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VIRTUAL SITE VISITS IN CONSTRUCTION MANAGEMENT EDUCATION: A PRACTICAL ALTERNATIVE TO PHYSICAL SITE VISITS

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SUMMARY*: Construction site visits and hands-on experiences are among the important instruments for educators in construction engineering and management to provide students with valuable knowledge and more engaging learning experiences. However, in addition to its existing logistical challenges, the COVID-19 pandemic has made site visits even more inaccessible as in-person classes and site visits moved to distant learning or got canceled. In a distance education system, conducting a physical site visit is not an easy task. This study focuses on the use of virtual site visits in construction and experiencing virtual hands-on training using immersive videos. Three types of video formats were used as the main content delivery methods in this pilot study namely, 2D flat, 360-degree, and 180-degree 3D videos. This method was adopted and tested in two courses that were previously face-to-face, which were then shifted to an online format due to the COVID-19 pandemic. The use of immersive videos gave students who would not have the ability to experience a physical site visit, the opportunity to experience the construction site environment and receive educational direction during a pre-recorded, hands-on, immersive video project. The goal of this study is to understand students' experience with the provided technology, necessary improvement, implications for future research, and the potential implementations of this technology. A costume set of questionnaires was designed to retrieve students' feedback on their experience which includes a comparison of different content delivery methods and four other study measures: knowledge retention, sense of presence, user experience, and overall satisfaction. Multiple statistical analyses were conducted on the collected data to provide both descriptive details and further insight into the study parameters and their relationship with each other and between different parameters.*

KEYWORDS: *Virtual site visit, Construction education, 360-degree video, Immersive Video*

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1. INTRODUCTION

Site visits provide a multitude of benefits to students in the field of construction by offering hands-on, real-world experience. These visits are an example of the learning process known as ‘experienced-based learning’, a learning model in which students are directly involved in learning opportunities (Baker et al. 2002). Research has shown that this experienced-based learning not only allows students to grasp core concepts better but also results in higher student enthusiasm (Janovy et al. 2009). Other factors that contribute to students' comprehension of the material and their ability to meet predefined learning goals include an understanding of the time element of relevant construction activities, an ability to visualize the related concepts, and an understanding of the different project roles (Eiris et al. 2018).

The COVID-19 pandemic forced higher education to move fully to distance mode education in an emergent and unplanned manner. This sudden change posed many challenges in meeting the educational goals of these courses. Specifically, site visits, hands-on, and project-based teaching content suffered the most, as this type of education and content more naturally requires a face-to-face delivery method. This challenge motivated the authors to implement a virtual site visit using 360-degree videos for their students and evaluate their feedback systematically through a survey. The virtual site visits allowed us to provide a fruitful experience and site visit exposure for the students in the semester filled with uncertainty and anxiety and showed us how this technology could become a tool for future use in order to overcome some of the barriers of a typical site visit. For instance, the substantial amount of information the student is expected to absorb in the short time of a site visit has been previously reported as a barrier to the efficacy of construction site visits (Eiris et al. 2018). The use of 360-degree videos and virtual site visits can solve this issue by allowing the students to experience the site visit at their own pace and revisit the moments they feel they need more time to absorb. Furthermore, virtual site visits can provide better accessibility, and increase equity in education in rural areas and locations where access to certain types of projects is not possible.

The remainder of the paper is organized as follows. Related works including the background of construction site visits in education, literature review of existing construction virtual site visits, and potential limitations of the virtual site visit are covered in Section 2. Section 3 describes the rationale and motivation for this research. Section 4 presents the methodology adopted in this study which includes video content creation, design of the questionnaire, formulation of study measure, and the data analysis method. Section 5 provides the results and discussion consisting of both descriptive and inferential statistical analysis of the collected data. Finally, the conclusion and future works will be discussed in section 6.

2. BACKGROUND

2.1 Construction Site Visits in Education

Construction site visits and experience-based learning sessions allow students to better understand the dynamic environment of a construction site and learn how to communicate with industry professionals. Site visits allow students to gain further insight into how textbook theories and concepts are applied within real-world settings. There, students can obtain direct and hands-on experience with construction processes, materials, safety practices, and equipment. These are invaluable educational opportunities which are not possible within the confined classroom environments. These forms of active learning often improve student retention compared to pure classroom-based learning. By interacting with professionals, students tend to gain more perspective on various construction roles, careers, and responsibilities, thereby improving their communication, decision-making, and teamwork capabilities. However, only a limited number of courses can offer these site visits (Blinn et al. 2015). A research survey found that most construction faculty members stated they had only 1-2 site visits, or none at all, for each core course in their program (Eiris Pereira et al. 2019). In this same study, faculty members recognized that it was highly beneficial for students to observe and engage in real-time with a construction site and the professionals involved. Respondents indicated that the most considerable barrier to engaging in more site visits is related to spatiotemporal challenges such as scheduling, planning, and physically transporting students. Additionally, only a limited percentage of faculty members reported taking advantage of virtual site visits for experienced-based learning. Several other barriers exist that prevent site visits from being fully utilized in construction education, one of which is student safety. As students may be brought to a potentially hazardous site, these concerns are an understandable impediment to using site visits for experience-based learning. Bringing a large number of students to a real, working construction site, and the safety challenges involved typically lead to limiting the number of site visits overall, and a reduction in the educational quality of the remaining visits (Mills et al. 2006). In addition to safety concerns, it may be increasingly difficult to schedule site visits due to ever-increasing class sizes and budget concerns (Leydon et al. 2013). On behalf of the schools involved, a study by Leydon et al. (2013) also identified financial burdens, a lack of administrative support, a limited number at local construction sites, a limited willingness of the teachers to participate, planning issues, and environmental conditions as other barriers to site visits.

A potential solution to these challenges is implementing virtual construction site visits by using digitally created or construction-sites recorded content and utilizing advanced devices like tablets, computers, and virtual reality headsets for content delivery. Virtual site visits can mitigate the safety challenges at the hazardous site by eliminating real-world risks, allowing students to safely engage with the site environment. In addition, there are also no limitations on the number of participants, scheduling constraints, or any geographical limitations of the site visit. This allows students to experience the virtual site visit together simultaneously, bypassing the group size restriction for the in-person visits. The virtual site visits can also align with the course schedule, without restrictions based on construction site availability and project timelines. The content is available on demand and students can re-visit the virtual site multiple times to reinforce the learning. Also, a virtual site visit is an economical alternative to the traditional site visit, requiring only a one-time investment and minimal maintenance and upkeep. The scalability, flexibility, and cost-effectiveness of virtual reality site visits significantly expand the educational opportunities for students compared to traditional in-person site visits.

2.2 Construction virtual site visits and related technologies

Engineering can be considered a more practical field than other, more traditional professions; and as a result, traditional teaching methods may not be appropriate. Therefore, a program that takes a more hands-on approach and utilizes innovative methods for assessment, teaching, and learning, could provide students with a more competitive education. Such a program would allow students to understand how engineering concepts are applied both in theory and practice. Research has indicated that these factors are especially important for students with limited knowledge of the subjects, who are expected to learn a large amount of information in a short period (Paez et al. 2015). With field visits becoming an increasingly difficult event to organize, programs must try to utilize new methods to obtain the same level of direct experience, while still keeping students safe and engaged. One option to achieve this is by utilizing virtual site visits. Studies have shown that virtual site visits can successfully duplicate the lessons gained from real-world experience when used either as an alternative to or in addition to, in-person field studies (Spicer et al. 2001). The options for designing these instructional virtual site visits are nearly unlimited. Different technologies could be employed, for example, to provide a direct observational experience, or to generate a more interactive 3D environment. The concept of virtual site visits has already received considerable attention from experts. For example, in 2009, virtual visits to sites around the world were provided to students to teach them key analytical skills for handling real-world scenarios (Jacobson et al. 2009). In addition, a study by Lee et al. (2009) compared traditional classroom learning to virtual reality (VR) based learning programs. It was determined that the VR environment had a positive impact on the student's perception of the quality and satisfaction of their education and their overall academic achievement. In 2015, VR was utilized for the study of astronomy, involving five educators and 20 students (Hussein et al. 2015). More recently, virtual site visits were used in a tertiary-level geology course to teach introductory students (Jolley et al. 2018).

