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USING IMMERSIVE VIDEO TECHNOLOGY FOR CONSTRUCTION MANAGEMENT CONTENT DELIVERY: A PILOT STUDY

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SUMMARY: *Construction management is considered a hands-on field of study which requires good spatial and visual cognitive ability. Virtual reality and other innovative immersive technologies have been used to facilitate experiential learning and to improve students' spatial cognitive abilities. Virtual environments have been criticized due to the gamified look of the environment. Static panorama pictures have been previously used to bring a better sense of reality and immersion at the same time in construction education. However, they cannot provide a continuous experience, and the sense of presence (immersion) is not ideal either. Immersive videos such as 360-degree videos can address this shortfall by providing a continuous experience and a better sense of presence. The use of this technology in construction education field is very limited. As a result, this study investigated a pilot experiment where a combination of 360, 180 3D, and flat videos was incorporated as an educational instrument in delivering construction management content. The content was recorded using different configurations from different body postures to further investigate the optimal way of utilizing this technology for content delivery. The content of the videos was focused on construction means and methods. Students reviewed the content using head-mounted display devices and laptop screens and answered a survey designed to capture their perception and experience of using this technology as an educational tool in the construction management field. The results show a positive perception toward using immersive videos in construction education. Furthermore, the students preferred the head-mounted display as their favorite delivery method. As a result, the prospect of incorporating immersive videos to enhance construction management education is promising.*

KEYWORDS: *Immersive Video, 360 Video, 3D video, Construction education, Virtual site visit, Mixed Reality*

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1. INTRODUCTION

Advanced visual skills are essential for practitioners in the Architecture, Engineering, and Construction (AEC) field. Virtual Reality (VR) and simulations have been used to assist students in increasing their awareness and advancing their perceptions of different concepts in AEC (Baxter and Hainey, 2019; Lucas, 2018a; Madden *et al.*, 2020). VR has numerous features, which make it an exciting tool for educational purposes. Its naturally interactive environment furnishes a more pragmatic learning experience than conventional type delivery methods such as lectures. VR technology can also provide differentiated and personalized learning experiences for students and hence be effective (Vlasova, 2020). Krokos et al. (2019) reported that students could retain more information and better employ their learning after participating in VR exercises. VR application can also affect students' engagement level. Rödström and Fredriksson (2017) explored Virtual Reality's effect on engagement in educational games and found VR simulations and applications increased engagement level of students, along with other effects of such applications on students' learning. Bodzin et al. (2020) developed An immersive game-based Virtual Reality (iVR) module in which the main goal was to learn about locations in certain watersheds. They implemented the module in an urban school and tested with 54 economically disadvantaged students and concluded that their VR application supported students' engagement with exploring the local environment. Construction programs strive to combine the traditional content with construction site visits and internships to improve the quality of lecture courses. This approach helps construction students to complement their learning experiences throughout the courses of a program. However, going on a site visit in large groups of students entails logistical challenges as well as safety concerns. Eiris Pereira and Gheisari (2019) reviewed challenges of site visits in construction programs and stated that Large class size, couse time frames, site administration, busy and crowded job sites, resource limitations along with the support-intensive nature of site visits are among major challenges to incorporate field trips in construction curricula. Djonko-Moore and Joseph (2016) investigated the use of field trips as an experiential learning tool and found distance and time are main challenges to successful implementation of experiential learning experiences through site visits. Internships are another way to enrich students' learning processes which provide valuable experience to them. However, both internships and site visits take time to implement and are not accessible to all students at all times. In addition, these two methods are not replicable. While there are many factors or hurdles that prevent students from taking advantage of these events, the repeatability feature of these educational components becomes noticeable. Internships and field trips are one time events; therefore, if students miss the whole or part of that, it will be almost impossible to repeat the educational experiment. Conversely, this feature is an opportunity in simulations and virtual environments. Students can interact many times with educational components in virtual environments without any time and location constraints. Research shows that students perceive their "mistakes" as an educational source as their lessons learned enable them to repeat the educational modules and show a correct interaction with the environment based on their previous wrong actions or decisions (Rokooei *et al.*, 2017). VR has various applications in the construction industry, including simulation of construction processes (Sampaio *et al.*, 2004), spatial construction understanding (Wang *et al.*, 2018), and construction safety (Li, 2017). This new technology provides an immersive experience to the users and allows them to experience scenarios that might be dangerous in real life. The Head Mount Display (HMD) is one of the delivery methods for such content, which provides the experience of being in a simulated environment. Besides the immersive visuals, such a technology can provide the user with spatial audio to make the experience even more realistic. Reality capture technologies such as laser scanning and immersive pictures and videos also provide a suitable platform for creating educational content in the AEC domain (Lucas, 2018b; Reyna, 2018; Shanbari *et al.*, 2016). Previously, immersive static pictures, both augmented and plain, have been used for providing students with real-like educational content (Lee *et al.*, 2020; Schmalstieg and Hollerer, 2016). However, the use of immersive videos using reality capture technology in construction management education is still in its early development compared to virtual simulations and immersive pictures. This paper discusses the development and deployment of immersive video content for construction management education by implementing this technology as an effective educational tool. A quantitative research method was utilized to describe initial students' perceptions and feedback. The data were gathered, compiled, modeled, and analyzed using statistical software, and descriptive analysis was used to describe the findings. The results contribute to the body of construction education knowledge by emphasizing the effectiveness and usability of immersive videos as a new technological tool in construction programs.

