A Pilot Study Investigating Immersive Virtual Reality in Design Education

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Abstract

Purpose – University of Nottingham Ningbo China (UNNC) was the first Sino-foreign higher education institution established in China. As a pioneering institution for innovation, UNNC aims to develop engaging pedagogy to stimulate and motivate students. One of these innovations is the virtual reality (VR) Design Movements (DM) experience developed by V-Room and the Faculty of Science and Engineering's Product Design and Manufacture (PDM) program. This pilot study explores facets of unique educational benefits brought by an initiative to develop an immersive VR (iVR) experience for the teaching and learning (T&L) of design history and its application in the PDM program.

Design/methodology/approach – The current pilot study evaluates the instructional effectiveness of teaching scientific knowledge in the iVR context. 28 undergraduate PDM students from various year groups participated in the study. It triangulates data from questionnaires, tests, and observations, measuring affective-motivational factors crucial in VR learning experiences: these factors include motivation, engagement, and emotional states, and student performance. The questionnaires examine the participants' overall emotions, motivation and engagement towards iVR learning experiences and their usage in T&L, while the pretest and posttest of the iVR training compare knowledge increments development under the innovative learning context.

Findings – Results show high levels of motivation and engagement throughout the pilot study, with participants indicating that they enjoyed, and were excited by, the use of iVR in educational contexts. Correlation analysis on affective-motivational ratings and learning experience showed positive correlations between the two. Paired-samples t-tests indicate significant knowledge gains in DM and the Bauhaus movement after the training.

Originality/value/implications – The study contributes to the scholarly understanding of students' preference between traditional instruction and digital instruction, as well as the motivation and attitude towards the digital experiences and the use of iVR in T&L. Policy on the use and implementation of technology in the classroom could benefit from the findings; and higher education institutions involved in the design of iVR for learning purposes could likewise be informed. The key points are creative use of technology and embracing innovations such as immersive learning, gamification, and VR technology, to redefine T&L.

Keywords: Virtual reality; immersive learning; design education; motivation and engagement; digital pedagogy; educational technology.

1 – Introduction

The COVID-19 pandemic has had a profound impact on nearly all people across various fundamental aspects of their daily lives. Of key importance is the effect of the crisis on education, as it has disproportionally affected young people and therefore the collective global future. The United Nations (UN) initially calculated that approximately 1.6 billion learners in more than 190 countries across all continents had been affected (UN, 2020), and a more recent report by UNESCO, UNICEF and the World Bank paints a very bleak picture of the economic loss: "this generation of students now risks losing $17 trillion in lifetime earnings in present value as a result of school closures, or the equivalent of 14 percent of today's global GDP, far more than the $10 trillion estimated in 2020" (UNESCO et al., 2021). The sudden outbreak of COVID-19 highlighted the fragility of traditional education and weaknesses in existing remote learning practices (Watermeyer et al., 2020; Gill et al., 2020a; Noori, 2021). Although current practices were often sufficient for surviving the crisis, they brought their own challenges and proved to be limited in terms of interaction, engagement and motivation (Khlaif & Kouraichi, 2021). These limitations have further highlighted the need for innovation in the educational sector, if remote delivery and blended learning are to become part of the new normal (Zaghloul et al., 2021).

University of Nottingham Ningbo China (UNNC) is China's first Sino-foreign campus, situated in Ningbo, Zhejiang on the east coast of the People's Republic of China (PRC). It is a global university, one of three international campuses under University of Nottingham. Since the outbreak of COVID-19, the university has placed more importance on digital transformation and increased its digital capabilities and online provisions. One of the initiatives that evolved from these efforts was the digital teaching and learning (T&L) transformation strategy. This strategy aims to: explore the use of digital pedagogy and emerging technologies throughout UNNC; enhance the online and offline learning experiences for all students enrolled; and develop digital T&L provisions throughout UNNC. Its ultimate goal is providing "an education that is more than a degree", which delivers on teaching excellence and unlocks students' potential for lifelong learning (UNNC, 2020).

At the forefront of UNNC's digital transformation is virtual reality (VR), which is becoming increasingly viable and popular in gaming, entertainment and education (Baxter & Hainey, 2020). VR allows for the creation of three-dimensional (3D) worlds and virtual objects, which enables users the illusion of being completely immersed, with the ability to interact (Sala, 2016). In education, VR has been used across several fields ranging from medicine to engineering, with encouraging results and positive impact (Li et al., 2017; Soliman et al., 2021; Holly et al., 2021).

