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Virtual Collaborative Spaces for Online Site Visits: A Plan-Reading Pilot Study

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Site visits or field trips are widely recognized by construction educators to engage students in active learning, supplement traditional lessons, and achieve better student learning experiences. However, site visits pose significant logistical and accessibility challenges for educational institutions and teachers, limiting the number of students who can benefit from them. Moreover, the restrictions on site visits have widened recently, as the reality of COVID-19 public health concerns have compelled instructors to fast-transition to online course delivery, canceling most site visits. The purpose of this study is to present construction students with online site visits to supplement contextualized learning in risky, unsafe, or impossible-to-achieve situations. In this project, Mozilla Hubs® was used to establish a virtual collaborative environment that resembled a real-world site visit to a building facility. A pilot study (i.e., a plan-reading assessment) was employed within the virtual environment that provided affordances involving an in-depth learning experience through collaborative communication. The findings demonstrate that virtual collaborative site visits give unique chances to deliver spatiotemporal contexts of sites online and provide an effective remote alternative when these learning opportunities are unavailable.

Key Words: Online site visits; Plan-reading activity; Virtual collaborative environment; Construction education; Virtual reality

Introduction

Direct observation of complicated and sensitive concepts is required in the Architecture, Engineering, and Construction (AEC) academic disciplines to deliver information and exchange ideas between scientists and students, resulting in collaborative learning experiences in real-world spaces (McGrath et al., 2015). AEC educators have used site visits or field trips to engage students in active learning, supplement traditional lessons, and achieve richer and deeper learning experiences (Ashford & Mills, 2006). Furthermore, Furthermore, site visits effectively allow students to speak and cooperate with their peers and other professionals in the real world. It improves students' understanding and exposes them to different real-world concepts introduced theoretically in class settings (Adedokun et al., 2011). Nevertheless, STEM site visits pose significant logistical and accessibility issues for educational institutions and teachers. For example, educational institutions are frequently hindered by a lack of financial resources, administrative responsibilities, safety concerns, and legal dangers in performing site visits. Teachers are under severe time limitations since they must follow strict instructional curricula. Students face additional stress during site visits since they are obliged to travel to remote areas, which conflicts with their attendance in other classes and other personal commitments (Zhang et al., 2017). Students with health issues frequently do not participate in these learning opportunities since it may be counterproductive for their health (Palaigeorgiou et al., 2017). As the reality of the COVID-19 public health issues has compelled schools to swiftly migrate to online course delivery methods, performing real-world site visits has become a challenge that impacted both students and instructors. Traditional online-based platforms for distanced education involve video-conferencing software (e.g., Zoom® and Microsoft Skype®), learning management systems (e.g., Canvas®), and emails (Denis McQuail, 2010). Since the online delivery approach is entirely different from face-to-face instruction, this rapid transition poses challenges for students, instructors, and institutions. For students who got used to face-to-face instruction, traditional online tools create a stronger sense of isolation and lack of contact (Fauville et al., 2021). These challenges further amplify the existing limitations of site visits, reducing STEM students' hands-on learning opportunities to enhance their knowledge understanding, information retention, creativity, and critical thinking in real-world spatiotemporal contexts(D. S. Anderson & Miskimins, 2006).

This paper aims to address this challenge by creating a fully online device-agnostic experience where groups of students can easily and repeatedly experience site visits that were previously impossible, dangerous, or expensive to visit. This paper focuses on illustrating the development of such an online site visit environment and exploring students' learning experience and the system's usability by conducting a pilot study (i.e., construction-related plan-reading activity). Construction management students were recruited to participate in a plan-reading activity as pairs within the online site visit. The contribution of this study to academia is to have a better understanding of the effectiveness of online site visits in construction-related education.

