel were impossible because of the Covid-19 epidemic restrictions. Findings add to work intending to build a modern taxonomy for design sketching and visual knowledge while accounting for immersive virtual collaboration and distributed workflows from sketching to 3D CAD and 3D printing. These are among the first indications of a drive towards synthesising historically demarked design process stages into a singularity of actions that merge and move simultaneously among ideation, design, and production. Participants in two international conference workshops shared ideas and discussed their local circumstances relating to the potential use and acceptance of new technologies already researched and adopted in other disciplines such as computer science and entertainment. A critical consensus was that the challenge of new technologies for our design education and profession is not as much about technology and its tools as the process and steps that enable change. Significantly, conversation pointed towards a strategy that enhances and augments habits in design education and the profession as the means to modify and transform culture and practice.

Keywords: Design sketching, immersive realities, technology diffusion, virtual reality, visualisation

1 INTRODUCTION
The authors are an international team who organically united in 2018 when they established the Design Sketching Special Interest Group (SIG) within the Design Society. There is broad interest in design sketching and research on visualisation as they are essential to design education, practice, and other disciplines. They believe that sketching and visualisation provide new ways to imagine, see, and solve problems. The Covid-19 pandemic, 2021, was an active period for the SIG. Members were invited to present as guest speakers at the plenary session of the 2021 Design Theory Symposium at Mines Tech Paris, France. They presented and chaired a track session at the 2021 International Design Education Research (IDER) Symposium: Explorations of Alternate Futures, Oslo Metropolitan University, Norway. They also chaired and edited a session, presented papers, and conducted workshops on "new collaborative workflows for sketching from immersive co-design to 3D CAD and production" at the 2021 Design Society (DS) 23rd International Conference on Engineering & Product Design Education (E&PDE), VIA University, Herning, Denmark, and the 2021 Design Research Society (DRS), Learn X Design International Conference, Shandong University, Jinan, China.

2 PROBLEM STATEMENT

Globalisation, a significant driver of the Industrial Age, weakened geopolitical and professional boundaries for productivity. Among this disruption, new technologies created gaps between the traditions of design education and advances made within the profession. Successful contemporary production is typically driven by interdisciplinary collaboration. At the same time, visual literacy is highlighted as one of the means for overcoming communication breakdowns and shortcomings presented by local languages (e.g., verbal, textual) and idiosyncratic specialist argot (e.g., professional jargon). Wide-ranging experts are now interested in visual knowledge as a natural next step following the adoption of design thinking methods established at the start of this century. Logically, we ought to investigate how we bridge the gap between tradition and the disruptive innovations that affect our discipline. How do we nurture a transformation in our education and practice after disruption? Design drawing and sketching (both called sketching here) are vital skills for designers and educators to develop their imagination, frame and problem-solve complex challenges, innovate and communicate better globally. This paper explores the impact of virtual reality (VR) sketching in design education.

3 METHODOLOGIES

The Sketching SIG's work utilises a methodological approach that conceives sketching and visualisation as a phenomenon with epistemological, technological, and practical implications. The group is progressively building a literature review that will help create an intellectual framework to facilitate their understanding of current use and future evolution. Some of that work is cited in this paper. The group is also dedicated to exploring the analogue and digital realities of sketching and visualisation and constructing new knowledge through collaboration and experimentation. On the latter, the two workshops held at international conferences in 2021 kept similar formats while considering variables, such as the different design education focus for each event. Characteristically, one event was dedicated to design engineering and product design, while the other event catered to a more expansive design audience.

The workshops were organised for up to twenty-five participants and comprised of two parts. They were conducted over Zoom by presenters from Australia, Netherlands, New Zealand, Spain, and the USA. Each presenter introduced their expertise and interest relating to design and sketching. Then, the background and aims of the workshop were explained. A quick overview followed on new technologies disrupting traditional ways of design, sketching and visualisation. Lastly, the team co-designed an artefact live and took the audience through each stage of the design process, ideation, design, and development which consisted of two-dimensional output (e.g., Photoshop), preparation for 3D CAD, repairing files, and converting them from virtual reality (VR) to 3D printing formats (e.g., OBJ, FBX, STL), representing new forms of production. Attendees viewed the process of multiple designers located in different countries simultaneously creating an artefact. Discussions about the process of building, communicating with each other, and the user interface were asked and answered during the demonstration. Attendees were invited to participate if they had access to a VR headset and controllers. Access to the immersive environment was available for free using Gravity Sketch and Landing Pad.