2. RELATED WORKS

Extended Reality (XR) is a broad definition that encompasses aspects of real-life (such as live events) in addition to multiple simulation technologies, including Virtual Reality (VR), 360◦ videos, Augmented Reality (AR), and Mixed Reality (MR). These forms of technology are becoming increasingly prevalent in society, along with smart wearables, opening new opportunities to implement XR into multiple fields such as healthcare, entertainment, education, manufacturing, architecture, and more (Chowdhury *et al.*, 2020). Currently, XR technology is being utilized in selected smart cities through a wireless connection (Dembski *et al.*, 2020). In the transportation industry, for example, XR technology is being applied to mobile navigation applications (apps) that can utilize a smart phone camera to provide an augmented exploratory experience (Hofmann and Mosemghvdlishvili, 2014; Kamilakis *et al.*, 2016). Other current XR technology applications include education, medical services, urban planning, and emergency response (Allam and Jones, 2021).

Outside of the construction industry, digital device use is rapidly increasing in the learning and education fields (Zawacki-Richter and Latchem, 2018). VR technology, in particular, has been titled the 21st Century's newest learning aid (Rogers, 2019). In practical application, studies have shown that students who engaged in VR learning were better able to retain and apply the information from their lessons (Krokos *et al.*, 2019). A similar result was seen in research by Zhao and Lucas (2015), who found workers showed improvements to active learning when trained with a VR program to recognize electrical power hazards. Further research was conducted by Jensen and Konradsen (2018) into applying the most common VR instrument, a head-mounted display (HMD), for learning and education purposes. The researchers reviewed situations where HMDs were successfully used to acquire cognitive, affective, or psychomotor skills and the influence of immersion and presence on HMD learning. They found that learners who utilized an immersive HMD showed greater engagement and spent longer on each defined learning task. These learners also showed a greater acquisition of cognitive, affective, and psychomotor skills at the end of their training. Jensen and Konradsen also identified a lack of content, and HMD designs with a greater emphasis on entertainment than education, as potential barriers to VR based education.

Virtual reality (VR), mixed reality (MR), and augmented reality (AR) have all been overwhelmingly incorporated into the construction industry. This change is anticipated to not only improve decision making and stakeholder communication (Elghaish *et al.*, 2019) but to lead to improved product delivery (Ammar *et al.*, 2018) and productivity (Leviäkangas *et al.*, 2017), and reduce on-site injuries and fatalities (Aghimien *et al.*, 2019). To allow for a complete digital transformation, the construction field needs to employ a variety of new technologies. To that end, a large portion of research has been conducted in the construction industry over the past twenty years on adopting these new and immersive technologies. As an example, Elghaish et al. (2020) examined the digitization of the construction industry by implementing immersive technology and UAVs, with a focus on the potential implementation, either alone or in combination, of these technologies. It was demonstrated that this immersive technology could successfully be utilized for use in construction education, team collaboration, controlling project remotely, and examining end-users' requirements.