Background

A virtual site visit is a multimedia simulation of a distant location that enables students to observe and interact with site-specific information using electronic devices (Klemm & Tuthill, 2003). Virtual site visits provide a learning environment that allows students to avoid being physically present on site while overcoming spatial-,temporal-, and logistics-related challenges associated with traditional real-world site visits (Wen & Gheisari, 2020). Therefore, the virtual site visit is a promising educational method to supplement traditional site visits and serve as an alternative when traditional site visits are impractical, inaccessible, or dangerous. Due to these technological benefits, virtual site visits have been applied to experience AEC fields, including familiarizing students with the built environment disciplines, assisting students realize the complexity of the construction sites, and improving students' comprehension of building structures (Crawford et al., 2015; Zhang et al., 2017). To effectively achieve these applications, multiple technologies have been explored to represent jobsites digitally. These included reality-capturing techniques using 360-degree images or videos (Eiris et al., 2020) and virtual reality (VR) using computer-generated simulation of reality (Le et al., 2015). Reality-capturing technology simulates a real-world field trip with high levels of realism, which allows students to visit the actual construction sites. In comparison, virtual reality technology enables students to freely explore anywhere on the construction sites and reach out to particular construction activities.

Virtual site visits offer spatiotemporal contexts of sites properly, allowing students to observe and understand construction projects; however, many students struggle to collaborate and communicate contextual information on such virtual site visits. Due to such collaboration and communication barriers, virtual collaborative spaces have been explored to present digital construction jobsites with synchronous and asynchronous collaborative affordance to enhance students' education quality (Le & Park, 2012). These digital spaces have been used to empower students' hands-on exploration and creativity (Van, 2007), environment visualization, verbal and non-verbal communication (Le & Park, 2012), and ultimately, information transfer and learning (A. Anderson & Dossick, 2014). Nevertheless, one of the main barriers to using virtual collaborative spaces is the hardware and software requirements that hinder their accessibility and wide user reachability. For example, complex and large models may result in rendering issues (low frames-per-second rates) due to hardware limitations (Du et al., 2018). In addition, several software compatibility-related issues might arise, for example, when using game engines for development purposes that are different from the platforms used to create models (Du et al., 2018). An alternative that can potentially resolve many of these challenges would be to develop web-based virtual collaborative spaces that are device-agnostic and easily accessible online. Such web-based virtual collaborative spaces have been previously applied in remote education (Yoshimura & Borst, 2020) in other domains, but this paper provides the first effort to integrate it for a construction-related application.

Research Methodology

The research goal of this study is to present construction students with opportunities to enable online location-independent site visits where contextualized learning is dangerous, unsafe, or impossible to achieve. It leads to the following objectives: providing a clear workflow of design and implementation of online site visit; exploring effectiveness of virtual collaborative spaces in construction education; and testing the system's usability. Two steps were accomplished to achieve this goal. First, a virtual collaborative environment was created using Mozilla Hubs® (*Hubs by Mozilla*, 2021) to provide an in-depth learning experience through collaborative communication in a virtual space that resembles a real-world site visit to a building facility. Then, a plan-reading activity was conducted to understand students' learning outcomes within the virtual site visit and test the system's usability.

Online Site Visit Development

The virtual experience was designed using Mozilla Hubs® because of its device-agnostic characteristics and minimum hardware and software requirements, allowing access to the virtual site visit experience through a web browser (Yoshimura & Borst, 2020). Various collaboration and communication affordances in Mozilla Hubs® was used (e.g., embodied interaction through avatars and virtual pointers, shared virtual spatiotemporal context of site visits, voice and text chat, desktop and camera sharing) to facilitate remote collaborative tasks in the virtual site visit (Sun & Gheisari, 2021). In this study, the virtual site visit was developed using a real-world educational facility at the University of Florida as a real-world building context. This facility consists of classrooms, laboratories, offices, and mechanical rooms, unavailable to the students due to COVID-19-related restrictions imposed by the CDC and the University of Florida. Figure 1 shows the technical development process of the online site visit. First, the 3D model of the building facility was developed in Autodesk® Revit. The generated 3D model in .rvt format was then exported into a .glb format using the SimLab® GLTF exporter (*Simlab Soft - Enabling Interactive VR*, 2021). Then the .glb file of the building model was imported to the Mozilla Spoke® (*Spoke by Mozilla*, 2021) to edit the 3D model and add other contents into the scenes before publishing it into Mozilla Hubs® (https://hubs.mozilla.com/odLEL5N/virtual-site-visit-plan-reading).

