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The Influence of Virtual Reality in the Built Environment Education: Evidence from Quantity Surveying Courses

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The integration of Virtual Reality (VR) in higher education has revolutionized learning experiences, yet its application in quantity surveying remains underexplored. This study addresses this gap by evaluating VR's effectiveness against traditional teaching methods in a university-level quantity surveying program. Conducted with final-year students in the 2022-2023 academic year, it comprises two experiments. Initially, students assess 2D architectural plans, followed by immersion in VR to explore the same structures. The first experiment gathers qualitative data through interviews, while the second collects quantitative data via questionnaires. Results indicate that VR notably enhances student motivation, comprehension of structural elements, and spatial navigation in virtual models, particularly in measurement and construction technology areas of the curriculum. However, the study also reveals diverse comfort levels and challenges in VR navigation, suggesting the need for tailored VR integration strategies in different subject areas. This research fills a critical gap in understanding VR's impact in quantity surveying education, highlighting its potential to enrich learning outcomes across various disciplines within the built environment sector.

Key Words: Virtual Reality, Augmented Reality, Digital Education, Digital Classroom, Interactive Teaching, Construction Education,

Introduction

Quantity Surveying is a crucial discipline within the Civil Engineering and Built Environment field, particularly concerned with cost management of construction projects. Traditional teaching methods in Quantity Surveying courses have primarily emphasised theoretical concepts, leaving students with a potential gap in their practical understanding of how these principles apply in real-world settings. Our research investigates an innovative model to bridge this gap by integrating VR technologies within a Quantity Surveying course at Liverpool John Moores University.

The study analyses the impact of introducing an immersive lab equipped with Extended Reality (XR) technology within the curriculum. We assess the effectiveness of this method of teaching based on students' experiences and learning outcomes, considering both quantitative and qualitative data. We delve into the pedagogical underpinnings, establishment process, and outcomes of this immersive lab experience, comparing pre- and post-lab student performance metrics, student feedback, and anecdotal evidence.

This case study aims to offer an evaluation of a practical implementation of XR in Quantity Surveying education, thereby adding a valuable perspective to the ongoing discourse on the role of technology in higher education. Additionally, we explore how our immersive lab setting encourages innovative thinking, facilitates the understanding of complex concepts, and enhances students' skillsets. Furthermore, our research sheds light on the extent to which such a VR-infused teaching methodology can increase student engagement, refine their understanding of theoretical concepts, and boost their overall learning experience. This case study represents a pioneering step towards the holistic integration of VR technology within the curriculum, paving the way for future exploration in related academic fields.

In the forthcoming sections, we delve into the concept of a digital classroom, focusing on the application of VR in education, specifically in construction education. This exploration is based on a thorough review of existing literature. Following this, we present our case study - the Quantity Surveying course experiment at Liverpool John Moores University. We detail the questionnaires conducted both pre and post-lab to assess the students' experiences and the impact of the VR-enhanced teaching method on their learning outcomes.

Digital Classroom

In the context of education, it is crucial to elucidate the environment in which learning occurs, commonly referred to as the 'classroom'. Traditionally, this term implied a physical location, but advancements in technology have revolutionized our understanding of this concept. The advent of technologies such as virtual and extended reality necessitates a redefinition of the classroom, pushing us beyond the confines of the term 'digital classroom'.

Though the terminology 'digital classroom' may suffice in an interim context, it may no longer fully encapsulate the vast possibilities that new technology offers for educational spaces. Surveying the existing literature, it is evident that attempts to define the attributes of a digital classroom are limited. Notably, Heleem (2022) has made a substantial contribution to this discourse by identifying key features of the digital classroom, including affordability, collaborative potential, ease of teaching processes, flexible learning, enhanced learning accessibility, and the introduction of innovative and interactive content.

While Heleem et al. (2022) emphasize the accessibility that digital classrooms afford in comparison to traditional ones, what distinguishes our approach is a commitment to interactivity and innovation in teaching. Thus, we propose a reimagining of the 'digital classroom' as an 'interactive learning experience,' a conceptual shift that reflects the changing technological landscape. From this perspective, learners are expected to engage with and reflect on their use of interactive tools within these innovative spaces. The experiential nature of this approach, positioned within the continuum of reality and virtuality, is among the focal points of this paper.