Therefore, UNNC created a special division, called V-Room, to help facilitate its digital transformation and develop innovative VR T&L-related experiences. The Product

Design and Manufacture (PDM) program collaborated with V-Room to create a VR experience that immerses users within the time period of various design movements (DMs). Throughout the 20th century, design history can be grouped into specific time periods and fashions, which are referred to as DMs. They each have a distinct style or prevailing inclination in art and design that upholds a specific philosophy or ideal, and were followed and promoted by groups of artists and designers for a defined period of time (Bürdek, 2005). The VR experience has the potential to aid T&L of design history and improve students' understanding of DMs and their key characteristics.

This study presents analysis and insights into undergraduate student views concerning the use of immersive learning (IL) practices and VR for the purposes of understanding DMs and design history. Our data is based on four components: motivation; engagement; emotional states; and student performance. These components were selected to explore how modern T&L practices can enhance the hybrid learning experience in higher education (HE) institutions. The results of this study can contribute to the ongoing discussion about the potential of IL and VR to provide novel pedagogical experiences in T&L throughout HE, while supporting the advancement of technology-enhanced and hybrid learning provisions. Ultimately, this study aims to encourage educators and educational institutions to embrace innovations and be creative with their use of technology, by creating learning experiences that exceed expectations and better resonate with students.

2 – Background

UNNC, the first Sino-foreign higher education institution, was established in 2004 (Feng, 2013) as part of China's investment into improving the quantity and quality of its higher education provision (Mok & Jiang, 2017). Within this context, UNNC has overcome many challenges over its short history and has developed many pedagogical innovations, being described as both an innovation and a center for innovation (Towey, 2014). UNNC consists of three faculties — Business; Science and Engineering; and Humanities and Social Sciences — each offering undergraduate and postgraduate programs. This study took place within the Faculty of Science and Engineering (FoSE), which consists of ten departments, each specializing in different areas. The PDM program is within the Department of Mechanical, Material and Manufacturing Engineering (M3). It equips students for a career in product design, industrial design, or the product development sector, and is aligned with the way the design process is conducted in industry today.

The authors of this paper are an interdisciplinary team at UNNC who are exploring the practical application of VR in HE and its potential for T&L, especially for highly practical subjects, such as those in science and engineering disciplines.

2.1 – Product Design Education

With the advent of digitalization and Industry 4.0 fast approaching, design education is playing a more important role in the design of products, services and systems. Product designers, often referred to as industrial designers, are innovators who need to use their creativity in combination with multiple theories and knowledge from different disciplines to conceive new products and services. These products and services solve problems and benefit users, while being technically feasible and viable for business. Design education is currently facing challenges, in both teaching theory and practical application, to solve design problems while also converting solutions into tangible products and services (Teklemariam, et al., 2014). Recently, designers are becoming more valued, because they are playing more significant roles beyond the design studio, as businesses better understand the importance of innovation to gain a competitive edge (Wrigley, et al., 2020). International corporations, such as Acer, Apple, Philips and Sony, have adopted holistic design programs that integrate design throughout the concept-to-market process, allowing designers to participate in decision-making from the initial concept phase right through to a product entering the market (Hertenstein et al., 2016; Blaich & Blaich, 1993).

Although design and designers are becoming more valued, in order to understand the significance and impact of design, it is important for new designers to understanding what has come before and how the profession has got to where it is now. Additionally, appreciating the past can be inspiring in the present and help to anticipate the future. Through the study of design history, students can relate their own interests to past activities and begin to locate themselves within the continuity of design practice (Margolin, 2000). However, we have observed that the T&L of design history can be difficult to convey and, therefore, to teach. The key issue is that design history classes can lack tangible references and thus have limited engagement, resulting in the topic being misunderstood, undervalued, and considered mundane. This problem is especially true for Chinese students, where design majors in Chinese universities place more emphasis on practice and less on theories, and can therefore have lower interest in learning design history (Zhu & Berry, 2018). In the 21st century, with the increased focus on sustainability, design education needs to cultivate new designers who understand and appreciate the past, and who are able to apply design strategies to solve the real issues that the world is facing (Kuriachan, 2014).