Reality-capturing and VR technology are the two fundamental technologies used for the development of virtual site visits (Wen et al. 2020). There are two different ways of using reality capture technology for site visit content delivery: using the real-time content capturing method and the pre-captured content method (Wen et al. 2020). The first method is site visit delivery by using real-time capturing technology. In these settings, students stream real-time video and images directly from the camera installed on job sites. They can also switch to different cameras and capture necessary images if needed (Arslan 2003). Further improvement was made with the addition of a capability that allows students to communicate with the associated individual on-site in real time (Jaselskis et al. 2011). In the pre-captured content method, the surrounding environment will be first captured in images and 360-degree panorama format (University of South Australia et al. 2019). Then the recorded content will undergo a preprocessing stage, where educators can design the interactive environments to create students' learning experience. The content can be either designed to be viewed by the traditional computer display or by the head-mounted display devices. Wen et al. (2022b) create a storytelling platform by using 360-degree immersive content to give students the narrative of a success story in the electrical industry with the goal of motivating and attracting young students to the field. Additionally, in 2019, geoscience students in both high school and undergraduate programs began using virtual field trips as a learning method (Mead et al. 2019). The use of 360-degree videos has been shown to have a positive impact on the construction education (Shojaei et al. 2020). Studies by Eiris, Wen, et al. (2020) and Eiris et al. (2021) have introduced a construction virtual site visit platform using panoramic 360-degree pictures guided by a virtual human, helping students to practice problem-solving. They also used 360-degree videos to create a safety training platform to foster the transfer of safety knowledge to practitioners and students in the construction industry (Eiris, Gheisari, et al. 2020).

Instead of capturing the existing real-world data, virtual reality technology, on the other hand, uses computer-generated content to create a virtual environment (Warwick et al. 1993) that provides students more freedom to explore the simulated space and object. Two steps in developing the virtual site visit with VR technology are using modeling software (e.g. Revit) (Zhang et al. 2017; Eiris, Gheisari, et al. 2020) to create the necessary 3D model for the environment and creating an interactive VR experience by using a gaming engine (e.g. Unity or Unreal Engine) (Maghool et al. 2018; Lucas 2018). Sun et al. (2022) have developed a virtual collaborative platform for online site visits that aims to provide students with extensive learning experience through an interactive environment and collaboration capabilities. VR technology was also used in conjunction with 360-degree videos in the creation of a virtual safety training platform for students and professionals in the construction sector (Eiris, Gheisari, et al. 2020). Similarly, Pham et al. (2018) successfully made use of a 'Virtual Field Trip System' (VIFITS) that used 360-degree panoramic VR technology to provide virtual visits for a construction safety class. Wen et al. (2022a) have also proposed another interactive virtual site visit platform where the participant can communicate with another conversational virtual guide which helps them better explore the virtual construction site.

Overall, virtual site visits have been found to represent a viable option for providing environmentally friendly, innovative, and hands-on student learning. Furthermore, the promises of virtual site visits go beyond distant education and could increase the accessibility and equity of education in rural areas, and under-resourced institutions, by providing experiences to students who will not be able to engage in a close-up visit to specific locations/projects. Therefore, applications of immersive video virtual site visits, especially in fully distance education settings, should be further studied.

2.3 Potential limitations of the virtual site visit

One of the potential drawbacks of conducting the construction site visit virtually is the lack of physical interaction within the construction site environment (Gandhi et al. 2018). Virtual site visit lacks the ability to provide student the unscripted conversations with workers. On site, students can ask questions and interact with builders and contractors which can create further opportunities for learning and gain useful insight into the construction works. Being physically present on the construction site also allows students to get firsthand observation of site conditions, progress, quality of work, and detailed inspection of the material as well as fully immerse themselves in the environment with the overall feel of an active construction site. In addition, the scale and size of equipment and structural components in the real construction site might be hard to fully appreciate through virtual settings compared to the in-person visit. The ability to walk around the construction site and experience the size and scale of actual different structural components and equipment in person still provides a much stronger understanding and realization of the actual physical size and scale of large construction projects which is hard to replicate in a virtual setting. Also, in-person site visits often allow students to engage in practical activities. This provides good opportunities to conduct safety training and operate various tools and equipment on the job site. These activities can be simulated virtually, but the hands-on learning that comes from direct involvement is absent. Students are limited to passively observing rather than actively participating or trying tasks.

In addition, virtual site visits may also present some accessibility challenges (Cook et al. 2019). While virtual site visits can sometimes be cheaper than physical trips, there might still be some associated costs such as hardware costs, software licenses, etc. Students from economically constrained backgrounds may also lack access to essential technological devices or reliable internet connectivity. Therefore, not all students can participate in virtual site visits.

Overall, virtual site visits provide various benefits such as a high level of flexibility and access when the traditional on-site visits are impractical. However, they still possess several limitations including a lack of physical interaction between students and the environment and accessibility challenges. Ultimately, although virtual site visits have yet to be capable of fully replacing the traditional, in-person site visit, it is a still an extremely useful tool in specific contexts like distance education or when in-person visits are unavailable.

3. MOTIVATIONS

Distance education in a hands-on and complex field such as construction management is challenging. It is even more challenging when doing distance education in a rushed manner, without pre-planning, as with the COVID-19 pandemic. The distant nature of the teaching made it even more important to give students an experience that mimicked real exposure to actual construction sites. The primary objective behind this research is to systematically test and report our findings on the use of virtual site visits in construction management education in order to help other instructors and institutions adopt such innovative solutions to complement their construction management curriculum. Another underlying motivation behind this experiment was also to allow students to get as close as possible to a real-life site visit, in order to complement their construction curriculum education in a situation where nothing else was possible.

4. METHODOLOGY

This research is the expansion of the findings of the previous research (Shojaei et al. 2020; Shojaei et al. 2021; Shojaei et al. 2022) with the aim of producing a deeper insight and evaluation of students' perception and experience from the virtual site visit. This study followed an Institution Review Board-approved protocol (IRB-20-265) to conduct a study on evaluating the use of virtual site visits in construction management distance education. Two groups of undergraduate students from building construction science and construction engineering management participated in this study. They were provided with an online platform that included immersive (360-degree and 180-degree 3D) and flat (2D) videos of active construction sites focused on timber framing, insulation, and finishing. Figure 1 depicts two sample shots of the immersive videos that students used as part of their virtual site visits. Students were asked to watch and experience the virtual site visit at their own pace and then answer the post-experiment survey. The questionnaire was developed based on a literature review and the gaps identified in the application of virtual site visits in construction education with the aim of understanding the experience of using virtual site visits from the student perspective and providing direction and better understanding for optimal future virtual site visits in this area. The questionnaire was validated through a pilot test with five students and two construction management instructors to ensure its usability and validity for the purpose of this study. The estimated time needed to complete the survey was 4 minutes. The survey was designed to measure students' perception of virtual site visits, with a focus on evaluating students' preferences of the three types of video content and understanding different aspects of their experiences during the experiment, in hopes that the results would help instructors in the future to conduct high-quality virtual site visits.