Virtual Reality

Virtual reality (VR) has evolved significantly since its inception in 1960, with the introduction of the Sensorama, a multi-sensory simulation device that combines 3D sights, sound, touch, smell, and even wind to provide a fully immersive experience (Rheingold, 1991; Mazuryk and Gervautz, 1996). VR is a computer-simulated world that allows users to interact with and change their experience due to sensory input supplied to the human brain. It is akin to an alternate universe created through technology, allowing users to immerse themselves in an interactive 3D environment that is remarkably similar to reality.

Recent advancements in VR technology, particularly in terms of visualisation and interaction, have made it more appealing to academics. In educational settings, VR has gained significant interest in the 1980s and the 1990s. It creates an environment in three dimensions for students to explore, increasing engagement and motivation. VR environments enable comprehended apprehension, comprehension, and extension, resulting in greater knowledge retention by students.

VR has been dubbed the "21st-century learning aid" due to its potential to improve educators' professional development, realistic simulations, and innovations. This new virtual environment draws students' curiosity and engagement, making it an essential aspect of higher education.

Virtual Reality in Education

To lay a robust foundation for our research paper, it is crucial to examine the existing literature and how the area of interest has been previously explored and utilised. In the following section, we highlight several major studies that provide significant information regarding the use of Virtual Reality (VR) in education. These studies have been organised chronologically for clarity and coherence.

Wang et al., (2018) conducted a review of the role of virtual reality in construction engineering education and training based on 66 journal articles. According to this study, the VR technologies used in Construction Engineering Training (CET) encompass desktop-based VR, immersive VR, 3D game-based VR, BIM-enabled VR, and Augmented Reality (AR). The paper underscored the transition from desktop to mobile formats, thus facilitating enhanced immersion and interactivity that accurately mirrors reality. Trackers and augmented reality, as the paper indicates, have been part of mobile technology since that time, primarily aimed at consumer use. VR and AR have been reported to improve student engagement and motivation, with BIM-enabled VR aiding in the spatial understanding of buildings in a highly visualised environment. The paper also identified limitations, including the focus on specific technologies rather than the full spectrum of VR development. The study suggested further research into VR compatibility with new educational paradigms and visualisation tools.

In 2020, McGovern et al., shifted the focus to enhancing business education through the use of VR, particularly to improve students' presentation skills. An experiment they conducted revealed benefits in broadening the range of skills acquired by students and enriching their overall educational experience. Additionally, the paper forecasted the impending use of 5G networks, which would allow for a faster and mainstream stream of video and audio content, leading to a more immersive experience. The authors concluded that careful planning is required to integrate VR into classrooms, and educators are encouraged to collaborate with VR companies developing educational software. This collaboration is mutually beneficial. However, they also identified challenges, including the unfamiliarity of the technology among students and staff.

In 2021, Khan et al., reviewed the integration of BIM and VR and developed a BIM to VR workflow model, incorporating student feedback. The paper asserted that VR enhances experiential learning and immersive simulations, stimulates hard-to-reach and hazardous environments, and improves traditional learning methods while adapting to student needs. Following the COVID-19 pandemic, there is a highlighted need to further develop distance learning. The paper concluded that VR is becoming increasingly affordable and accessible and could become a mainstream tool in Architecture, Engineering and Construction (AEC) education.

Lastly, Tan et al., (2022) focused on the use of AR and VR, alongside future trends augmenting AEC education. The paper reviewed 82 studies, emphasising the need for flexible educational paradigms in light of the COVID-19 crisis. The paper's findings categorise AR and VR into immersive learning, structure analysis, visual aid design tools, teaching aids, virtual operational guides, and safety training. Current limitations such as user-friendliness and accessibility were also noted. Despite these limitations, the paper summarised the conclusion that AR and VR present opportunities for educational reform.

To conclude this section, it is evident that there is a need for redefining distance learning and developing new technologies to facilitate remote interaction, particularly following situations such as a pandemic. Improvements in technology, coupled with the emergence of networks like 5G, allow for further implementation of these technologies, particularly with consumer VR and AR units available at low cost. To facilitate this, there is a need for open communication with various stakeholders in universities. Tutors and professors need to collaborate with the industry on creating and utilising case studies that allow students to practise the use of technology in education, leading to its practical use. While challenges are associated with this approach, these can be minimised through continued investigation and efforts towards developing a new paradigm that utilises digital technologies.