2.2 – VR in Product Design Education

VR has become a mature technology, with various devices now available on the market, and application in various industries. In VR simulation, a computer generates an environment through which users can maneuver and interact with objects and other simulated people ("avatars") (Schroeder & Axelsson, 2006). In essence, VR can offer solutions that are believable to our senses and that recreate real-life experiences (Hale & Stanney, 2014). These environments are usually depicted as a 3D virtual world that can either replicate real world constraints or be manipulated to bend reality (Christou, 2010). The most common forms of VR include: desktop VR (monoscopic or stereoscopic); immersive VR (iVR); collaborative systems; and mixed or augmented reality (Christou, 2010). The focus of this study was on iVR and its use in Product Design education. In iVR, users wear a head-mounted display (HMD) that projects a stereoscopic view of a virtual environment according to the user's position and orientation. iVR is often referred to as the ultimate version of VR systems, as it can be enhanced by audio, haptic and sensory interfaces (Mazuryk & Gervautz, 1995).

In literature relating to the use of iVR in Product and/or Industrial Design education, a study by Akdaş & Çalgüner (2021) showed that the use of VR/iVR in product and/or industrial design education dates back to 1997, while Hamurcu et al. (2020) suggested that studies regarding the use of iVR in design education started to increase in 2016. Both studies highlighted that many researchers only focus on one phase or aspect of the design process.

Shih et al. (2019) explored the differences in learning outcomes for iVR compared with traditional design sketching classes. They found that iVR sketching had a sense of presence and was different to the experience of sketching on paper and computer, which strengthened the spatial awareness of students and also made the interaction between relevant components and people more accurate. However, they concluded that there were differences (inaccuracies) that required adaptations in learning due to the unfamiliar interface and learning methods. Roberts et al. (2020) explored VR-based 3D modelling tools, such as Tiltbrush and GravitySketch, for their intuitiveness and intended to develop 3D forms at scale, circumventing the need for computer-aided design (CAD) software, such as Rhino and SolidWorks, which can be rigid and restrictive. They found that the subjects who fully engaged in the activity produced thoughtful sketch-models with minimum tuition. However, similar to Shih et al. (2019), they found that students lacked familiarity with the system and equipment, which caused limitations of sensory attributes, and there was a lack of industry support and tutorials. Lukačević et al. (2021) investigated engineering students' ability to understand and identify different mechanisms and their functions within an iVR environment. They concluded that iVR did not enhance their subjects' ability when compared to conventional methods.

Many researchers underline the versatility of iVR in various design processes and emphasize the importance of integrating iVR throughout the design process (Weidlich, 2009; Adenauer, 2013; Berni & Borgianni, 2020). Although the application of iVR in design processes, early design stages, and skill-based training are valid and noteworthy, there is a lack of research regarding the use of iVR in the broader T&L context of Product Design education. As highlighted in studies from Hamurcu et al. (2020) and Aldoy & Evans (2021), currently design programs are not fully exploiting the opportunities afforded by digital technology and first it is necessary to solve the issue of how it will be integrated into design education. iVR has the ability to genuinely redefine the way in which teachers and educators can create meaningful learning experiences that can motivate and engage learners in new and innovative ways. For example, Roberts et al. (2020) used iVR to test bus usability, to better understand the bus users' experience. Their iVR environment provided a platform that could demonstrate general use, alternative scenarios, and product/service interactions; and was able to locate pain points. Tang et al. (2021), used iVR as an empathy tool to increase users' knowledge and awareness of web accessibility issues. Through disability simulations, the iVR application not only introduced knowledge of disabilities and web accessibility, but also enabled users to experience accessible and inaccessible designs. This study found that participants' knowledge and awareness improved after using the iVR application, and highlighted that iVR is able to raise students' interest in learning and should be applied in more areas of T&L.

Unlike sketching and product evaluation (which can be achieved using many existing techniques and software), the aforementioned studies provided an immersive experience which was previously not feasible within the confines of a classroom setting, and redefined the T&L experience. This difference in kind is captured by the Substitution, Augmentation, Modification, Redefinition (SAMR) model (Puentedura, 2013), as illustrated in Figure 1.