4.1 Content development

The creation of immersive video content comprises two different stages: Recording the video and processing the video content. Regarding the content-capturing aspect, four different cameras, with their unique features and capabilities, were used in this research for capturing different types of video content.

In this study, four different cameras (GoPro Fusion, Lenovo Mirage, Qoocam, and GoPro Hero) were used for video capturing for the virtual site visit applications. The GoPro Fusion is selected for its great stabilization and ability to capture high-quality video. It offers capturing at a staggering 5.2K resolution at 30 frames per second. The high resolution of the captured video will provide an immersive viewing experience with great details of the construction sites. The built-in stabilization capabilities ensure smooth footing from a moving camera which in turn can decrease the level of motion sickness for students. Qoocam, on the other hand, is known for its versatility as it is capable of capturing video in both 360° and 180° 3D format which allows for the creation of different types of immersive content. Its strong battery life also makes possible longer recording sessions at construction sites. The ability to record long sessions on site is useful as it will provide more comprehensive footage of the sites and the construction-related activities. The 360-degree video provided by Qoocam and GoPro Fusion records the spatial environment and the entire surroundings of the site which provides flexibility in visual observation for the student. Lenovo Mirage was selected due to its affordable pricing and the ability to 180° 3D video capturing with its dual 180-degree lenses. Its recorded stereoscopic 3D video enhances the depth and immersion level of the virtual site visit which can imitate how the object is perceived in the real in-person visit. In addition, GoPro Hero is used to shoot traditional, flat video that is used for the point of comparison to the recorded immersive video. Besides, these four cameras also come with compact and durable designs that facilitate the mounting process onto the helmets or other equipment at construction sites.

The camera position in all video capture configurations was placed at the human head level to produce a natural viewing perspective for the participants. To provide extensive and detailed video content to the users, two approaches were proposed for the locations of camera placement, installing the camera directly on the construction workers and placing it on a tripod. The video from the tripod-based camera can deliver a more comprehensive view of the construction site and its surroundings, while the video from the human-mounted camera gives a more detailed view of a particular work process or activities.

In the video processing stage, two 180° videos are stitched together to create the 360° videos, and 180° 3D videos are generated by the combination of footage from two adjacent lenses. Even though the majority of cameras do include built-in stabilizers for video recording, Digital stabilizer is still applied to the content during the processing to prevent a viewer from getting sick while watching the videos. The frame rate when watching immersive videos with HMDs is also a significant factor. Users could become nauseous and feel unwell if the frame rate is too low. However, there is a compromise to video quality if the content is opted for a higher framerate. Therefore, it is important to find the correct balance between video quality and frame rate before conducting any video capturing.

Figure 1: Sample images from the virtual site visit videos.

4.2 Study measure

There are a total of twenty-five questions in the post-experiment survey. The first three questions aim to evaluate students' feedback regarding the level of quality, attractiveness, and informativeness of the three video formats. The response to these three questions could aid instructors in creating high-quality virtual site visit content that is more attractive to students and information-rich, which hopefully can better engage them and allow them to focus on the content during the learning experience.

The next twenty questions in the questionnaire are used to measure four parameters to evaluate student perspective on construction virtual site visits in the following categories: knowledge retention, sense of presence, user experience, and overall satisfaction. The participants' responses were analyzed descriptively and statistically for each population group and across all populations. Finally, the last two questions aim to find out whether students prefer immersive video over textbook/lecture for learning about a topic in construction management and whether immersive video technology can motivate them to pursue education and a career in construction. The value of each of the four parameters is calculated by adding up the ratings (min: 1, max= 5) from the available questions in their categories before normalizing the total to a 0 to 100 scale (Eiris, Wen, et al. 2020).

User experience score: aim to measure the ease of use of the technology from the student's perspective. This parameter is calculated by using the answers to six questions listed in Table 3. This includes comfort when viewing the video, the spatial characteristic of the audio and video elements, and clarity of the content.

Knowledge retention score: This metric aims to understand how students have learned from the virtual site visit application in various aspects. This includes how well they remember the content of the videos, recall the sequence of the work done, whether they can differentiate different components and materials during their experience, and whether they feel that the content provided is practical. This parameter is calculated by using the answers to six questions listed in Table 4.

Sense of presence score: This parameter aims to evaluate students' level of engagement and sense of presence in virtual construction job sites. This parameter is calculated by using the participants' responses to seven questions (see Table 5) on several factors that are believed to influence participants' sense of presence (Usoh et al. 2000). These questions include students' ratings on how engaging the content is, how present they feel when viewing the video, student opinion toward the spatial characteristic of the audio and video elements, and the clarity and realism of the video content.

Overall satisfaction score: This section contains three questions, and the score aims to evaluate students' overall satisfaction with the technology, and their opinion on whether they consider this technology useful and would prefer using this technology in the future (see Table 6).

5. RESULTS AND DISCUSSION

Two groups of undergraduate students for this study were chosen from Mississippi State University (MSU) and Lawrence Technological University (LTU), who were in their junior and sophomore years (respectively), and in pursuit of a Bachelor of Science in building construction and/or construction management degrees. The participants from MSU teams (junior) have more in-depth knowledge and extensive background in the construction field than the LTU team members (sophomore). Descriptive statistics and Inferential statistics are used in this study.

5.1 Descriptive statistical analysis

A descriptive analysis was conducted on the results to understand the students' preferences among the different options of video configuration and interpret their rating of the virtual site visit from different aspects. Table 1 and Figure 2 present the results of different teams' ratings on each type of video configuration in terms of video quality, informativeness, and attractiveness. In the quality category, 360-degree video was given the highest rating from both participating teams (85.60% and 77.60%), while there is little difference between the ratings of the other two configurations with the flat video's ratings overtaking the 180-3D video rating by just over two percent. In the second and third questions, students were asked to rate the level of information they perceived from different video formats for their virtual site visits and the attractiveness of each of them. The 360-degree video is still rated by both LTU and MSU teams as the highest among the three video configurations in informativeness and attractiveness categories with the 180-3D videos coming in second for both criteria. Another interesting point is that the rating of the 360-degree seems to be consistent within the first three questions, while the other two had a lower attractiveness rating compared to their initial ratings in terms of being informative, and their overall quality. This suggests that while the 180-degree 3D video and flat video could be informative to a lesser degree, they were considered much less attractive compared to 360-degree videos.

The 360-degree video has received the highest ratings across all three categories of video quality, informativeness, and attractiveness. The strong preference for 360-degree video is likely caused by the sense of immersion it offers. By providing students the ability to look around the entire site with a 360-degree view, it provides the closest experience to the actual construction site visit. The immersive quality of the 360-degree video seems to enforce student engagement and interest, as indicated by its high attractiveness ratings. On the other hand, the low attractiveness score for the flat and 180-3D videos implied that these two video formats might not provide the equivalent degree of immersion as the 360-degree video which has potentially led to a less engaging experience for the virtual site visit. The high ratings in the informative category for the 360-degree videos also suggest that it best mimics the in-person site visit experience which allows students to observe more intricate details of the construction site, offering an experience that fosters active learning. Conversely, the low informativeness ratings for flat and 180-3D videos indicate that students weren't able to absorb as much detail from the site environment compared to the 360-degree video setting. This aligns with previous research which underscores the significance of immersive formats in enhancing student engagement and learning (Dede 2009).

Overall, the result of this survey suggests that 360-degree video should be prioritized for adoption as the format for virtual site visits in construction education programs. It provides an engaging yet informative virtual viewing experience, suitable for the complex nature of construction sites. There might be some limitations of utilizing 360-degree video format such as accessibility and cost, but given the promising outcome of student learning with this setting, 360-degree video should be selected as the primary choice for virtual site visits and the flat and 180-3D videos can also be used for supplementary resources.