A Case Study in Quantity Surveying Course

In order to investigate the employment of virtual reality (VR) and immersive experiences in a classroom setting, as discussed in previous sections, two experimental applications of VR were undertaken by two Year 3 Quantity Surveying students. This focus was specifically on their cohort. The data collected from these two experimental trials were analysed in two distinct ways: firstly, utilising a quantitative method, and secondly, adopting a qualitative approach. To facilitate the ease of identification between the two different experimental trials, each will be assigned a number in the following sections. Experiment 1 will focus on the qualitative aspects, while Experiment 2 will concentrate on the quantitative aspects. The data in the succeeding sections will correspond accordingly.

Experiment 1

Design of Experiment 1

This experiment aims to investigate the implementation of Virtual Reality (VR) technology in UK higher education for students studying construction disciplines. Specifically, it aims to discern whether VR technology enhances the learning experiences of these students. Existing research posits that VR may enhance classroom learning experiences by providing more engaging and intuitive environments. This study will centre on third-year Quantity Surveying (QS) students at Liverpool John Moores University, who will utilise a VR headset to traverse three virtual worlds and then participate in a semi-structured interview based on their experiences.

Qualitative research methods will be employed to navigate this emerging field, utilising open-ended questions to identify overarching themes. Semi-structured interviews will be conducted with third-year QS students, who will have had prior experience with VR headsets. They will be asked open-ended questions regarding their perceptions of VR, its pros and cons, and its comparisons with traditional teaching techniques. The participant group will comprise an equal number of female and male students.

The data collection process will involve six students (three males and three females), each spending approximately 30 minutes exploring three different virtual world models before taking part in a semi-structured interview. The interviews will consist of 12 open-ended questions designed to stimulate discussion and allow follow-up probing questions for further examination of their responses and the topic at hand.

The experiment design will necessitate six QS students visiting the Henry Cotton LJMU building for a VR session followed by a semi-structured interview. Before using the VR headset and hand controllers to navigate the virtual worlds, students will be provided with a participant information sheet and consent form. Following their VR experiences, students will be interviewed regarding their understanding of VR in construction, its advantages and disadvantages, and whether they deem VR to be superior to traditional teaching methods.

Data analysis and evaluation will involve the transcription of audio recordings and their structuring into units of analysis. Initial classification techniques will be used to compartmentalise the raw data, which will subsequently be grouped, clustered, and coded. The coding process will include refinement, the creation of code books, and the application of labels to codes. The identified themes from the data interpretation will be used to answer the research objectives and questions, thereby creating a narrative that aligns with the students' perspectives. This approach incorporates a constructivist perspective that acknowledges the unique learning experiences of each student, recognising that diverse opinions on adopting VR in UK higher education may emerge.

Results

This experiment set out to assess the understanding of VR technology amongst LJMU students, by querying their existing conception of VR. This effectively distinguished students already aware of VR's use, benefits, and drawbacks from those less informed. Those unfamiliar with VR presented different perceptions compared to students who were already knowledgeable about VR, its use, and its pros and cons.

The six QS students demonstrated varying levels of understanding of VR; two possessed a good understanding, two a basic understanding, and the remaining two exhibited minimal to no understanding of the technology before participating in the experience. Students with a robust understanding initially envisioned a more realistic representation of virtual reality, whilst those with limited understanding had a more rudimentary grasp.

When asked about their VR experience, all six students offered largely positive feedback, despite acknowledging a few challenges they encountered during the immersive experience. Student 4 observed that it was a novel experience, however, after about 20 minutes of wearing the headset, they began to feel a bit dizzy or nauseous. Student 3 echoed this sentiment, acknowledging the distinctive nature of the technology and its pronounced divergence from conventional methods.

To gauge whether students' perceptions had altered post-VR experience, they were asked about any shifts in their opinions. All six students reported a positive change, finding the technology both intuitive and captivating. Two students noted that VR was more straightforward than interpreting 2D drawings.

To comprehend the potential benefits of VR for higher education in construction disciplines, students were asked about the perceived advantages for their discipline and which they thought would benefit the most. Architecture was frequently cited, with four students agreeing that architects would derive the most benefit from VR in higher education. Quantity surveying was mentioned twice, construction management once, and one student expressed a belief that all disciplines would benefit equally.

Student 5 suggested that all disciplines would profit from VR, instead of privileging a single one. They noted, "The industry doesn't comprise a singular discipline; we all collaborate to produce a project."