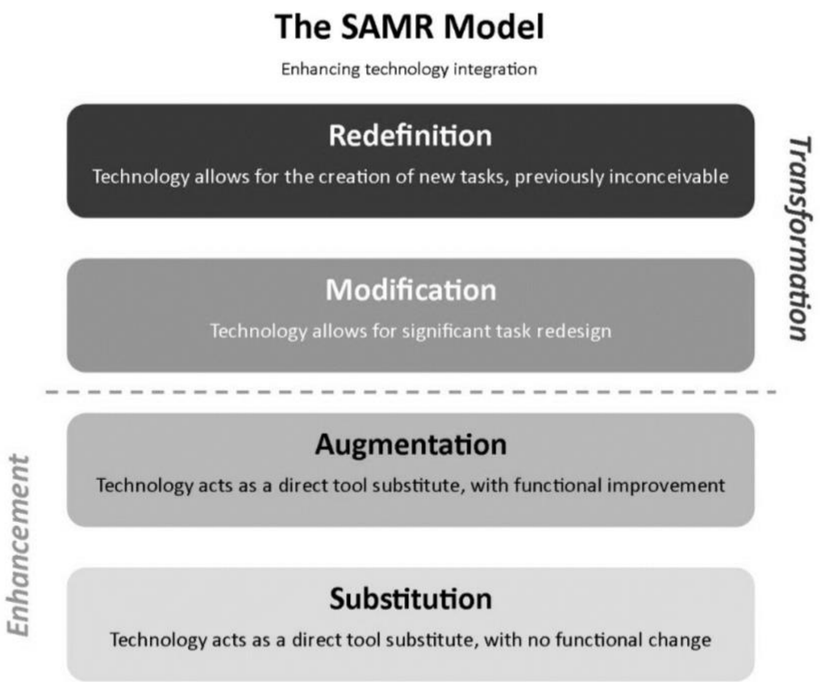

Figure 1 – The SAMR model, developed by Ruben Puentedura (2013).

The SAMR model aims to describe and assess the levels of technology integration in T&L contexts: the lowest level, *Substitution*, refers to technology as a substitute without functional change; *Augmentation* refers to technology with functional change; *Modification* describes technology as a tool for redesigning tasks; and *Redefinition*, the highest level, describes the use of technology as a tool for creating completely new tasks, which were previously inconceivable. In the design sketching study by Shih et al. (2019), for example, iVR was used at the Substitution or arguably the Augmentation level, whereas in the bus user experience study by Roberts et al. (2020) and the disability experience study by Tang et al. (2021), iVR was utilized to create new T&L experiences that were previously inconceivable in the classroom. These therefore meet the redefinition requirement of the SAMR model.

The key pedagogical question, then, is how are digital resources being employed to fundamentally transform our teaching practice and open up new T&L opportunities that were previously not feasible. Thus, this study aims to produce meaningful learning experiences that redefine T&L in the broader contexts of design education. To this end, the iVR experience developed by PDM and V-Room transports users back through time to the specific eras of different DMs, allowing them to virtually experience and interact with design history first-hand, improving their knowledge and understanding.

2.3 – Student Motivation and Engagement

For decades, educational researchers have argued that there is more to learning than "cold" processing of information (Pintrich et al., 1993): it has been described as "a process that leads to change, which occurs as a result of experience and increases the potential for improved performance and future learning" (Ambrose et al., 2010, p.3). Learning is not something imposed upon the learner, but rather it is something for which they themselves are fundamentally responsible. Learning is thus the direct result of their attitude and ability to respond and interpret their experiences (Loughran, 2002). As a result, learners can comprehend and visualize concepts, ideas and even the world in a new light, and the change in the learner can occur at the level of knowledge, attitude and/or behavior. Learning also involves motivation: learners who develop motivational beliefs and behavior are more likely to overcome challenges, invest more energy, and seek out experiences; and tend to demonstrate higher levels of academic achievement (Parong & Mayer, 2018; Dörnyei & Ushioda, 2021). An essential factor of the learning process is the learning content, and its ability and effectiveness to motivate and engage learners, as it is the learners themselves who dictate how much effort they will apply in the learning process (Mohamed & Alsayed, 2021). Bråten et al. (2007) suggest that motivating students is important, as without it teachers have no entry point. They further suggest that engagement is critical, because it is the vehicle through which classroom instruction influences student outcome and performance.

According to Maehr & Meyer (1997), motivation is a theoretical construct that can be used to explain the initiation, direction, intensity, persistence and quality of behavior. This concept of motivation is used to identify personality factors, thoughts, beliefs, and social variables that underlie observed behavior in a motivated learner (Steadward et al. 2003), which can be interpreted as the learner's personal investment in a particular learning activity (Maehr & Meyer, 1997). Therefore, we can regard motivation as the enthusiasm that encourages the learner to persist with and/or enjoy learning. It is the learner's energy and drive to work effectively and learn, in order to achieve their goals and fulfil their potential (Martin, 2003).

Figure 2 shows that we can delineate three distinct types of motivation operating within a continuum, ranging from *amotivation* (no motivation towards an activity), through to *intrinsic motivation*, with *extrinsic motivation* in the middle (Ryan & Deci, 2000). Extrinsic motivation is when motivation is influenced by external factors and/or rewards, often determined by others. Intrinsic motivation mainly comes from within the learner and is considered an autonomous and self-determined value (Ferrer et al. 2022; Legault, 2017; Chen et al. 2010).