Table 1: Ratings on the quality, informativeness, and attractiveness of each video type.

Questions	Population	Video configurations					
		360 Video		180 3D Video		Flat Video	
		Mean (%)	STD (%)	Mean (%)	STD (%)	Mean (%)	STD (%)
How do you rate different video configurations in terms of quality?	LTU	85.60	17.81	77.60	17.62	80	16.32
	MSU	77.60	16.65	73.33	18.85	75.65	14.09
	All population	81.60	17.53	75.46	18.19	77.82	15.25
How do you rate different video configurations in terms of being informative?	LTU	92	20	76	15.27	69.6	15.40
	MSU	76	20	73.33	20.54	75.65	20.78
	All population	84	21.38	74.66	17.96	72.62	18.36
Which video configuration was more attractive?	LTU	90.40	15.40	68.8	17.39	66.4	19.76
	MSU	78.40	19.07	71.66	15.18	70.83	19.13
	All population	84.40	18.20	70.23	16.22	68.61	19.38

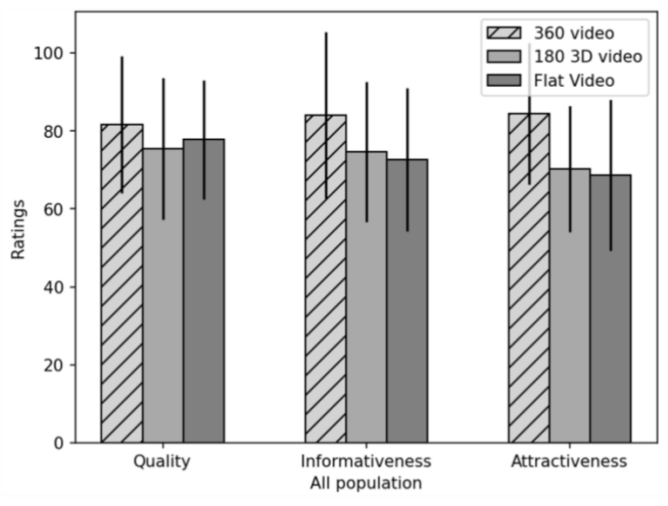

Figure 2: Ratings on different video types across all population.

Table 2 and Figure 3 present the result of the descriptive analysis of the different study measures from each population separately alongside them combined (the ALL category). Based on students' feedback, students' overall experience with the system is found to be positive with the average user experience score of 81.39 (STD = 12.34%; Max = 100.00%; Min = 46.66%). This high rating in the overall user experience score demonstrates the satisfaction of students in using the system and also implies the potential for adopting this virtual site visit application to enhance traditional construction education.

From Table 2, we can see there is a considerable difference between LTU and MSU user experience scores (LTU:84.66%, MSU:78.12%). The difference between the two teams' experiences could be interpreted due to the internet connection issues reported by MSU participants during the experiment. A weak internet connection impacted students' ability to stream the video properly and smoothly since streaming 360-degree videos requires more bandwidth than streaming traditional, non-360 content. This limitation negatively affected the MSU user experience score of the virtual site visit application. Poor internet connectivity could pose challenges in implementing an effective construction virtual site visit, especially in remote areas. This result underscores the need for construction programs to ensure a robust and adequate internet connection before adopting virtual site visits in order to enhance the virtual site visit experience.

The reported average knowledge retention score among all participants is 75.71% (STD = 12.46%; Max = 100.00%; Min = 46.66%) which indicates a good level of knowledge acquisition from the virtual site visit. Furthermore, there is only less than a 3 percent difference between the two teams 'knowledge retention scores which can also suggest that virtual site visits can be used effectively among all students regardless of the extent of their construction-related background. The student's strong knowledge retention scores indicate that the virtual site visit can effectively enhance and support student learning. This also demonstrates the promise of virtual site visits as an effective form of remote learning to supplement classroom-based material and boost student understanding of the theoretical concept.

The average score in the sense of presence categories is 78.91% (STD = 13.27%; Max = 100%; Min = 37.142%), which demonstrates a fairly good extent of engagement and sense of presence during the experiment. However, from Table 2, it can be seen that LTU participants possess an average score of 84 percent, almost 10 percent more than their MSU counterparts. The high sense of presence score should have resulted from the immersion and engaging experience provided by the 360-degree video. The lower score among the MSU teams can be understood as the consequence of the unreliable internet connection. This again reinforces the need for consistent and capable internet connectivity to ensure a satisfactory sense of presence.

Table 2: Descriptive statistics for different study measure.

Study Measure	Quantitative Variables											
	Mean (%)			Standard Deviation (STD) (%)			Maximum (%)			Minimum (%)		
Team	**LTU**	**MSU**	**ALL**	**LTU**	**MSU**	**ALL**	**LTU**	**MSU**	**ALL**	**LTU**	**MSU**	**ALL**
User experience	84.66	78.12	81.39	12.50	11.50	12.34	100	100	100	50	46.66	46.66
Sense of presence	84	73.82	78.91	12.34	12.39	13.27	100	100	100	48.57	37.14	37.14
Knowledge retention	77.16	74.26	75.71	13.58	11.32	12.46	100	100	100	60	46.66	46.66
Overall satisfaction	88.80	76	82.40	16.52	14.90	16.86	100	100	100	33.33	33.33	33.33

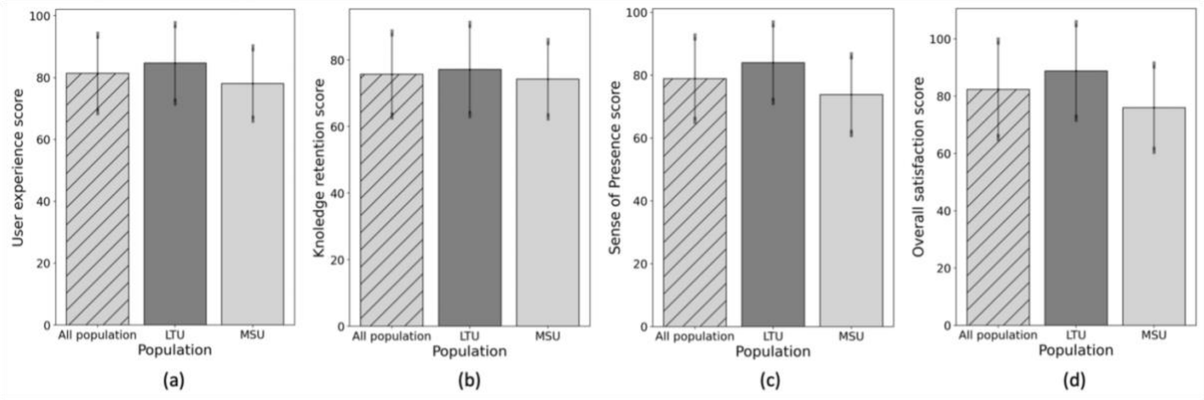

Figure 3: Results of Study measures by different populations: a) User experience score b) Knowledge retention score c) Sense of presence score and d) Overall satisfaction score.

Table 2 also indicates that the average overall satisfaction score of students on the technology is 82.40% (STD = 16.86%; Max = 100%; Min = 33.33%) with 88.8% from the LTU team compared to the MSU team at 76%. Similarly, the difference could be explained by the internet issue that occurred while MSU participants were conducting the survey. This technical issue caused glitches and thereby affected students' viewing experience, and interaction with the system and hampered the immersion of the system. The high overall satisfaction score from the LTU team demonstrates the usefulness of virtual site visits for effectiveness in delivering engaging and valuable learning experiences, provided that the technology functions properly.