Traditional education that is restricted to a text-based approach with limited visual cues can fail to encourage the appropriate level of engagement between the student and material, especially in the field of construction (Deshpande and Salman, 2016). In addition, a lecture-based format may be interpreted by the student as abstract and may not provide an adequate representation of real-world scenarios. Experimental education methods, however, including active learning, have shown significantly more success than these traditional methods (Lumpkin *et al.*, 2015). By utilizing the latest technology, construction students may engage in an immersive reality-based simulation that mimics real-world scenarios and allows the user to freely explore a virtual 3D simulation of a real construction project. Utilizing this advanced form of visual communication has been shown to improve the users' ability to learn, understand, and obtain construction knowledge compared to traditional students in the same environment (Eiris Pereira *et al.*, 2019; Eiris *et al.*, 2018). In construction engineering, Wang et al. (Wang *et al.*, 2018) conducted a survey of education and training-based implementation of VR with an emphasis on VR technology, application, and future directions. Five major VR technology categories were classified in this study, including desktop VR, 3D game-based VR, immersive VR, augmented reality and building information modelling. Of particular importance, it was found that the use of desktop VR improved both the student's comprehension and their motivation. Immersive VR, for this study, was defined by the use of sensor gloves and suits, HMDs, and a virtual structural analysis program and CAVE system that forms the environment by using a VR power wall of the user's location and was found to improve user's concentration. This form of VR also provided users with greater control over their training environment. VR that uses building information modelling for construction engineering was successfully implemented to visualize scheduling information, the construction site, enhance users' experience via a question-and-answer game, and allow students to engage real-world elements in VR. Overall, the application of VR was most common for use in design education, building visualization, training operational tasks, structural analysis education, and safety training. As an example, Lucas (Lucas, 2018b) looked at students' use of VR to provide construction training that emphasized wood frame assembly. An analysis of the student’s evaluation of this technology showed the use of VR positively impacted the students learning and understanding of the construction process. VR has also been utilized for various other safety-related applications, such as actively monitoring the site and informing laborers about the site's likely dangers (Cheng and Teizer, 2013), transferring the safety information to laborers (Guo *et al.*, 2012), and height safety training (Chander *et al.*, 2019, 2021). More recently, Zhoa and Lucas (2015) developed a VR platform to educate workers on electrical power hazards. The outcomes of this research confirmed better active learning by the workers using this system. Hilfert and Konig (2016) investigated the use of HMDs to test human behaviour in various hazardous job situations that generally require real-life practice when instructing novice workers. Pedro et al. (2016) used virtual content in a construction class to transfer safety knowledge by mobile-based virtual simulations.

Regardless of the advantages that VR can offer, its adaptation rate is very slow. This is arguably the result of several restraints of the technical aspects of this technology including display quality and lack of realism (Schwaab *et al.*, 2011), usability parameters (Huang *et al.*, 2010), high recognition inaccuracy rate (Gieser *et al.*, 2013), equipment upfront cost (Wiecha *et al.*, 2010), content development cost (Wiecha *et al.*, 2010), and motion sickness (Abdul Rahim *et al.*, 2012). VR settings produce computer-generated simulations, while 360° reality capture technologies create true-to-reality simulations of situations.

360° panoramas are uninterrupted stretches of the entire area surrounding a spectator, giving a sense of presence to the individual (Bourke, 2014). 360° video is a novel technology for generating immersive reality-based content. An educational gamified application that includes such technology could contribute to more involvement of the users and improve the level of user immersion (Pham, Dao, Pedro, *et al.*, 2018). Eiris et al. (Eiris *et al.*, 2018) stated that 360° panoramas use low computational processes, simple content creation process, and produce realistic simulations that are immersive. 360° reality taking techniques produce an un-modelled view of the real setting that resembles the actual reality, presenting an inherent advantage compared to other virtual reality methods. One potential downside to the level of visual freedom in 360 videos is that it allows for the ability to overlook events with a 360° video that are not purposefully highlighted in the field of view, increasing the user’s perception of their workload (Ardisara and Fung, 2018). Despite this, the immersive environment created through the use of a 360° video does allow the user to feel a stronger sense of physically being present and their involvement in that environment (Rupp *et al.*, 2019). This increased sense of being at the location may then potentially lead to higher levels of engagement and increased user interest (Harrington *et al.*, 2018). When comparing 360° videos for educational purposes among a number of platforms, it was identified that the higher the level of immersion provided by the device, the higher the sense of presence, which resulted in a higher level of user interest in the subject of the video (Rupp *et al.*, 2019).