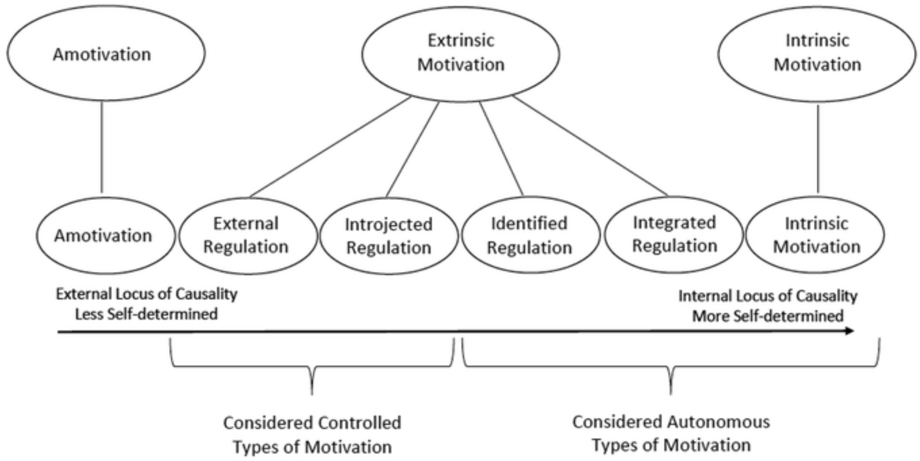

Figure 2 - Motivation Continuum (Howard, 2017)

Explicitly related to motivation is learner engagement, which is critical for enhancing learning outcomes for all learners (Schlechty, 2001; Saeed & Zyngier, 2012; Halverson & Graham, 2019). Similar to motivation, it is multi-dimensional, consisting of academic and social interaction processes (Gunuc & Kuzu, 2015; Kuh, 2005). However, engagement as a concept is not as well defined (Appleton et al., 2008). According to Skinner & Belmont (1993), engagement relates to the passion and emotional involvement when participating and completing learning activities. Schlechty (2002) describes engagement as *active*, requiring learners to be committed and attentive within the learning task, finding some inherent value in what they are doing, with enthusiasm and diligence. Blumenfeld at al. (2006) argue that motivation alone is insufficient for academic performance, while Marks (2000) closely links learner engagement to academic achievement and optimal human development. Conclusively, motivation and engagement have a reciprocal relationship: positive motivation can lead to an increase in learner engagement; and an increase in learner engagement can lead to continued success/performance, in turn resulting in further increases in motivation (Afflerbach & Harrison, 2017).

The present study aims to investigate iVR as a means to encourage and increase intrinsic motivation in learners, through the creation of innovative, interactive and engaging learning experiences.

3 – Method

This study loosely replicates a study conducted by Parong & Mayer (2018), where the instructional effectiveness of iVR is compared to a slideshow for teaching scientific knowledge and the efficacy of adding a generative learning strategy within a VR lesson is examined. The study was identified due to the similarity in the participants and learning content. All PDM students had similar learning content in slideshow format (PowerPoint presentation) within the Industrial Design and Professional Practice 1 class, during the Autumn semester of the 2nd year of the PDM program. The present pilot study was conducted in the Spring semester; therefore, all registered PDM students had, at some point, experienced similar learning content in slideshow format, prior to the iVR pilot study. This study examines whether and how iVR can motivate, engage, and resonate with learners, compared with the conventional methods currently used in the PDM program.

3.1 – Participants

The participants in this study were students registered on the PDM program at UNNC. They were from various year groups, all of whom participated on a voluntarily basis. An email invitation was sent to all PDM students, calling for volunteers to participate in the pilot test, highlighting that no prior knowledge or experience with VR technology was required. Participants in the pilot test had to meet the following inclusion criteria:

- Be registered as a PDM student at UNNC
- Had already attended and passed the MMME1014 class
- Be mentally sound to consent to participate
- Consent to participate in the study

In accordance with the University of Nottingham's Code of Research Conduct (UNNC, 2021) and Research Ethics practice, ethical approval was sought and obtained before commencing the pilot test. Furthermore, informed consent was obtained from all participants before conducting the study.

Of the 112 registered PDM students, 32 volunteered to participate in the pilot study, with four dropping out before the pilot test was conducted. Of the remaining 28 volunteers, 64% (18) were female and 36% (10) were male; 54% (16) were from the 2nd year of the PDM program and 46% (12) were from 3rd year. Interestingly, 76% of participants had used VR technology before, and 71% planned/expected to use VR in the future, which shows that they were interested in, and were actively exploring, VR technology.