Table 3 presents the result of students' responses to the six questions used for User experience evaluation. The data shows comfort ratings ranked the highest in this study measure (88.40%). The ease of use of the technology (85.60%), information clarity (80%), and spatial audio (85.18%) all received high ratings from the participants while the spatial quality of elements only received a rating score of 75.20%. In addition, the lowest rating among the questions is the closeness of the content in the video compared to students' previous on-site visits (74%). This might be related to the quality of the program's content.

The high comfort and ease-of-use ratings indicate that the technical aspect of the virtual experience has been well-executed and there are minimal technical barriers in bringing the virtual technology to student adoption. This suggests that with appropriate IT support and resources, virtual site visits could be potentially an effective learning tool for a large construction student population. The high ratings of spatial audio also underscore its significance in producing an immersive virtual environment experience. The low ratings on the level of closeness of the content to real life and the spatial qualities of elements imply that the realism of content in the immersive videos in comparison to the actual construction site does have an impact on the user perception and experience while using this technology. This also indicates the need for enhancement in creating authentic virtual construction site conditions in order to maximize the educational experience. Educators should also put more effort into content development in terms of both the richness and quality of the content. The selection of sites and construction activities for video capturing is also crucial, and educators should choose the one that best represents the actual condition of the construction site to mimic a genuine site visit experience. The video content should also be captured at the highest quality with at least 60 framerates or higher as lower framerates could potentially cause users to have motion sickness. However, the overall positive feedback from the survey suggests that the user experience of the virtual site visit could be improved with thoughtful and detailed content design, and the virtual site visits potentially enrich traditional learning with an engaging simulated environment. Additional research on best practices for instructional design would be beneficial to maximize the educational impact of the virtual site visit application.

Table 3: User experience measures questionnaires and results.

Q#	User experience Questionnaires	Ratings across different population					
		LTU		MSU		All Population	
		Mean	STD	Mean	STD	Mean	STD
Q1	Did you feel comfortable watching the videos?	91.20	13.01	85.60	22	88.40	18.11
Q2	How do you rate ease of use of this technology?	88	14.14	83.20	17	85.60	15.67
Q3	How do you rate the clarity of the presented information?	84	18.25	76	14.14	80	16.65
Q4	Does spatial audio help you in better experiencing the environment?	91.2	14.23	79.16	16.81	85.18	16.57
Q5	How close was your experience with the videos to your previous construction sites visits?	73.6	20.59	74.40	22.74	74	21.47
Q6	How do you rate the spatial quality of the elements (Scale of the space)?	80	20	70.40	19.25	75.20	20.02

Table 4 presents the knowledge retention measures questionnaires and results. The results show that, on average, students found that virtual site visits provide practical construction-related information (79.66%) and are helpful for students in learning building assemblies (76%), building materials (79.2%), and building components (75.6%). However, students have difficulty remembering the video's contents (67.2%), and recalling the sequence of the construction work activities (76.63%). In general, the LTU team provides higher ratings than the MSU team in all categories but in memorizing the sequence of work. The findings suggest that virtual site visits can be a valuable instrument to provide construction-related knowledge and familiarize students with critical aspects of buildings including assemblies, materials, and components. However, it might be not so helpful for assisting memorization and recall of certain sequences and activities. This implies that virtual site visits can enhance learning in some areas but still need to be integrated with some other instructional pedagogical method to achieve maximum comprehension and memory retention.

Table 4: Knowledge retention measure's questionnaires and results.

Q#	Knowledge retention Questionnaires	Ratings across different population					
		LTU		MSU		All Population	
		Mean	STD	Mean	STD	Mean	STD
Q1	Did the videos provide practical construction information?	83.33	15.98	76	14.14	79.66	15.38
Q2	To what extent were you able to Identify different components of the building?	78.4	18.18	72.8	19.89	75.6	19.07
Q3	To what extent were you able to distinguish what materials being used in building elements?	82.4	17.62	76	19.14	79.2	18.49
Q4	Could you recognize and memorize the sequence of the work being done?	71.66	15.18	81.6	12.8	76.63	14.77
Q5	Did you find this technology helpful in learning building assemblies?	80.8	15.79	71.2	18.33	76	17.61
Q6	To what extend will you remember the content of the videos?	66.4	19.76	68	17.32	67.2	18.41

Table 5 presents students' answers to the seven questions for the sense of presence study measure. Level of realism, clarity of content as well as spatial elements and spatial audio within the video are chosen to be the main parameters to determine the participants' sense of presence. The results show that on average, spatial audio, the realism of content, and clarity of information received high ratings among other factors with 83.6%, 85.6%, and 80% respectively while the ratings for level of engagement, the spatial quality of elements, sense of presence and sense of realism are all under 80%. The ratings from the seven questions from the LTU team are all above the 80% mark compared to only one from the MSU team's response. There is a 20% percent difference in the spatial audio ratings and more than a 10% difference in the sense of presence and sense of realism between the two sides. This again reinforces the importance of the quality of videos and the workflow of setup during a virtual site visit as the technical problem (e.g., internet connection) can immensely affect the user's viewing experience. Smooth workflow and high-quality 360-degree video can mimic the experience of the physical construction site which can elevate students' sense of presence. Common problems such as stuttering in video or audio can hamper users' sense of immersion. Visual and audio quality and clear information delivery should be among the top priorities when developing such virtual content.

Table 5: Sense of presence measure's questionnaires and results.

Q#	Sense of presence Questionnaires	Ratings across different population					
		LTU		MSU		All Population	
		Mean	STD	Mean	STD	Mean	STD
Q1	How realistic the content seemed to you?	88	17.32	83.2	22.12	85.6	19.81
Q2	How do you rate the clarity of the presented information?	84	18.25	76	14.14	80	16.65
Q3	Does spatial audio provide more awareness about the construction site surroundings?	93.6	11.13	73.6	19.76	83.6	18.81
Q4	How do you rate your Sense of presence on the site?	81.6	17.24	68.8	18.33	75.2	18.76
Q5	How do you rate your feeling of space and sense of realism?	80.8	16.81	70.4	17.43	75.6	17.74
Q6	How do you rate your level of engagement with the material?	80	16.32	74.4	18.72	77.2	17.61
Q7	How do you rate the spatial quality of the elements (Scale of the space)?	80	20	70.4	19.25	75.2	20.02

Table 6 presents the results of the questionnaires of the overall satisfaction measure. It can be seen from the response that the LTU team shows more satisfaction and optimism about the technology compared to the MSU team. The MSU students' ratings of the three questions are all under 80 percent compared to around 90 percent ratings from the LTU team. The data show that overall, participants are satisfied with the virtual site visit as an education method and quite optimistic about the prospects of the application of VR technology in construction education. Participants also demonstrate a high willingness to use virtual reality video technology to learn more about construction in the future. This indicates that with enhancement to the parameters/factors mentioned above, virtual site visits could potentially serve as a supplement or alternative to future site visits in construction education.

Table 6: Overall satisfaction measures questionnaires and results.