It was found that displaying the 360° video on a VR headset instead of a mobile phone also increased feelings of immersion, user enjoyment, and was viewed as a more positive learning experience (Rupp *et al.*, 2019). Furthermore, users prefer using HMD devices instead of a flat screen such as a Laptop computer (Shojaei *et al.*, 2020). Snelson and Hsu (2020) found similar results in a review of 360° video users who responded positively to the use this technology for their learning experience, while results measuring the impact on learning were mixed. A more in-depth approach was used by Gold and Windscheid (2020) in a study to examine differences in student perception of presence, workload, emotions, teaching quality, and classroom observations by a student teacher when the classroom was presented in either a 360° video or a traditional 16:9 classroom video. Student teachers (59 total) were randomly chosen to watch a particular video format and then self-report on the aforementioned variables, and to a describe the relevant events they identified in the video. At the conclusion, this study found the 360° video resulted in a greater perceived presence by the student teachers.

Argyriou et al. (2017) discussed the production of an immersive application based on a 360° video on the value of cultural heritage education. They used a gamification framework to devise appealing experiences and improve the depth of the user’s immersion in virtual environments built with the 360° videos. Izard et al. (2017) employed

360° immersive visualization of an operating and an anatomical dissection room, to produce an immersive environment for training on equipment applications. They argued that interactive and visual learning tools motivate health science students to study more and enhance their long-term memory. Static 360° panoramas have previously been employed as a tool to visualize the safety-related aspects of construction and evaluate the severity of the dangers. Eiris Pereira et al., (2019) developed a safety education program utilizing 360° panoramas augmented by layers of information. The developed educational framework leveraged augmentations such as animations, objects, or sounds, on 360° panoramas aiming to improve hazard-identification abilities. Pham, Dao, Kim, et al., (2018) designed a static 360° panorama program to present safety-related training to learners. They verified the effectiveness of the platform by observing no analytical variations in the danger identification scores of learners who visited actual construction sites and learners who only used the immersive content. Moore et al. (2019) conducted a study to design and analyse various safety hazard identification scenarios using VR and 360° panorama techniques. Even though the users recognized VR to be cleaner and simpler to use compared to 360° content, the 360° panoramas gave a true-to-life depiction of an actual construction site which may be messy or dirty in reality and was more beneficial than VR in expressing how a construction site and related hazards may seem in reality (Moore *et al.*, 2019).

3. ENABLING TECHNOLOGY

The recent technology advancements played an important role in the current movement towards a more digitalized industry in order to improve efficiency, productivity, safety, and many other key performance criteria. The particular enabling technology for this research includes the immersive video capture cameras and HMDs. Table 1 presents a comparison of immersive video capture cameras and their main features. This table is not comprehensive by any means. There are different cameras available in the market, and each camera has different features. However, the chosen cameras and their main features satisfy the purposes of this discussion, which is to provide an understanding of the current technology's advantages and limitations. There are two main configurations of the immersive video capture cameras. The ones with two lenses beside each other capture 180° videos with depth perception (180° 3D), and the ones with two lenses on the opposite site capture 360° videos without any depth perception (360°). Lenovo mirage can only capture 180° 3D videos while Qoocam can record both 360° and 180° 3D videos. The rest of the cameras can only capture 360° videos. The highest video resolution possible currently is 5.2K at 30 frames per second (fps).