Students were allowed to use specific tools within Mozilla Hubs® that would assist in their collaborative work. For example, students could communicate and collaborate with their peers via voice and text chat, as well as other drawing tools (Figure 2-a). Students were also allowed to share 2D drawings with their peers in real-time via uploading files (Figure 2-b).

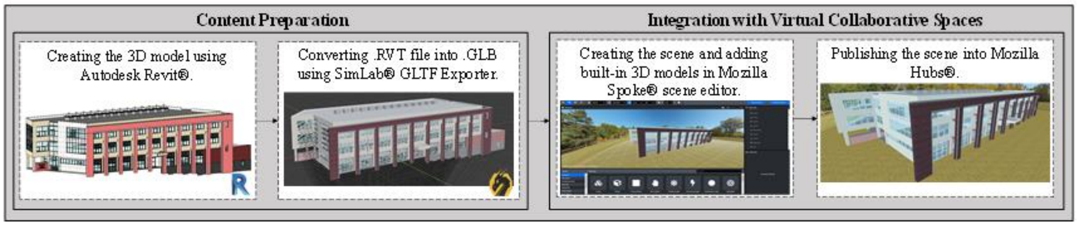
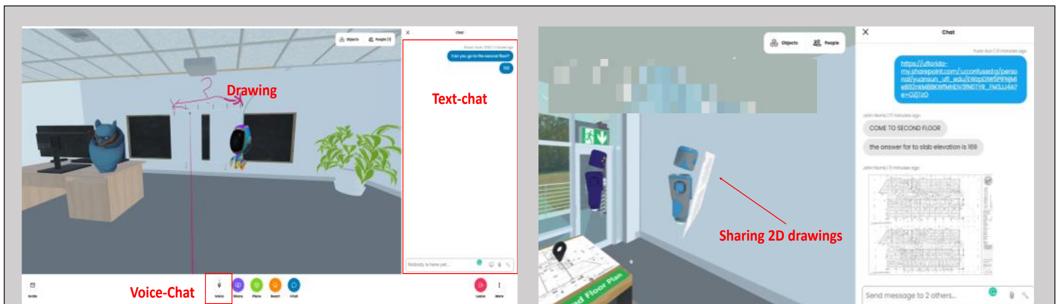


Figure 1. The technical development process of the online site visit



(a) Student-student interaction and communication in the virtual site visit (b) Sharing 2D drawings in the virtual site visit

Figure 2. Collaboration and communication affordances in the virtual site visit condition

Pilot Study – A Plan-Reading Activity

The purpose of this virtual site visit was to create a similar experience for students to walk inside a building facility and examine common plan reading tasks and interpret 2D drawings on the site. 2D drawings (e.g., plan views, elevations, detailed sections) are the only legally recognized design documents that depict buildings' spatial relationships, dimensions, details, and components (Sweany et al., 2016). These 2D drawings are commonly referred to on the sites by different project team members to comprehend and communicate the design and construction of building elements (Foroughi Sabzevar et al., 2021). Therefore, there is a need for educational programs to train better AEC students on how to effectively and adequately read plans while enhancing their interpretation and comprehension skills. Such plan-reading training commonly employs site visits to establish cognition, perception, and visualization of objects in both 2D and 3D (Chen et al., 2011). However, physical site visits were canceled due to COVID-19 and logistics-/safety-related challenges. This study developed an online site visit using Mozilla Hubs® to perform an actual plan-reading activity in an educational facility. Such environments not only enable students to communicate, interact, and collaborate within the same virtual space but also allow them to explore an interactive 3D building facility virtually, look at specific building components (e.g., walls, ceilings, doors, windows) on the building site, while having access to the 2D drawings associated with that building.