Participants from Asia, Europe, Asia Pacific, the Middle East, the Americas, and the United Kingdom were invited to discuss the workshop experience. Participants were asked to download the Miro online tool before the discussion session. Miro is an online whiteboard platform that helps groups co-create conceptual models through live ideation, hyperlinking, note-taking, sketching and visualisation. Attendees were asked to record comments, suggestions, and thoughts about their workshop experience. They could ideate visually with an analogue pen and paper (photo upload) or enter ideas through text or sketching or via digital touch screen devices or stylus and tablet.

A framework based on two interrelated and complementary theories for new technology and digitalisation were trialled for each contribution [1, 2]. A list of queries to trigger conversation and facilitate the group discussion was also provided.

- Do you use digital and immersive technologies? If so, what do you use them for?
- If you do not use digital and immersive technologies, do you see a need for them?
- If you are interested in using them, what would you need for their implementation?
- How can we reach educators, practitioners, and students to promote change?
- What activities can promote the redefinition of education and practice?

- What would it take for students and practitioners to change a habit and embrace digital transformation?

The framework was based first on the SAMR model [3] of substitution, augmentation, modification, and redefinition. These are the key factors that affect the introduction and use of new technology in education. This theoretical model proposes that the most significant impediment to introducing innovation in education is not technological but cultural. The challenge to evolve is a constant for education and innovation throughout history: how to persuade educators and students to try new things and modify and create a new vision and practice? The SAMR model identifies a process for technological change and implementation in two stages.

First is the substitution and augmentation of a group's tradition with new technology. That enhancement will be effective if the group reaches a point of modifying their habits. Ultimately, technological change will prove successful if the participants go through a cultural transformation utilising a practical process of reinterpretation, redefinition, and construction of a new vision for their future.

The second interrelated theory was based on the RACE model [4], which stands for reach, act, convert and engage. This structure was first used for digital marketing as a conscious effort by institutions or companies to implement new technologies. This was useful here as it helps unpack four key phases that start the promotion of digitalisation, engagement with it, and adoption of new technologies through effective behaviour change. The interrelated framework envisaged that participants would position themselves and their ideas on some areas of either or both sides of the habit transformation column or the digital transformation column. Workshop participants were invited to visualise their situation, annotate the pros and cons, ideate on them, cross-reference, place their textual and visual thinking in the most fitting cell and directly free sketch relationships among components in the framework (Fig. 1).

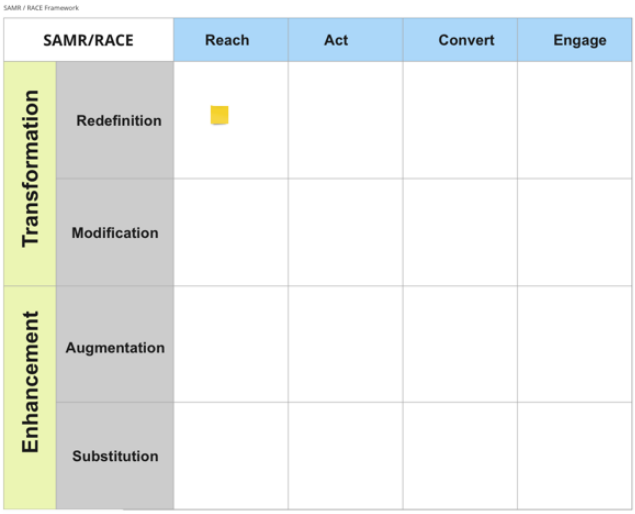

Figure 1. SAMR - RACE framework based on Puentedura [3] and Chaffey [4]