In conclusion, this experiment underscores the importance of recognising the advantages of VR technology in higher education, especially for construction disciplines. By integrating VR into the curriculum, students can acquire a more pragmatic perspective, bolster their understanding of construction processes, and augment their overall learning experience. Regarding the drawbacks of using VR in higher education, based on their experiences, five students reported experiencing nausea while using the VR headset, three reported discomfort due to its tightness, two mentioned the high cost, two mentioned the requirement of initial training, and one raised the potential of time waste if the technology failed during a lesson. Some students found the headset snug and uncomfortable and expressed concern about potential limitations regarding the duration of VR use. Others suggested that initial exposure to VR could be challenging due to a lack of knowledge and the risk of technological failure during a lesson. However, Student 1 maintained that there were no significant limitations, asserting it would take only half an hour to learn to use the equipment and navigate the environment.

Experiment 2

Design of Experiment 2

The experiment incorporated a design involving the use of Head Mounted Devices (HMDs) and hand controllers within a Virtual Reality (VR) environment, subsequently followed by a questionnaire to amass quantitative data from the participants' responses. The experiment consisted of 16 male and 4 female participants, adding up to a total of 20 participants. Participants were made aware of potential discomfort and physical sensations during the immersion process. They were introduced to the operation of the VR Head Mounted Devices (HMDs) and hand controllers to ensure their safety and comfort.

The participants, all students, were then immersed in a template model in Prospect Iris VR, a firm that facilitates the use of VR through Revit onto its software. This helped the students to gain confidence in controlling and navigating around the model. The primary aim of the experiment was to determine if VR would influence students' learning compared to existing learning methods. Meta Quest 2 headsets were employed, and two hand controllers were provided to allow participants to navigate and control what was visible through their HMDs.

The research methodology adopted was a positivist worldview, emphasising validity, reliability, and objectivity. The experiment was conducted in a controlled environment to elaborate and validate connections without external factors influencing the participants' responses. Data was collected via Jisc surveys and a questionnaire considered the most effective method owing to its simplicity and ease of completion. The data was garnered from 17 questions, which required roughly 5-10 minutes to complete. Convenience sampling was used to recruit students for participation in the experiment, as it wasn't time-consuming. Post-completion, participants were requested to remain in the room and were provided with a link to complete the questionnaire. The experimental design was selected for its capacity to immerse students in the virtual world and make individual decisions based on their experience using HMDs and hand controllers. The experiment applied descriptive analysis to assess the collected data and identify correlations among factors. A Likert scale was utilised to measure psychological constructs, such as motivation, measurable via a psychometric scale. The experiment adopted 4 and 5-point Likert scales for the questionnaire, used to compute the Relevant Importance Index (RII).

Ethical considerations were observed, with a consent form provided to students to sign, date, and return before attendance. Students were briefed on the technology involved, the risks associated with VR, and the discomfort potentially experienced once the HMDs were donned. The experiment endeavoured to provide a comprehensive understanding of the VR experience and its impact on students' decision-making.

The experiment utilised a questionnaire to collect information about students' experiences and character-specific queries pre- and post-experiment. Participants were divided into categories: those who were male, those who were female, and those with prior industry experience. It was observed that a majority of students had industry experience during their time on the QS course, a proportion that was higher than anticipated.

Results obtained from Experiment 2

The reporting of results from this experiment will focus on the following aspects: ease of use, navigation, and implementation within education.

The ease of use of the VR headset yielded positive results, with all respondents finding it easy to operate following a brief session. This level of comfort increased with extended use, as shown in an experiment with civil engineering undergraduate students reviewing structural designs and drawings. The experiment also investigated students' ability to navigate through 3D models based on their previous experience. A 5-point Likert scale was employed to evaluate familiarity, with 60% of students responding 'slightly' or 'not at all' regarding their levels of familiarity.

The latter section of the questionnaire inquired about students' confidence in navigating around the building after examining 2D construction drawings. Over half of the respondents expressed confidence, with a Relevant Importance Index (RII) of 0.715, which was higher than the RII from question 5.

The conclusion drawn from the experiment was that VR headsets can serve as an effective tool for students to gain industry experience and a deeper understanding of the industry. The experiment aimed to contrast the confidence of students using VR and 2D construction drawings for navigation within buildings. The findings indicated that 95% of students felt confident navigating around the building, with an aggregate RII of 0.84. VR facilitated learning and enhanced the depiction of 2D drawings, even for students and professionals with low spatial awareness.

In the realm of education, all students recommended the introduction of VR, with a RII of 0.93. The feedback from students suggested they would be more engaged using VR in education compared to 2D drawings. Motivation, a crucial component within education, was perceived by all students as being positively impacted by VR.