Experimental Methodology

The plan-reading study was performed to explore how online site visits could provide construction students with opportunities to collaborate on construction-related activities within a digital jobsite. The online site visit experiment was specifically designed and conducted for a construction management course. An educational building facility was selected for the online site visit in this project. This class was chosen due to its course modules on how to effectively read, understand, and use construction documents to facilitate communication. As a part of this course module, students are typically required to walk in a building facility and use the building 2D plans to perform a plan-reading activity. However, due to safety and health restrictions imposed by COVID-19, this class was only offered online, and students were not able to do the on-site plan-reading activity. First, all students participated in an online two-hour session focusing on plan-reading importance and techniques. Then, students were randomly assigned as pairs to complete a plan-reading activity within the online site visit. In addition to the plan-reading activity, students were required to respond to an online demographics and a system usability survey afterward. All online questionnaires were created and distributed through Qualtrics® (*Qualtrics XM*, 2021). The experiment protocol to collect the data for this activity was approved by the University of Florida Institutional Review Board (IRB# 202100453).

Study Metrics

The study had two primary metrics: plan-reading performance and system usability. Students worked in pairs to complete a plan-reading assessment that required answering a series of plan-reading questions. The course instructor and the graduate teaching assistants designed, discussed, and approved the questions to ensure that they met the module's plan-reading learning objective. The rate of correct responses (i.e., the percentage of correct responses out of all possible answers on the nine questions) and task completion duration (i.e., the time difference between when students started the plan-reading assessment and submitted it) were used to evaluate students' plan reading performance. System Usability Scale (SUS) was also used to understand users' experience within the virtual environment. SUS is a validated 5-point Likert-scale unidimensional questionnaire that assesses users' perceived usability of a system (Brooke, 1996). The SUS has been widely applied across various disciplines and fields. Numerous researchers have established its reliability, validity, and sensitivity to a variety of independent variables (Pedroli et al., 2018). The SUS was used in this study to assess the quality of the user experience by determining the: (1) effectiveness (i.e., users' ability to complete tasks using the system); (2) efficiency (i.e., users' resource consumption level while performing tasks); and (3) satisfaction (i.e., users' reactions to the system's performance). Additionally, student demographic information (i.e., age, gender, educational level, and their familiarity with plan-reading and virtual collaborative environment) was collected to understand the background of the participants. The study outcomes were analyzed using descriptive statistics.

Results and Discussion

A total of 18 students (9 pairs) participated in the online site visit study. Table 1 shows their demographic information.

Table 1

Online site visit participant demographic information

Parameters		**Responses Number** (Percentage)
Gender	Females	2 (11%)
	Males	16 (89%)

Educational Level	Undergraduates	15 (83%)
	Graduates	3 (17%)
Educational Background	Construction Management	14 (78%)
	Other (e.g., Architectural and Civil Eng.)	4 (22%)
Familiarity with Mozilla Hubs®	None	12 (67%)
	Some knowledge of	3 (17%)
	Fair	3 (17%)
	Competent	0 (0%)
Familiarity with Plan Reading	None	0 (0%)
	Some knowledge of	5 (28%)
	Fair	9 (50%)
	Competent	4 (22%)

Plan-Reading Performance and System Usability

The objective of the plan-reading assessment was to use the number of correct answers and task completion duration to evaluate students' plan-reading performances (Table 2). The number of correct answers followed a mean of 76% ± 1.5%. The observed students' text feedback indicated that the online site visit helped students' understanding of plan-reading. For example, one of the users indicated that "*the system could help me figure out architecture objects."* The task completion duration (min: secs) displayed a mean of 21:05 ± 09:21. It should be noted that the task completion duration might have been longer because of some technical challenges (e.g., unstable network connection) encountered by several students. For example, a user experienced such technical difficulties and indicated that *"I have to take a while to load into rooms and sometimes I was kicked out room."*

Table 2

Results for plan-reading performance

Variables	Mean (SD)
Rate of Correct Responses	76% (1.5%)
Time (Mins: Secs)	21:05 (09:21)