Table 1: Comparison of immersive video capture cameras and their features

Features	Insta360 One X	GoPro Fusion	Ricoh Theta V	Samsung Gear 360	YI 360	QooCam	Lenovo Mirage
Type of videos	360	360	360	360	360	360 / 180 3D	180 3D
Number of Lenses	2 x f/2.0	2 x f/2.0	2 x f/2.0	2 x f/2.2	2 x f/2.0	3 x f/2.2	2 x f/2.1
Max Video Resolution	5.7K@ 30fps	5.2K @ 30 fps	4K @ 29.97fps	4K @ 24fps	5.7K @ 30 fps	4K @ 60 fps	4K @ 30 fps
Photo Resolution	18 Megapixels	18 Megapixels	15 Megapixels	15 Megapixel	5760×2880	4096 x 2160	13 Megapixel
Stabilization	Yes- 6 Axis	Yes - 6 Axis	Yes- limited	No	No	yes - 3 axis	No
Memory	MicroSD up to 128GB	2xMicro SD up to 128GB	Internal only - 19GB	MicroSD Card up to 256GB	Micro SD up to 256GB	Micro SD up to 256GB	MicroSD up to 128GB
Battery	60 Minutes	60 Minutes	80 Minutes	100 Minutes	50 Minutes	3 Hrs	2 Hrs
Price	$399	$299	$379	$199	$159	$329	$299

In this study, a mix of four cameras, namely, GoPro fusion, Lenovo Mirage, Qoocam, and GoPro Hero (depicted in Figure 1) were used to better understand each camera's advantages and limitations for the purposes of this study. The GoPro Fusion was chosen to bring the highest quality video and the best camera stabilization into the mix. Lenovo Mirage was used due to its lower price and capability of recording 180° 3D videos. Qoocam was used due to its versatility and unique feature of being able to record both 360° and 180° 3D videos and having the highest battery runtime. The GoPro Hero was used to provide a comparison point between the conventional videos and the immersive ones in the study.

The other aspect of enabling technology for this research is the content delivery method. The content can be delivered through HMD (Figure 2) or can be used through conventional displays such as laptops, tablets, and phones. The videos can be played locally from the device or through broadband access by using intermediary providers such as YouTube or Vimeo. In this study, all the content delivery was conducted locally.

FIG. 1: Enabling technologies, Cameras

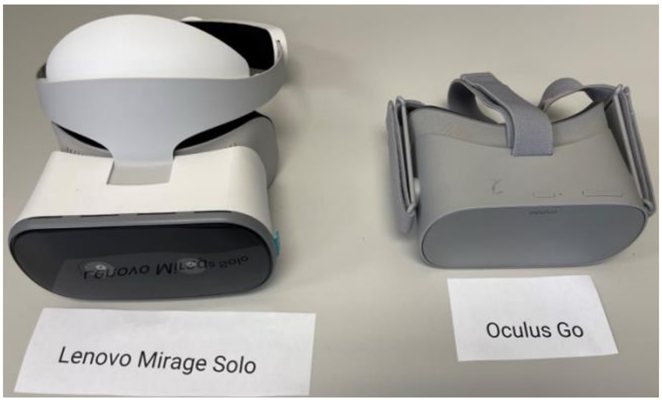

FIG. 2: Enabling technologies, HMDs (Right)

4. METHODOLOGY AND MOTIVATION

Construction processes are comprised of complex tasks involving many details. It is not always possible to provide an opportunity for every and each student to gain hands-on experience on each task or subject. Site visits, small mock-up construction, and internships can be used to complement the lecture-based education and provide students with a more realistic perception of the work process. However, each of these solutions comes at a price and accessibility of students to them varies depending on their location, status, and connections. As a result, this study explored the incorporation of 360° and 180° 3D immersive videos in construction education by implementing the system as a complementary tool to students' hands-on construction activities and evaluate their perceptions toward this educational tool through a survey. The survey was developed based on a thorough literature review in this field and following the guidelines of Groves *et al.* (2011). It was validated through 3 construction management instructors and a pilot study including 5 students (13% of the target population) to ensure face validity, internal consistency, and usability in its target population. The authors were interested in learning whether this technology might be used to capture construction processes already being done by the students and use it to transfer knowledge in order to help them to learn from their mistakes and other students' mistakes, learn the construction process, get familiar with the conditions of the job site, and construction means and methods.