Certain modules in the quantity surveying course were listed to achieve a consensus on which modules could most effectively benefit from VR. Eighty percent of students singled out the measurement module as reaping the most advantages with the use of VR, possibly due to its specific relevance to a crucial aspect within a QS role.

Measurement within Prospect IRISVR can only be conducted by an admin account, which might have contributed to the favourable student responses. All the selected responses pertained to modules that necessitate on-site visualisation, such as construction technology, management, and measurement. This aligns with the literature suggesting that technological intervention, such as VR for an "enhanced visualisation environment", can improve teaching and learning by providing users with real-world sensations.

In the experiment, 6 out of 20 students had previously utilised VR, whilst the prior experience of 14 students was deemed non-applicable. Post a 15-minute engagement with the models, 95% of the participants reported feeling either 'very' or 'extremely' confident navigating the structure. Concerning the ease of VR headset usage, as stated in question 12, all responses inclined towards it being 'somewhat easy' or 'very easy'. Cross-tabulation of the responses revealed that prior experience with a VR HMD bore even lesser significance, indicating that users quickly acclimated to its usage. Every participant who had used a VR HMD prior to the experiment affirmed feeling 'extremely' confident whilst navigating the model.

Despite this, 40% of the students encountered issues or discomforts (e.g., cybersickness). However, no correlation was found with the prior use of a VR headset. This indicates that comfort with VR is subjective, varying from one individual to another. Over time, it's plausible that comfort levels could elevate as students get more accustomed to the feel of the headset.

Supporting this, Sagnier, Loup-Escande, and Valléry's (2020) findings reveal an insignificant correlation between cybersickness and factors such as prior usage or gender, corroborating the primary data results. It implies that the HMD usage experience is indeed individualistic and that the positive impact on motivation (queried in question 17) was perceived as 'likely' or 'very likely'.

A minor correlation was found between the discomfort or difficulties caused by the HMD and the gender of the student operating it. The gender ratio within the experiment was similar to the distribution in the third-year QS course. However, the initial recruitment aimed for a more equal gender distribution, which might have inadvertently skewed the results.

Conclusion

This paper undertook an exploration of the potential of virtual reality (VR) technology in the context of higher education, particularly within construction discipline courses such as quantity surveying. Virtual reality technology, through the provision of synthetic, immersive environments, can offer transformative benefits to students, notably enabling them to practice and enhance their abilities within a secure, controlled environment devoid of real-world repercussions.

One of the key findings from the study was the significant potential for VR to enhance educational experience in a variety of ways. Notably, students found the interactive and experiential nature of VR learning environments engaging, supporting a deeper understanding of complex topics. This was especially salient in modules such as measurement where the immersive qualities of VR can provide a much more spatially accurate experience of a construction site. This capacity of VR to deliver spatially intuitive learning experiences aligns more closely with the interests of end-users, often leading to improved participation and learning optimisation.

Nevertheless, it is also essential to balance these potential benefits against the challenges posed by VR integration. An important point of concern raised was the physical discomfort associated with extended VR headset use, contributing to motion sickness, eye strain, and disorientation in some students. Moreover, a section of students displayed a strong preference for traditional teaching methods over VR, signalling the necessity for a nuanced approach to integrating VR within higher education settings.

The study also compared the effectiveness of VR with traditional teaching methods. It is crucial to highlight that while students appreciated a blend of both approaches, the balance of preference tilted significantly towards one or the other, suggesting that VR should serve as a complementary educational tool rather than a replacement for conventional methods.

In the specific context of quantity surveying, students responded positively to the incorporation of VR, particularly in the examination of 3D models, which were found to be significantly more engaging than 2D construction drawings. However, a comparison between university teaching methodologies was less favourable, with the persistent use of 2D drawings seen as a significant limitation. Despite these challenges, the study revealed an overall positive sentiment towards VR's potential to enhance learning experiences, with all respondents acknowledging its potential benefits and expressing their openness to its broader implementation.

In conclusion, this study underscores the transformative potential of VR technology within higher education, especially in construction discipline courses, while also highlighting the challenges inherent to its adoption. To capitalise on VR's benefits without undermining traditional pedagogical approaches, institutions should ensure proper training is provided alongside small group lessons to enable comprehensive understanding of the technology. It's also essential that further research be conducted to better understand the specific modules, such as collaboration or construction technology, where VR could provide maximum educational benefit. While VR can indeed serve as a valuable adjunct tool to enrich students' learning experiences, its adoption must be carefully calibrated to account for individual student preferences and the physical demands associated with its use.

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