Table 3 shows the *System Usability Scale (SUS)* results. Based on the obtained results, the overall usability score of this system was 62.65 out of 100. The obtained score seems acceptable based on Bangor et al. (2009) 's overall platform usability scoring system. The outcome shows that the usability of this developed system is between "Good" and "OK," and the acceptability range is low marginal. Nevertheless, the score (62.65) of virtual site visit is comparable with other studies exploring the effect of virtual collaborative environment in the education field (Granić et al., 2017). Despite showing low-marginal acceptability of overall usability in online site visits, some students' feedback acknowledged the potentials of such site visits to improve students' learning motivation. For example, one student indicated that "*the system was fun to use*," and another one stated that "*it could help me actually see the building better*."

Table 3

System usability scale (SUS) results

Questions	**Responses**
Scale: Strongly Disagree (1) – (5) Strongly Agree	Mean (SD)

Q1: I think that I would like to use this system frequently	3.67 (1.029)
Q2: I found the system unnecessarily complex.	2.56 (1.247)
Q3: I thought the system was easy to use.	3.67 (0.907)
Q4: I think that I would need the support of a technical person to be able to use this system.	2.78 (1.396)
Q5: I found that the various functions in the system were well integrated.	3.78 (1.003)
Q6: I thought there was too much inconsistency in this system.	2.72 (1.227)
Q7: I would imagine that most people would learn to use this system very quickly	4.00 (0.840)
Q8: I found the system very awkward to use.	2.83 (1.098)
Q9: I felt very confident using the system	3.50 (1.043)
Q10: I needed to learn a lot of things before I could get going with this system.	2.67 (0.907)
Overall Usability Score (Bangor et al., 2009) :	62.65 (3.114)

Conclusion and Future Work

This project utilizes collaborative spaces for conducting online site visits to overcome barriers associated with current learning and teaching approaches where contextualized learning is risky, unsafe, or impossible. For this purpose, an online site visit was developed in a virtual collaborative space. A pilot study for a plan-reading activity was conducted within the online site visit to understand students' learning experience within the online site visit and the virtual environment's usability. Results showed that the online site visit effectively helped students learn 2D drawings interpretation. Moreover, the system displayed low marginal acceptability, which illustrates a slightly unnecessarily complex system with technical issues that might not be easy to use. The observed results within the online site visit indicated that students could interact with the virtual environment and collaborate within the shared virtual spatiotemporal contexts. Additionally, the web-based virtual collaborative space was easily accessible online, allowing student access with any device. Moreover, the technical development process to create such an online site visit is not complex. Mozilla Hubs® and other new virtual collaborative platforms eliminate the need for computer programming and reduce the time investment for course instructors to develop the digital spaces. Overall, the study findings contributed to improving the existing online site visit in AEC education by creating a clear workflow of design and implementation of online delivery of spatiotemporal contexts of sites and offering an effective device-agnostic alternative when these learning opportunities are not available. However, there were specific research and technical challenges in implementing such online visits in this study that should be noted

This study also had a few research and technical limitations. First, the sample size of students was small (i.e., only 18 participants). Future research should collect a larger group of students from multiple AEC backgrounds. Moreover, this study only applied a plan-reading activity to evaluate the learning outcome in the virtual site visit. Additional studies should be conducted to understand the effects of virtual site visits on other construction-related educational activities. The low quality of the building texture diminished the sense of being on a real-world construction site, which could have been caused by the material texture settings used to export the 3D model. Additionally, Mozilla Hubs®' limitations on content file size degraded the quality of submitted 2D drawings within the environment, which might have impaired students' plan-reading abilities. Applying real-world construction materials textures and modifying the sizes of 3D components, text, images, and 2D drawings to achieve an appropriate quality might improve usability outcomes of the virtual environment. Finally, the students reported technical challenges (e.g., audio inconsistencies, low-resolution visual contents, fluctuating bandwidth, internet connection issues) that might have ultimately led to longer activity completion duration. Using students' computers and relying on their personal internet connections might have led to several technical difficulties. Future research should explore laboratory-controlled settings better to explore the benefits of such online site visits.

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