This study followed an Institution Review Board approved protocol (IRB-19-170) to conduct a pilot study of trial recordings followed by evaluation through a survey by a group of college students in a four-year construction management program to evaluate the feasibility and students' perceptions of the immersive video capture technology for construction education. Trial recordings took place during the construction process of two modular tiny houses as a hand on learning method for delivering construction means and methods while getting them acquainted to other aspects of the work such as safety, scheduling, estimating, and more. The group that participated in this study was comprised of 38 students. The students watched different configurations of videos using different delivery methods and completed a questionnaire to capture their perception and initial feedback toward this technology as a complementary educational tool to their routine education process.

4.1 Content creation process

The content creation process includes raw video capture and then processing the video. Kavanagh's, et al. (2016) case study revealed that a natural point of view is critical for 360° video creation. As a result, in this study, all the video capture configurations in terms of the camera's point of view designed to be at head level to provide a natural point of view for the users. Two main approaches were tested in terms of the camera location, mounting the camera to a user and mounting the camera on a tripod. Figure 3 depicts the different configurations of the cameras' positions. Figure 3 (A) and (D) depict the use of shoulder mounts while Figure 3 (B) and (C) depict the use of helmet mounts for content recording. Figure 3 (E) shows a camera mounted on the tripod. The user mounted cameras were used to provide a close look at the user work process while the tripod-mounted camera was used to provide a more holistic view of the job site and simulate the job site surrounding experience for the final users.

FIG. 3: Different camera positions

The video processing in this study was done through each camera's proprietary software. The 360° videos were compiled through stitching two 180° videos, and the 180° 3D ones were compiled through combining the videos from two adjacent lenses together. Most of the cameras have image stabilizers built-in which stabilize user movements. However, it is also essential to use a digital stabilizer during processing to ensure the final users will not get sick when they are watching the videos. One notable issue is the importance of the fps when the user is experiencing immersive videos using HMDs. Lower fps could potentially make users nauseated and make them feel sick. There is a trade-off between the video quality and fps as higher quality videos will be captured with lower fps and lower quality videos can use higher fps. Finding the right balance between the quality of the video and fps, considering the current limitations of the technology is a challenge that needs to be carefully considered before any video capture trials.

5. IMPLEMENTATION AND RESULTS

In contrast to VR content development where the developer controls everything, recording real-time 360° video is prone to capturing unwanted and even incorrect scenarios. The video needs to be directed closely according to a previously decided scenario if the purpose is to convey a particular message in a specific way. In other words, to control the content, the creators need to control the real-time workflow in a pre-defined scenario. Multiple data collection trials were conducted where construction management freshman students were building a modular tiny house as a hands-on learning method. Figure 4 depicts a sample of a wide view 180° 3D video captured in one of the trials. The top image shows how two separate lenses see the job site and how it appeared in an HMD. The bottom picture shows the output video if the video is compiled for reviewing with a laptop or other flat-screen devices. The wide view data collection (depicted in figure 4) is aimed to capture the whole environment of the construction job site and its surrounding, so the users can experience it before even setting foot to an active job site.

FIG. 4: A sample of the wide view 180° 3D videos

Another configuration of data collection was close takes from the actual workflow using 180° 3D cameras. Figure 5 depicts an example of the close take 180° 3D videos. These videos intended to provide the users with a more detailed view of the actual construction work process with an immersive and close to real-life detail and feel.

FIG. 5: A sample of the close take 180° 3D videos

The last video configuration was the use of 360° cameras for data collection. The 360° videos were used only for close take of the construction process in this study. Figure 6 depicts two sample views of the 360° footage. It should be noted that the videos are spherical and depending on the delivery device, the user can rotate the viewpoint and watch any point of interest in the videos. This can be better seen in figure 7 where the sample shows how users using a laptop can use the directional interface highlighted with an arrow to change their viewpoint and a panoramic picture of what would a user with an HMD can experience by moving his head to change his point of view.