4 RESULTS AND DISCUSSION

The four events that our SIG members attended in 2021 were well received. Their approach kept a finger on the pulse of designers' and educators' concerns. There was a consensus that we need to reinterpret and redefine our tools of the trade and the competency skills for this century. In presentations at previous E&PDE conferences, research results demonstrated different steps in the evolution and extension from traditional physical design sketching taxonomies to more modern digital applications of these skills [5-7]. It was noticed that design sketching is also evolving into other domains, uses, and through new tools. Importantly, digital technologies today enable sketching for design workflows in ways never seen before. As a result, the conventional function and meaning of sketching have become more ample and undefined since it's expanded from traditional pen and paper to new know-how, such as user experience (UX), immersive experiences (e.g., VR) and new forms of distributed design and production. In parallel, sketching technology in these new platforms has become cheaper and more intuitive. Therefore, the focus is moving from cost and technicalities to prioritising concept and meaning-making, simulation, trialling of function and shaping within specific ecosystems, and testing for model failure and

sustainability, before moving to physical outputs. The global Covid-19 pandemic is also influencing change in design sketching by accelerating the adoption of digitalisation and immersive technologies.
Both workshops showed similar interest and feedback from attendees. Most participants preferred to watch the demonstration instead of participating actively, while presenters worked collaboratively from their own countries. This was understandable since most attendees did not have experience in Gravity Sketch and Landing Pad collaborations.
The collaborative environment for the software was launched earlier in 2021. Several participants preferred to give opinions rather than work with the framework provided. The demonstration provided evidence to improve understanding and defined parameters with the audience. The sketching from ideation to VR, co-designing and production, and the post-workshop discussion using Miro were used to visualise similar problems, similarities and differences between traditional and new technologies and local circumstances in different parts of the globe. The VR prototypes assisted the discussion in developing a conceptual model as preliminary validation for a future cadastral model to implement transformational change and new technologies for design education and its profession. The feedback was positive concerning how easy it was to work in VR. However, there was a nuance about the time needed to adjust to a completely immersive environment. Some hesitations were pointed out, such as concentration and focus, length of time that the activity runs before one feels unsteady and a different sense of control over the work.
Traditionally there is a sense of total control when sketching with pen and paper in a two-dimensional environment and on the computer screen when working in 3D CAD. The sketcher depends on fingers, wrist, and forearm movements most of the time. In contrast, VR creates a feeling of being within the drawing. The former feels like working from the outside in, while the latter feels like working from the inside out. When sketching in VR, the designer needs to involve both arms and the whole body to draw an object. Then, the sketcher needs to keep walking around the object and through the virtual environment space to sort the sketch out. The feeling is closer to sculpting, minus the haptic feedback, rather than traditional sketching in two dimensions (Figure 2).

Figure 2. Highlights from workshops experience

During the second part of the workshop, the trigger queries given to the attendees were also answered in similar ways. On the side of the SAMR model, participants who shared the view that design education needs substitution of technology to augment habits and improve practice said that they suffered from financial shortcomings. Most design education is constantly cash-strapped, and there is not enough money to pay for things academics currently need. Most of the time, the technology they want is not approved in the yearly budget. Therefore, design education primarily works with traditional or simpler materials (e.g., pen and paper, 3D CAD).
On the side of the RACE model, comments were made that higher management above design schools and departments tend to be risk-averse in bringing in new technology. They are not experts on current and future trends in the design profession, its practice, and the industry. It can be that management looks after the business bottom line and cannot see or act on larger local, regional, or national implications. An old premise of *"if it's not broken, don't fix it"* has previously worked well for them. Besides, there is

no assurance of a safe return on investment if they decide to support technology considered the domain of other disciplines (e.g., computer sciences, entertainment, gaming).

The attendees freely provided comments on technology and management issues. Several academics were open and upfront about their views and desires concerning the modifications needed in design education to keep up with changes. However, there was no clarity on what percentage of participants were willing to embrace and use immersive technologies in their day-to-day work in design education. Several participants from the industry contacted the first author afterwards to learn the steps and costs involved in implementing the technology in their professional practice as they saw potential value in it. On reflection, two significant differences observed between people in academia and the industry were in attitude and speed of adoption of new technology. Attitude dramatically comes down to the degree and level of control and decision-making power about what, when and how to accomplish goals. Typically, academics go from day to day, with workloads bursting at the seams. They have a high demand for their current specialisation and can only think of expanding to other areas of expertise if they are supported with time and training. The other difference, the speed to adopt technology between education and industry, is another example of how our SIG's work has shown that traditional designers can effectively use VR. However, we live in a time that technology mediates the generation and diffusion of knowledge unevenly through society and across the world. Economists say that the diffusion of technology favours a phenomenon of *"haves and have nots"*. Breakthrough technologies are generally expensive and stay for a long time with privileged clusters before they find a way to the periphery [8]. That was also the case with immersive technologies.