Q#	Overall satisfaction Questionnaires	Ratings across different population					
		LTU		MSU		All Population	
		Mean	STD	Mean	STD	Mean	STD
Q1	Would you use this technology to learn about construction in future?	90.4	19.25	73.6	18	82	20.30
Q2	What is your overall evaluation of this educational method?	88	15.27	76	18.25	82	17.72
Q3	How useful do you see such technologies to be used in construction education?	88	19.14	78.4	16.24	83.2	18.23

Table 7 presents students' responses to the two questions that are used to evaluate the significance of Immersive video technology in construction management education. The report shows that almost 92% of participants are willing to use immersive video over the traditional textbook and lecture as a means to learn more about construction management-related topics and 88% of them stated that this technology could motivate them to pursue education in, and/or a career in construction. The findings indicate that immersive video can increase student engagement and enthusiasm in construction education. The immersive content offered by 360-degree video has provided an interactive and practical view as well as valuable insight into construction practices and the environment. This active learning method will enhance student learning compared to the passive absorption of information. This technology may also inspire students to choose a construction major. This further suggests that integrating virtual site visits into construction education could be an effective strategy to attract and retain students. Additionally, the results also suggest that there are opportunities to incorporate immersive video in different construction-related topics such as site planning, safety training, equipment operation, construction management, etc. In essence, the results present a strong motivation for construction programs to integrate immersive video into their curriculum as a strategy to enhance construction education and engage future construction professionals.

Table 7: Participants' responses on immersive videos and construction education.

Q#	Questionnaires	Response across different population					
		LTU		MSU		All Population	
		Yes	No	Yes	No	Yes	No
Q1	If given the choice, would you choose an immersive video over a textbook/lecture for learning about a topic in construction management?	23	1	22	3	45	4
Q2	Can this technology motivate you in pursuing education and career in construction?	22	3	22	3	44	6

5.2 Inferential statistical analysis

Next, Inferential analysis methods such as the Mann-Whitney U test and Spearman Rho test are used to provide more insight into the survey results. *Comparison test*: The Mann-Whitney U test is applied to the four study measures (knowledge retention, sense of presence, overall satisfaction, and user experience) of the two teams to examine whether the differences in the background of the two teams in terms of previous knowledge and experience in construction field affect their views and experiences of the virtual site visit program. Table 8 presents the research hypotheses that were developed in response to this objective.

The results of the Mann-Whitney U test on the two teams' study measures are shown in Table 9. For the knowledge retention score, there is no difference detected between the two groups ($p=0.618569$, $p > 0.05$). Therefore, the null hypothesis H_0 of research hypothesis (1) "The knowledge retention scores of LTU and MSU team are equal despite differences between their previous experience and knowledge in construction" cannot be rejected. However, the result of the analysis suggests that there is a difference in user experience scores between the two. ($p = 0.044600$, $p<0.05$). Thus, the null hypothesis H_0 of research hypothesis (2) "The user experience score of LTU and MSU team is equal despite differences between their previous experience and knowledge in construction" can be rejected for the alternate hypothesis H_1. Similarly, the result indicates that the sense of presence score and overall satisfaction score between the two teams also appeared to have significant differences with the respective p values of 0.003064 and 0.000601 ($p = 0.003064$, $p<0.05$, $p = 0.000601$, $p<0.05$). Hence, the null hypothesis H_0 of research hypothesis (3) and research hypothesis (4) can be rejected in favor of the respective alternate hypothesis H_1.

Table 8: Participants' responses on immersive videos and construction education.

Research Hypothesis (1)	H_0: The knowledge retention score of LTU and MSU team are equal despite differences between their previous experience and knowledge in construction.
	H_1: The knowledge retention score of LTU and MSU team are not equal
Research Hypothesis (2)	H_0: The user experience score of LTU and MSU team are equal despite differences between their experience and knowledge in construction.
	H_1: The user experience score of LTU and MSU team are not equal
Research Hypothesis (3)	H_0: The sense of presence score of LTU and MSU team are equal despite differences between their experience and knowledge in construction.
	H_1: The sense of presence score of LTU and MSU team are not equal
Research Hypothesis (4)	H_0: The overall satisfaction score of LTU and MSU team are equal despite differences between their experience and knowledge in construction.
	H_1: The overall satisfaction score of LTU and MSU team are not equal

Notably, despite having less experience and knowledge in construction management, the LTU team does possess a similar knowledge retention score with even better user experience, and sense of presence score compared to a more senior, MSU team. This can be explained by the problem of poor internet connection encountered by the MSU team mentioned in section 5.1. This also demonstrates that possessing extensive experience with construction is not necessarily a prerequisite for students to benefit from this technology and also implies the significance of higher internet bandwidth for the virtual site visit. Furthermore, the positive feedback from the less experienced LTU students could also be inferred that this technology can be particularly impactful on users with lower construction backgrounds and experience. The enhanced visual experience delivered by the 360-degree videos enabled students to enhance their learning by vividly contextualizing and visualizing the construction-related activities. The 360-degree video could serve as an effective tool for different students from diverse educational backgrounds in construction.

Table 9: Statistical analysis results for difference measures' questionaries.

Population	**Score**	**Mann-Whitney U**	
		Statistic	**p value**
Between LTU and MSU	**Knowledge retention**	286.5	0.618569
	User experience	209	0.0446004
	Sense of presence	160	0.003064
	Overall satisfaction	137.5	0.000601

Correlation test: Spearman Rho test is used to find the correlation between three different scores (Knowledge retention, sense of presence, and user experience) and the relationship between those three scores with the properties of the contents such as clarity, realism, and spatial chrematistics of the contents. Multiple correlation analyses were conducted to assess the relationship between the four study measures across all the participants.

Table 10: Results of the Correlation test between different study measure.

Population	Relationship between	Spearman Rho	
		correlation coefficient	p value
Across all population	**Knowledge retention and User Experience**	0.76	8.61849e-11
	Knowledge retention and Sense of presence	0.82	3.06225e-13
	Sense of presence and User Experience	0.85	1.25591e-15

The outcomes of the correlation analysis are presented in Table 10. The results suggest that there is a strong proportional correlation between the user experience score and knowledge retention score (correlation coefficient = 0.76 > 0.6 and <0.8, p < .05, p-value = 8.61849e-11) which indicates that there is a strong relationship between the two components. This suggests that as the user experience score increases, the knowledge retention score will increase accordingly. These findings are supported by the previously presented observations from the descriptive and statistical analysis in this paper. This implies that future virtual site visit platforms should optimize technical aspects of the system like ease of use, audio and visual quality as well as engagement factors like interactivity, and feedback to maximize user engagement and boost knowledge acquisition.

Regarding the knowledge retention and sense of presence score, the results indicate that there is a very strong proportional correlation between the two (correlation coefficient = 0.82 > 0.8, p < .05, p-value = 3.06225e-13). This demonstrates the significance of the feeling of being "present" and being immersed in the virtual environment for effective learning. The key parameters of the sense of presence score are mentioned in section 4.2 which implies that improving this related aspect of the virtual content such as visual and audio fidelity can directly increase the student knowledge retention capabilities. The content design should also prioritize providing an authentic viewing experience, and offer interactive and explorable content to increase presence and knowledge gain.

Similarly, it was found that there is also a very strong proportional correlation between the sense of presence and user experience score. (Correlation coefficient = 0.85 > 0.8, p < .05, p value = 1.25591e-15). It should be noted that three parameters (clarity of information, spatial audio, and spatial quality of element) are used to calculate both the user experience and sense of presence score. Improving these three shared elements of the content will simultaneously enhance both the sense of presence and user experience score. In addition, the feeling of being present and the immersive and realistic virtual environment tend to improve user satisfaction and experience. Similarly, enhancing user experience-related factors such as providing a user-friendly user interface, intuitive navigation control, and clear information presentation may in turn strengthen the user's sense of presence as well. Overall, these two variables may have a reciprocal relationship in such as way that optimization to one will boost the other. The visual representation of the relationship between the three measures is illustrated in Figure 4 to better demonstrate the data points and their significant correlation.