FIG. 6: Two sample views of the 360° videos

FIG. 7: Samples of different viewpoints and interface of 360 videos

The collected and processed videos were shown to a group of 38 construction management students to experience different video configurations with different delivery methods (HMD and Laptop). Then, the students' perception and initial feedback regarding this technology as an educational method were collected and analysed through a survey comprised of 15 questions. Following is the summary of the findings based on their feedback.

Table 2 presents the first six questions of the survey, which were Yes/No questions, and their results. All the students agreed that the quality of the videos was satisfactory (Q1). Also, it is evident that students saw a difference in the perceived information from different formats (Q2). This shows that the students agreed that all the video configurations produce satisfactory quality, but the amount of knowledge transfer is different. This issue will be further investigated in question 7 to better understand their perception about the best configuration. The majority of the students (90%, 34 students) chose that they would like to use this technology as an educational method (Q3). Furthermore, the majority (97%, 37 students) reported that the spatial sound helped in better experiencing the construction environment (Q4). Also, 35 students (92%) agreed that the spatial sound provides more awareness of the construction site surroundings surrounding (Q5). Four students reported that they felt uncomfortable during the videos, while the majority (89%, 34 students) did not feel uncomfortable during the videos (Q6).

Table 2: Survey questions 1-6 and results

No.	Question	Yes	No
1	Is the quality of the videos satisfactory?	100% (38)	0
2	Do you see or perceive more information in different formats?	100% (38)	0
3	Would you use this system to learn about construction means and methods?	90% (34)	10% (4)
4	Does spatial audio help you in better experiencing the environment?	97% (37)	3% (1)
5	Does spatial audio provide more awareness about the construction site surroundings?	92% (35)	8% (3)
6	Did you feel uncomfortable during the videos?	11% (4)	89% (34)

Questions 7-10, presented in Table 3, had multiple choice answers in which students could only pick one. These questions were designed to better understand the students' perception toward the different configurations of training videos and delivery methods. Twenty-five students (66%) chose 360 videos as being more informative, while thirteen students (34%) chose 180 3D videos, and most interestingly, none chose conventional flat videos (Q7). It clearly shows that immersive videos had an advantage over the conventional flat videos. Each student chose the same answer in question 8, where they were asked about the attractiveness of each video configuration. It can be deduced that there is a correlation between the perceived level of information and the attractiveness of each video configuration. The majority of students (79%) preferred having instruction naturally within the videos instead of having them added to the video later. (Q9). A majority of previous studies (such as Eiris Pereira et al., 2019; Eiris et al., 2018; Pham, Dao, Pedro, et al., 2018) that utilized immersive technologies in construction education had instruction and information augmentation added to the content as a post-capture process. This was mainly due to the fact that their content was based on static panorama pictures. This shows that immersive videos have the potential to be more attractive and informative compared to the commonly used static panoramas. The majority of the students (84%) preferred HMD as their favorite delivery method (Q10) while six students (16%) preferred laptops as their favorite delivery method. This is potentially because it is more immersive and they could easily change the viewpoints and focus on any point of interest.

Table 3: Survey questions 7-10 and results

No.	Question	Choices		
7	Which video configuration was more informative? (flat video, 180 3D, 360)	360 66% (25)	180 3D 34% (13)	Flat (0)
8	Which Video format is more attractive?	360 66% (25)	180 3D %4% (13)	Flat (0)
9	Is it better to have instructions within the video or added after the video?	Within 79% (30)	After 21% (8)	-
10	What was your favourite delivery method? Head mounted display (HMD) or laptop	HMD 84% (32)	Laptop 16% (6)	-

Table 4 presents questions 11 and 12 with their results. These two questions were designed based on a Likert scale to measure students' overall evaluation and usefulness of this technology in construction education in a more quantitative manner. The results show that students' overall evaluation of immersive videos as an educational method was positive (Q11) and they found this technology to be useful in construction education (Q12).