Visionaries promised that VR would be popular and affordable soon after its invention and sequential incremental innovations in the area. That has been an undelivered promise for more than seventy years. VR had a slow start in the 1930s with the description of *Stereopsis* [9], then in the 1950s with the invention of the first virtual reality (VR) experience theatre *Sensorama* [10] and the first headsets were introduced in the 1960s, such as *The Sword of Damocles* [11]. Now technology is catching up with the promise in the form of extended reality (XR), which includes augmented (AR), mixed (MR) and virtual (VR) environments [12].

These technologies seem closer to becoming a creative and communication tool for designers and people in general. One benefit of Covid-19 is that big digital and manufacturing corporations have invested heavily in technology that can be used during isolation and lockdowns. Meta (previously known as Facebook) bought the company Oculus and launched the first VR all-in-one headset kit for under US$1,000.00 at the start of the pandemic. Today, the same kit sells for US$299.00. Asian mobile phone companies are strategising to offer VR headsets with their phone plans as part of their marketing and sales wars. These price changes in two years have forced all previous forecasts to be recalculated; however, those still give a sense of the magnitude that immersive technologies will have on culture. At the start of Covid-19, Price Waterhouse Coopers [13] estimated that VR would increase at a rate of 18% growth per year and be used by at least 23 million professional jobs worldwide, an equivalent close to a US$2 trillion boost to the global economy by 2030. That was in addition to the then-current VR use for other purposes. In the United States of America alone, that was estimated as 52.1 million VR users in 2030.

This SIG's work has opened two opportunities for future research. One for mapping XR and other technology's role in the technology diffusion into design education and practice. The other is to research the knowledge translation inherent to technology diffusion and its effects on the new nature and division of labour in education and the industry. Representatively, we are already tracing the new landscape of design sketching that changed the minute it left two-dimensionality and moved into three-dimensions and later immersive realities. In its origin, sketching was a static mark on the walls of a cave. It was an artefact (Latin- *arte*: made with skill, artificial; *factum*: man-made) that presented a symbol and also represented animals, objects, and people in their natural environment as realistically as possible. Today, that artefact can be an abstract concept (drawn in your mind) and a physical or digital two-dimensional and three-dimensional object that requires an observer's gaze to travel around it to understand it. Immersive realities force the designer to do more. XR artefacts need the sketcher's physical involvement to experience it interactively within specific eco-systems. This artefact is an active narrative that asks designers to build a new visual grammar that considers time and a new physical-virtual space as influential variables.

Visual knowledge also needs to cover new methods and techniques for design and production. Exemplary, new software in development that fuses into one both old sequential design processes from

ideation to development and new production methodologies that synthesise old industrial assembly and waterfall project management into agile manufacturing. Gravity Sketch and Shapr3D are light architecture programming examples that work towards the singularity of sketching, design, and production in one application. In contrast, older software like SolidWorks has grown big by the accumulation of components. Jon Hirschtick's OnShape, promises and compares well against SolidWorks, which he also founded in 1993. OnShape is a browser and cloud-based 3D CAD, data management, collaboration, workflow, and analytics application. What and how we learn, teach and work is already changing with the effect of technology. We already see that labour, once clear cut and divided into niches, is also coming into a singularity that will displace several old specialisations. New professionals are now mobile and work-together-apart in synchronous and asynchronous scenarios with increasing assistance from artificial intelligence and machine learning.

5 CONCLUSIONS

This paper talks about the VR presentations and workshops performed by the authors. Outcomes of these participatory activities helped forecast that upcoming immersive technologies will have a similar impact on design education and professional practice as home computing, accompanying software breakthroughs, and the internet had in the 1980s, 1990s and 2000s. The paper also shares views from participants that design education and professional practice may also suffer from a natural human reluctance to evolve like any other profession or social group. It also proposes that there are means to keep the principles of design and education paramount while embracing technological diffusion and its subsequent modification and transformation of professional education, habits, skills and practice.

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