To acquire a more detailed insight into the relationship between different video content characteristics, settings, and the study measures, further correlation analysis of the data was conducted. Table 11 presents the result of the correlation analysis between the user experience score, sense of presence score, and different parameters of the video content including spatial audio quality, the spatial quality of elements, clarity of the content, and the usability of the technology. The correlation coefficient of the clarity of content, the spatial quality of element, the realism of the content, and spatial audio in the sense of presence category are 0.72, 0.73, 0.64, and 0.58 respectively. Similarly, three of the correlation coefficients in the user experience category, content clarity, spatial audio, and ease of use are also below the 0.80 value. The analysis of the results shows that the user experience score possesses a very strong proportional relationship with the spatial quality of the element (correlation coefficient = 0.803 > 0.8) as well as a strong correlation with the other three parameters (correlation coefficient < 0.8 and >0.6). This indicates that participants will have a better experience using the virtual site visit if the device and user interface are more intuitive and the video content possesses higher clarity with great quality in spatial audio and elements' spatiality. This suggests that future virtual site visit application creators should pay more attention to crafting a user-friendly platform and offering high-fidelity site elements.

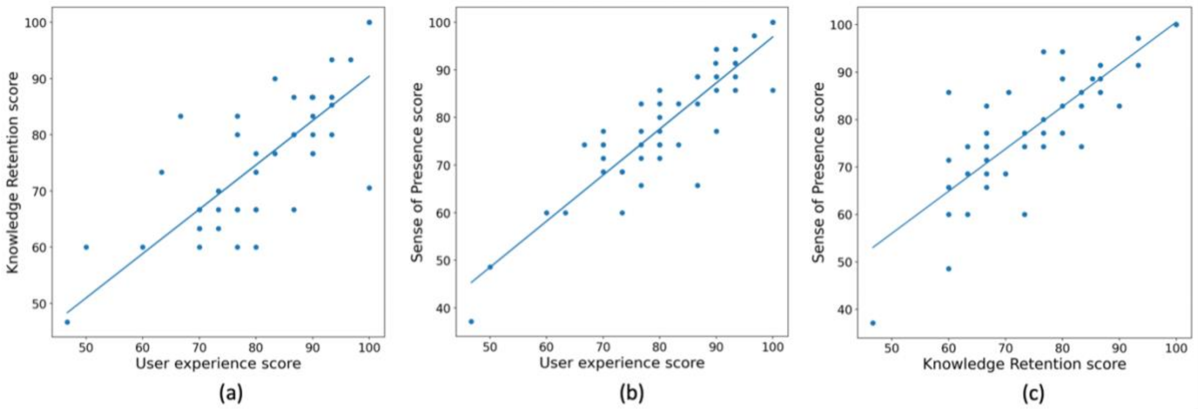

Figure 4: Relationship between different study measures a) User experience and Knowledge retention b) User experience and Sense of presence c) Knowledge retention and Sense of presence.

Similarly, a strong proportional correlation between the sense of presence score and the realism of video content was also detected. High-quality video content is crucial to enhance the level of immersion of the content. Therefore, different factors related to content recording and creation such as camera resolution, and video rendering should be well-optimized to create a high-quality visual of the construction site. Additionally, an authentic view of construction sites can trigger the user's sense of awareness of the environment. This suggests that using actual footage from the construction site as conducted in this research, instead of computer-generated one, can lead to an improved sense of presence. In addition, spatial audio and clarity of content also exhibit a noteworthy correlation with a sense of presence. Enhancing the quality of audio and providing informational content can also amplify the user's experience in the virtual construction environment. These results can be used by future educators as a basic framework when developing similar virtual site visit content in order to increase the level of presence and engagement of the participants as well as their viewing experience.

Table 11: Relationship between properties of video content with Sense of presence and User experience score using Spearman Rho test.

	Sense of presence		**User experience**	
	Correlation Coefficient	**p value**	**Correlation Coefficient**	**p value**
Clarity of the content	0.72	2.76025e-09	0.69	2.70531e-08
Spatial quality of element	0.73	1.62412e-09	0.803	2.19468e-12
Realism of the content	0.64	5.29970e-07	N/A	N/A
Spatial Audio	0.58	8.59960e-06	0.62	1.08179e-06
Ease of use	N/A	N/A	0.63	6.35225e-07

6. CONCLUSION AND FUTURE WORK

In this study, a pilot virtual site visit was conducted at Mississippi State University and Lawrence Technological University with the aim of providing students with an experience as close as possible to a physical site visit. The promises of virtual site visits go beyond distant education and can increase the accessibility and equity in education in rural areas and under-resourced institutions by providing experiences to students who will not be able to receive a close-up visit to specific locations/projects. The analyses of the results of the students' post-experiment survey were conducted to provide future educators and faculty a better insight into student opinions and preferences on the technology. This can help educators conduct high-quality, virtual site visits, by using the evaluations and feedback of the students as a baseline for designing and conducting their virtual site visits.

Fifty students participated in the virtual site visit and completed a follow-up survey to capture the essence of their experience and their feedback. Descriptive and inferential statistical analysis methods were performed on the response dataset. This study assessed the virtual site visit from five aspects: students' preferences on the type of content delivery method, user experience, knowledge retention, sense of presence, and overall satisfaction. The results showed that 360-degree videos were rated the best instrument compared to the other two, and the students rated the virtual site visit experience as attractive and informative.

From the results of the analysis, it is found that the average user experience ratings among all participants are pretty satisfactory (81.39%). The average sense of presence and knowledge retention scores are reported to be slightly lower at 78.91% and 75.71% which show a good degree of engagement and information acquired during the experiment. Furthermore, the average satisfaction score reaches 82.4% which indicates fairly high approval rates and optimism about the prospect of this technology in construction education. Moreover, the data from the study also showed that virtual site visits could be used to attract more students to the field of construction management, which can help address the shortage of skilled staff in this field.

Furthermore, students were able to follow the direction of the site visit, and recognize the materials, the sequence of the construction procedure, and other details within the virtual site visit. The clarity of the presented information was identified as a potential area for improvement in future iterations. Comparison-wise, both teams reported similar ratings on knowledge retention level, but significant differences between the user experience and sense of presence score existed. This can be explained by the disruption to the MSU team virtual site visit sessions which was caused by the slow and unstable internet connections. Alternatively, this difference can be interpreted as perhaps this technology can provide a higher impact on users with lower construction backgrounds and experience. Based on statistical analysis, there is an overall strong proportional correlation between user experience, sense of presence, and knowledge retention score. Either increment in one value will lead to a rise in the other two parameters. It is also found that the sense of presence and user experience score receive direct influences from how user-friendly the technology is and different properties of the contents such as quality of spatial audio, spatial element, clarity, and realism of contents.

Future research is needed to improve the current virtual site visit body of knowledge and to tackle the existing limitations of this study. First, the reliability of the analysis of the study could be affected by the limited number of participants (fifty construction students). A larger sample size would better lead to a more generalized conclusion. Secondly, apart from students' current level of seniority in construction education and class level, there is no other student's personal information collected which restricted the scope of studies and conclusion. Having more demographic information such as age, sex, work experience in the construction industry, and other related information such as level of familiarity and experience with VR technology, could allow a better understanding of participants' backgrounds, as well as a more expanded scope of analysis which could lead to different results. In addition, in this study, participants are only required to complete the questionnaire survey once they have tried all three different types of video delivery formats. Thus, the result could be influenced by their view of the Virtual site visit overall. Future studies can let students respond to a more personalized questionnaire survey for each video delivery type once each method is tested to obtain more insight into student perspectives on the varieties of content delivery methods. Content-wise, more variety of useful construction sites and scenarios can be captured and included in future works. Interaction between participants and the VR environments is also a great addition to the quality content which will further foster student engagement.