3.2 – Apparatus

The iVR experience was created in Unity3D, a feature-rich, robust and dynamic game development engine with a dedicated integrated development environment, developed and maintained by Unity Technologies (Wang et al., 2010). The iVR experience was administered through the HTC Vive VR headset, which is a head-mounted VR display that provides a fully immersive experience. The headset uses "space scale" monitoring technology that allows the user to move through the 3D environment, utilizing motion-tracked handheld controllers that allow interaction with the surroundings.

3.3 – Learning Material

The instructional material consisted of a lesson about the Bauhaus design movement (Gropius, 1992) rendered in the iVR environment. Learning content related to the key design characteristics, history, iconic designs, and influential figures within the DM. The learning content was delivered through various interactive activities including interactive videos and slideshows, 3D models, games and puzzles. The iVR experience was developed in line with the theory of microlearning (Gill et al., 2020b), which focuses on a single learning outcome, is multimodal, is typically delivered in short bursts, and is highly interactive. Additionally, gamification elements were embedded throughout the iVR environment, as they have the potential to increase learner motivation and engagement (Alsawaier, 2018). Gamification is defined as the use of game mechanics, aesthetics, and thinking to engage and motivate learners to solve problems and promote learning (Kapp, 2012). The total duration of the iVR experience was limited due to concerns about VR sickness (Geršak et al., 2020), and required approximately 10-12 minutes to complete all activities.

3.4 – Instrumentation

The study included a pre-questionnaire, post-questionnaire, pretest and posttest. The pre-questionnaire collated basic demographic information, such as age, gender, and year of study. Additionally, it examined the participants' prior knowledge and experience with VR technologies, and their motivation and expectations towards VR in educational contexts. In total there were 12 multiple-choice items in the pre-questionnaire. The post-questionnaire utilized Parong & Mayer's (2018) framework for construct validity, which consists of: 14 Likert scale items that extrapolate the learner's motivation, engagement, and emotional states during the iVR experience; eight multiple choice items regarding interactions within the iVR experience; and six multiple choice items about the overall experience.

The pretest and posttest were identical, as the goal of these tests was to understand the student's preexisting knowledge about Bauhaus and see if there was any significant change after the learning phase. The test began with a simple knowledge rating (*How would you rate your understanding of Design Movements*; *Please rate your understanding of Bauhaus*), then there were five multiple-choice items and open-ended questions testing various key facts and features of the Bauhaus design movement. These were relatively simple, testing the knowledge found within the iVR experience.

3.5 – Procedure

The test procedure was uniform for all participants: completing the pre-questionnaire, pretest and a basic tutorial about the iVR experience. Once these were completed, each participant was instructed to interact with as much of the learning material as possible. Due to the number of participants and time available for the pilot study, each was given approximately seven minutes, which was sufficient to interact with multiple types of learning content. After the iVR learning phase, participants completed the post-questionnaire and posttest, and the researchers also obtained reflective comments and feedback from participants.

4 – Findings and Discussion

This section presents and discusses the significant findings from the pilot study. As mentioned in Section 3.1, it was interesting to find that a majority (76%) of participants had previous knowledge of and experience with VR technology, and most (71%) planned to use VR in the future. The results showed that 34% of participants had used VR on their mobile phone, such as with Google Cardboard; and 29% had used a desktop VR, such as HTC Vive (as used in the pilot study). The remainder (25%) had used a standalone VR headset such as Oculus Quest or Rift. This indicates that students were already exploring and interested in VR technologies. However, 60% of participants stated that they had used VR for entertainment, such as playing games or watching media content, whereas only 3% had used VR for educational purposes, which could be due to the lack of access or availability of such VR content. Nevertheless, the amount of engagement with VR technologies was considered a positive aspect, at the least familiarizing students with it.

A reliability test on the 14 affective-motivational statements, including the Likert-scale ratings of engagement, motivation, and emotional states, presented a high Cronbach's Alpha value ($\alpha = .81$). And the 6-item ratings on learning experience were also consistently reliable ($\alpha = .83$).