Table 4: Survey questions 11,12 and results

No.	Question	Mean	Mode	S.D.
11	What is your overall evaluation of this educational method? Likert (5-1)	3.98	5	0.87
12	How useful do you see such technologies to be used in construction education? Likert (5-1)	4.02	5	0.86

The last part of the survey was three open-ended questions (questions 13-15 presented in table 5) to capture students' feedback about the challenges, most interesting aspects, and suggestions for future use of this technology in construction education. The availability of HMD headsets, rare blurriness of video when the camera moves too much, technological glitches, cannot replace real-life experience, and lack of personal experience were identified as the main challenges by the students (Q13). Being so realistic, focus on a subject, having the viewpoint of a worker, being able to go back and learn from the past jobs, sense of presence in the 360 videos, being able to turn all the way around the construction site and see the whole site, and providing a better perspective in 3D format were identified as the most interesting aspects of this technology (Q14). Augmenting the videos with transcripts, better audio, and creating videos of ways no to do tasks as well as the right ways to do them were identified as suggestions to better use these tools in construction education (Q15). A few other comments made by students read as "feels like you are there", "in 3D view you can see everything happening around you all at once", "the videos help in explaining the process".

Table 5: Survey questions 13-15

No.	Question
13	What challenges do you see in using such technologies?
14	What is the most interesting aspect of these tools?
15	What do you suggest to better use these tools in construction education?

VR and immersive videos provide unique applications for education and many other areas. However, the use of them can cause different types of safety hazards if not implemented properly. It is paramount that educators take extra caution when they are deploying such a technology in their classrooms. These safety hazards can be categorized into physical and physiological. Posture, hygiene, and immersion injuries are among the physical ones. Immersion injuries such as spatial collision are important when multiple users are immersed in a virtual environment and are operating in each other vicinity. The users are technically blind in the real world, and there is a possibility that they collide with each other if the safe operation of multiple users is not carefully planned beforehand. In such cases, it is recommended to use designated physical space for each user to minimize the risk of collision. Furthermore, a third party observer can be used to intervene when two users get close to each other. Physiological issues include visual and motion sickness. It is recommended that students take some time to get familiarized with the virtual world before the start of the educational experience. Also, they need to be aware of the motion sickness symptoms so they can stop the experience before pushing themselves over their limits.

6. CONCLUSION AND FUTURE WORK

This study implemented immersive video capture (360° and 180° 3D) in a freshman construction management class as a complementary tool to the students' conventional education and evaluated the students' perception and initial feedback through a survey. The results showed that the outlook of using immersive videos for construction education is positive. Students reported that they perceived a different amount of information in different configurations. Most of them preferred 360 videos, closely followed by 180 3D videos. Also, it was observed that spatial sound helped the students to get a better feeling and understating of the surroundings. High-quality videos with high frame rates are a critical underlying requirement for this technology to become useful. The quality level that the currently available equipment can produce is satisfactory. However, improvement in this area will impact user acceptance and the wide adaptation of this technology as an educational method.

Traditional media for teaching purposes may face challenges, including the difficulty of the camera used to record the classroom's entirety. This may be overcome through the use of a 360° video that can record in all directions and change the focal point based on the perspective of the user. In this way, the video provided is customized to the student's needs, eliminating the need for the camera operator to predict the most appropriate angles and allowing for a more tailored experience. It could reasonably be assumed that greater control of the user's ability to observe their surroundings would increase the validity of users' ratings of the quality of teaching and their ability to assimilate information. Educators may also utilize this aspect of the 360° video to highlight key features of the content in real-time without having to set up the camera at the most appropriate location in advance.

An advantage of this educational method is the much higher outreach and increase accessibility due to the possibility of using broadband and remote access to the material, which would give the user an immersive and real-like experience of the content without being near there. Such technological tools enable construction programs to embed new educational components in their curricula and effectively transfer the construction knowledge. These tools can also engage the new generation of students who typically grow and use technological features in their daily lives. However, while statistical measurements show the suitability of the sample size in this study, the generalization of conclusions is not warranted. A larger sample size, a more diverse educational subject list, and students' different class levels will enhance the power of analyses. Also, a longitudinal study can address the consistency and robustness level of findings at different stages. Future work for this research includes a more in-depth study with more participants and a more comprehensive survey followed by quantitative analysis with a comparison of conventional educational methods, virtual simulations, and augmented static panoramas. Content creation from multiple viewpoints of the same content to allow the user to change the viewpoint plus gamification of the content using rules and user interfaces is also part of the future direction for this study.

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