REFERENCES

Arslan, G. 2003. Design of a Web-Based Virtual Construction Site Visit for Education of Civil Engineering Student (Part I). In *Towards a Vision for Information Technology in Civil Engineering*, 1–8. Nashville, Tennessee, United States: American Society of Civil Engineers Available at: http://ascelibrary.org/doi/10.1061/40704%282003%2936 [Accessed December 7, 2022].

Baker, A.C., Jensen, P.J., & Kolb, D.A. 2002. *Conversational learning: An experiential approach to knowledge creation*. Greenwood Publishing Group.

Blinn, N., Robey, M., Shanbari, H., & Issa, R.R. 2015. Using augmented reality to enhance construction management educational experiences. In 8.

Cook, M. et al. 2019. Challenges and Strategies for Educational Virtual Reality. *Information Technology and Libraries* 38(4): p.25–48.

Dede, C. 2009. Immersive Interfaces for Engagement and Learning. *Science* 323(5910): p.66–69.

Eiris Pereira, R., & Gheisari, M. 2019. Site Visit Application in Construction Education: A Descriptive Study of Faculty Members. *International Journal of Construction Education and Research* 15(2): p.83–99.

Eiris, R., & Gheisari, M. 2018. Site visit application in construction education: a descriptive study of students' perspectives.

Eiris, R., Gheisari, M., & Esmaeili, B. 2020. Desktop-based safety training using 360-degree panorama and static virtual reality techniques: A comparative experimental study. *Automation in Construction* 109: p.102969.

Eiris, R., Wen, J., & Gheisari, M. 2020. iVisit: Digital Interactive Construction Site Visits Using 360-Degree Panoramas and Virtual Humans. In *Construction Research Congress 2020*, 1106–1116. Tempe, Arizona: American Society of Civil Engineers Available at: https://ascelibrary.org/doi/10.1061/9780784482865.117 [Accessed October 2, 2022].

Eiris, R., Wen, J., & Gheisari, M. 2021. iVisit – Practicing problem-solving in 360-degree panoramic site visits led by virtual humans. *Automation in Construction* 128: p.103754.

Gandhi, R.D., & Patel, D.S. 2018. Virtual reality–opportunities and challenges. *Virtual Reality* 5(01): p.2714–2724.

Hussein, M., & Nätterdal, C. 2015. The benefits of virtual reality in education-A comparision Study. *Bachelor Thesis, University of Gothenburg/Department of Computer Science and Engineering*.

Jacobson, A.R., Militello, R., & Baveye, P.C. 2009. Development of computer-assisted virtual field trips to support multidisciplinary learning. *Computers & Education* 52(3): p.571–580.

Janovy, J., & Major, K.M. 2009. Why We Have Field Stations: Reflections on the Cultivation of Biologists. *BioScience* 59(3): p.217–222.

Jaselskis, E. et al. 2011. Innovation in construction engineering education using two applications of internet-based information technology to provide real-time project observations. *Journal of construction engineering and management* 137(10): p.829–835.

Jolley, A. et al. 2018. Virtual Field trips in tertiary science. *University of Canterbury, EQC, Frontiers Abroad and LEARNZ.*

Lee, E.A.-L., Wong, K.W., & Fung, C.C. 2009. Learning Effectiveness in a Desktop Virtual Reality-Based Learning Environment. *17th International Conference on Computers in Education, ICCE 2009*: p.832–839.

Leydon, J., & Turner, S. 2013. The Challenges and Rewards of Introducing Field Trips Into a Large Introductory Geography Class. *Journal of Geography* 112(6): p.248–261.

Lucas, J.D. 2018. Immersive VR in the construction classroom to increase student understanding of sequence, assembly, and space of wood frame construction. *J. Inf. Technol. Constr.* 23: p.179–194.

Maghool, S.A.H., Moeini, S.H.I., & Arefazar, Y. 2018. An educational application based on virtual reality technology for learning architectural details: challenges and benefits. *Archnet-IJAR: International Journal of Architectural Research* 12(3): p.246.

Mead, C. et al. 2019. Immersive, interactive virtual field trips promote science learning. *Journal of Geoscience Education* 67(2): p.131–142.

Mills, A., Ashford, P., & McLaughlin, P. 2006. The value of experiential learning for providing a contextual understanding of the construction process. In 1–13. University of Technology Sydney

Paez, D., & Rubio, L.A. 2015. The Use of Field Trips in the Context of Engineering Collaborative Teaching: Experiences of Hands-On Geomatics Activities in Colombia. *Wisdom of the Ages to the Challenges of the Modern World Sofia, Bulgaria*: p.17–21.

Pham, H.C. et al. 2018. Virtual field trip for mobile construction safety education using 360-degree panoramic virtual reality. *International Journal of Engineering Education* 34(4): p.1174–1191.

Shojaei, A., Mahdavian, A., Rokooei, S., & Al-Bayati, A. 2022. Use of Virtual Site Visits in Construction Management Distance Education. In *Construction Research Congress 2022*, 182–191. Arlington, Virginia: American Society of Civil Engineers Available at: http://ascelibrary.org/doi/10.1061/9780784483985.019 [Accessed October 20, 2022].

Shojaei, A., Rokooei, S., Carson, L., Ford, G., & Mahdavian, A. 2020. Immersive Video Capture Technology For Construction Management Education. *20th International Conference on Construction Applications of Virtual Reality (CONVR 2020)At: MIDDLESBROUGH, UK*: p.11.

Shojaei, A., Rokooei, S., Mahdavian, A., Carson, L., & Ford, G. 2021. Using immersive video technology for construction management content delivery: a pilot study. *Journal of Information Technology in Construction* 26: p.886–901.

Spicer, J.I., & Stratford, J. 2001. Student perceptions of a virtual field trip to replace a real field trip: Student perceptions of a virtual field trip. *Journal of Computer Assisted Learning* 17(4): p.345–354.

Sun, Y., Albeaino, G., Gheisari, M., & Eiris, R. 2022. Virtual Collaborative Spaces for Online Site Visits: A Plan-Reading Pilot Study. In 688–678. Available at: https://easychair.org/publications/paper/FLKJ [Accessed October 2, 2022].

University of South Australia et al. 2019. Implementing work-integrated learning in online construction management courses. *Journal of University Teaching and Learning Practice* 16(1): p.122–136.

Usoh, M., Catena, E., Arman, S., & Slater, M. 2000. Using Presence Questionnaires in Reality. *Presence: Teleoperators and Virtual Environments* 9(5): p.497–503.

Warwick, K., Gray, J., & Roberts, D. 1993. Virtual reality in engineering. *Institution of Electrical Engineers, London*: p.196.

Wen, J., & Gheisari, M. 2020. A Review of Virtual Field Trip Applications in Construction Education. In *Construction Research Congress 2020*, 782–790. Tempe, Arizona: American Society of Civil Engineers Available at: https://ascelibrary.org/doi/10.1061/9780784482872.085 [Accessed October 2, 2022].

Wen, J., & Gheisari, M. 2022a. Conversational Virtual Humans on 360-Degree Virtual Sites: Guiding Students on a Site Visit to a Mechanical Room. In *Construction Research Congress 2022*, 140–149. Arlington, Virginia: American Society of Civil Engineers Available at: http://ascelibrary.org/doi/10.1061/9780784483985.015 [Accessed October 2, 2022].

Wen, J., & Gheisari, M. 2022b. Using Immersive Storytelling to Attract Students to the Construction Field. In *Computing in Civil Engineering 2021*, 1393–1400. Orlando, Florida: American Society of Civil Engineers Available at: http://ascelibrary.org/doi/10.1061/9780784483893.170 [Accessed October 2, 2022].

Zhang, C. et al. 2017. An Educational Tool based on Virtual Construction Site Visit Game. *Modern Applied Science* 11(8): p.47.