The participants gave significantly higher ratings for enjoyment, engagement and motivation, with an average rating from 14 items of 4.15 out of 5 (SD = .43). Examining the individual items, Item 111 ("I felt excited during the lesson") on intrinsic motivation in T&L is encouraging for educators and educational institutions, highlighting the need for VR technology and emerging technology educational interventions in general. This is supported by Mareta et al. (2021), who conducted a similar pilot test that showed that students had a very positive attitude towards using VR for learning. Items on emotional states, such as Item 10 ("I felt happy during the lesson", M = 4.61, SD = .49, and the reversed coded negative emotional Item 14 ("I felt sad during the lesson", M = 1.28, SD = .65) received the highest ratings of the study, indicating that participates genuinely enjoyed the iVR prototype and learning method. In terms of motivation, Item 5 ("I would like to learn this way in the future", M = 4.12, SD = .86) and Item 9 ("I felt motivated to understand the material", M = 4.21, SD = .67), received high ratings, indicating that the participants were motivated not only by the use of iVR in education, but also to understand the learning content within the iVR experience.

A Pearson correlation coefficient was computed to assess the linear relationship between the "average rating of motivation, engagement, and emotion", from Item "iVR general learning experience" and Item "interest of using VR in future learning". Similarly, the result shows a robust positive correlation between the two variables, $r(26) = .71$, $p < .001$. The results demonstrate that the positive affective-motivational factors during learning had promoted a rewarding learning experience, and the positive implication is carried forward to students' future learning plans.

Table 1 – Correlations between the "Rating of Motivation, Engagement, and Emotional States" and "iVR General Learning Experience", "Interest of Using VR in Future Learning"

N = 28	Motivation, Engagement, and Emotional States
General Experience	.56 (*p* = .002)
Future Learning Interest	.71 (*p* < .001)

A Pearson correlation coefficient was computed to assess the linear relationship between the "average rating of motivation, engagement, and emotion", and the "iVR general learning experience" in the questionnaire (Table 1). There was a positive correlation between the two variables, r (26) = .56, p = .002. Another correlation analysis was performed between the "average rating of motivation, engagement, and emotion" and the "interest of using VR in future learning". Similarly, the result shows a positive correlation between the two variables, r (26) = .71, p < .001. The results demonstrate that the positive motivations during learning had promoted rewarding learning experiences, and the positive implication is carried forward to students' future learning plans.

Corroborated with the correlation analysis, the researchers' observed that interaction types within the iVR experience heavily influenced participants' motivation and engagement, as overly complicated or confusing interactions broke immersion. Simple and playful interactions tended to motivate participants to engage with the learning content, whereas interactions that were complicated or difficult to operate produced negative reactions with the result that participants quickly moved on to the next learning content. The risk here, then, is one of disengagement when tasks are not properly supported, and it might be useful to think in terms of where additional, remedial tasks might be added in order to ensure that all students have access to all content. One of the benefits of VR is the greater ease with which we can collect interaction data from the end users, and this has the potential to be employed to discover any unused or ineffective content.

The engagement during the pilot study was extremely high, as reflected in item 7 ("I felt that the lesson was engaging", M = 4.39, SD = .56), and was further supported by the participants' responses in the overall experience section of the post-questionnaire, where the overall engagement received a mean rating of 8.11 (SD = 1.26) out of 10. However, during the pilot study, researchers acknowledged that the type and length of learning content significantly impacted the immersive experience and overall engagement within the iVR environment: when videos were more than two minutes long, participants lost interest and focus, and moved on to other learning content before the videos had finished. Therefore, we recommend that video content within iVR environments should be divided so that their length does not exceed one minute, as this was noted as the average time of engagement in the iVR data. Additionally, text length also highly influenced participants' engagement levels: lengthy text components (ranging from 100 to 200 words) were found to be ineffective, with participants complaining about discomfort and dizziness when trying to read it in the iVR environments. We recommend reducing text length as much as possible, employing concise statements, and where possible, completely replacing text with audio, ideally within interactive elements such as slideshows or puzzles; similar recommendations were made by Pike et al. (2019).

A paired-samples t-test was performed to compare participants' ratings of their knowledge of DMs before and after the training (Table 2). There was a significant difference between the pretest (M = 1.71, SD = .81) and posttest (M = 2.50, SD = .79); t (27) = -4.18, $p < 0.001$). Prior to the iVR experience, the majority (83.4%) of participants rated their DM knowledge between "Poor" and "Fair" (Poor 6.7%, Limited 26.7%, Fair 50%). After the iVR experience, the majority (86.2%) rated their knowledge as being between "Fair" and "Excellent" (Fair 24.1%, Good 55.2%, Excellent 6.9%). Another paired-samples t-test was performed to compare participants' ratings of their knowledge of the Bauhaus before and after the training (Table 2). Again, there was a significant difference between the pretest (M = 1.64, SD = .91) and posttest (M = 2.36, SD = .83); t (27) = -4.95, $p < 0.001$).

Table 2 – Standard error mean and standard deviation of participants' ratings of their knowledge of Design Movement (DM) and Bauhaus (BH)

N = 28	Mean	SD	SE Mean
DM pretest	1.71	.810	.153
DM posttest	2.50	.793	.150
BH pretest	1.64	.911	.172
BH posttest	2.36	.826	.156

Although this is not a reflection of their learning improving with the use of iVR, it does highlight that they became more confident about the subject matter and felt more comfortable with it than before. Although the participants generally performed better in the posttest than in the pretest, this is not a valid reflection of knowledge acquisition, as the posttest was administered directly after the iVR experience.

More Pearson correlation coefficients were computed to assess the linear relationship between the affective factors (engagement, motivation, emotion), the *rating of the overall learning experience in Bauhaus VR Prototype*, and iVR posttest performance (DM posttest and BH posttest). There were positive correlations among these variables (Table 3). The results demonstrate that positive affective factors (including the motivation, engagement, and emotions) and learners' positive overall learning experience had significantly correlated with the posttest performances.

Table 3 – Correlations between the affective factors (engagement, motivation, and emotion), the rating of the overall learning experience in Bauhaus VR Prototype, and the DM posttest and BH posttest

N = 28	**DM posttest**	**BH posttest**
Affective factors	.49 (p = .009)	.42 (p = .027)
Overall learning experience	.58 (p = .001)	.40 (p = .037)

During the post-questionnaire phase, we asked participants to give feedback about their overall experience, suggestions for improvement, and any concerns that they had. Many participants expressed excitement and interest towards learning in iVR environments, and eagerness to use VR technology for T&L purposes, as in the following:

> *"It's much more interesting than I expected."*
> *"The interaction is very interesting and learning something in this way is fantastic."*
> *"I am eager to learn this way"*
> *"I think it's very interesting for me to get the knowledge by using VR technologies. And it will increase my learning interests."*

Participants also indicated their concerns with reading within VR environments, as we observed. The following comments address the length of text components and the clarity of text, with calls for text to be replaced with visuals or interactive activities:

> *"The text is very long and if I read the text it will be a little bit dizzy for me."*
> *"It is a little bit unclear to see the text when I was moving."*
> *"It could be better if more texts could be turned into entities or animations."*

Observations from the pilot study also revealed that the amount of time each participant had within the iVR experience impacted the study. As discussed, due to time constraints, each participant was restricted to approximately seven minutes, resulting in participants struggling to interact and experience all of the available learning content in the iVR experience. Additionally, as this was the first time that the majority (70%) of participants had used VR through an HMD, it was noticeable that the initial experience was perturbing, as participants were more focused on familiarizing themselves with the VR technology and movement before engaging with the learning content. Given more time and opportunity to repeat, the feedback and results may differ, exposing a potential limitation of our study.

Overall, the results suggest that iVR can positively impact motivation and engagement, and potentially move learners through the motivation continuum towards the intrinsic side. The challenge now is for educators and educational institutions to be creative with their use of iVR, and to find meaningful opportunities to implement iVR to maximize its impact.

5 – Conclusions and Future Work

In conclusion, this pilot study examined students' motivation and engagement towards the use of iVR in design education, specifically for design history purposes. The value and importance of understanding DMs has been highlighted by many scholars (Walker & Attfield, 1989; Fallan, 2010; Whitehouse, 2009). However, DMs are difficult to convey, experience and, therefore, teach, which results in them often being misunderstood and undervalued. The findings of this study show that participants in the pilot study enjoyed and were excited by the use of iVR in this educational context, with high levels of motivation and engagement produced. Positive emotions emerged, with students highlighting their enjoyment and eagerness to use iVR more in higher education.

Further insights included that interactions and duration directly impacted the users' immersion and engagement: it is, therefore, important to consider these elements when designing iVR experiences. We suggest keeping media content as short as possible and to the point, dividing content up and limiting the duration to roughly one-minute bursts, where possible. In terms of interactions, we found that convoluted and complex interactions negatively impacted the users' engagement and overall experience. Therefore, we recommend that interactions be creative, but simple, and integrated within content where possible, so that they do not overwhelm users and distract from the learning.

As this was a pilot study, our future work will involve further refinement and iterations of the iVR experience, based on these findings. One study that will be conducted will focus solely on the interaction, duration and modality of the learning content. Furthermore, in future studies, we will aim to give each participant longer to experience the learning content. We look forward to investigating these things, and sharing our future findings.

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