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Exploring Online Social Collaborative Spaces as an Alternative to Physical Site Visits in AEC Education: Development, Evaluation, and Insights

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Site visits are crucial in Architecture, Engineering, and Construction (AEC) education, offering students hands-on experience and practical insights. However, physical visits often encounter challenges such as logistical constraints, safety concerns, and limited accessibility. Consequently, there is a growing trend towards web-based virtual learning environments, providing flexible and accessible alternatives to traditional site visits. This study discusses the development and evaluation of an Online Social Collaborative Space (OSCS) as a substitute for real-world site visits. The workflow for OSCS development is outlined, followed by a pilot study involving students to assess the OSCS. The evaluation focused on quantitative measures of workload, ease of use, and sense of presence within the environment. The findings aim to enhance conventional AEC education practices by offering insights into the feasibility and effectiveness of immersive online social collaborative spaces as substitutes for physical site visits.

Keywords: Online Social Collaborative Spaces, AEC, MEP, Education, Site Visits

Introduction

Site visits are a vital component of Architecture, Engineering, and Construction (AEC) education, bridging classroom learning with real-world experience through hands-on practice in dynamic jobsite environments (Sun et al., 2022). This active learning approach enhances students' understanding, creativity, critical thinking, and information retention (Anderson & Miskimins, 2006), while also fostering collaboration with peers and industry professionals and broadening career awareness (Adedokun et al., 2012). However, physical site visits face significant challenges, including restricted accessibility, scheduling conflicts, safety risks, financial and logistical constraints, as well as limited participation capacity, which negatively affect their implementation (C. Zhang et al., 2017). Alternative training methods are therefore necessary to overcome these barriers while retaining the educational value of site visits, improving both accessibility and effectiveness in AEC education.

Virtual site visits have been explored to overcome the challenges associated with traditional in-person site visits, relying mostly on Virtual Reality (VR) technology to simulate real-world site experiences (Wen & Gheisari, 2020). For example, Lucas and Gajjar (2022) found that students using VR simulations for learning wood framing had a better understanding of construction techniques than those taught only in traditional classrooms. Maghool et al. (2018) developed a VR environment for architecture students to observe the construction process and architectural details of a house, leading to greater engagement, clearer understanding of construction processes, and improved knowledge retention compared to traditional classes. Some researchers have also integrated 360-degree images and videos, as well as avatars, as part of their developed VR environments to make them more realistic. For example, Pham et al. (2018) developed a 360-degree panoramic VR system for construction safety education and found that students using VR scored higher on post-visit assignments than those who attended physical site visits. Eiris et al. (2021) explored how virtual human (avatar) appearance fidelity affects students' learning and engagement in electrical trade training, finding that low-fidelity avatars can achieve educational outcomes similar to high-fidelity ones. The advantages of VR-based site visits over traditional visits include the ability to simulate real-world experiences in a safe environment, overcoming the spatial, temporal, and logistical limitations of physical site visits while offering flexible learning opportunities without requiring physical presence (Wen & Gheisari, 2020). However, these methods face accessibility challenges, including the high costs of equipment and software, complex operation, and potential side effects such as dizziness and eyestrain (Cook et al., 2019). Furthermore, head-mounted displays (HMDs) as the most commonly used VR hardware, are typically limited to single-user operation (H. Zhang, 2017). While collaborative VR can be used, the high costs and technical knowledge needed restrict collaborative interactions, which are a vital component of real-world site visits (Sun et al., 2022).

To address the limitations of both in-person and VR-based site visits, Online Social Collaborative Spaces (OSCSs) have emerged as a practical alternative. OSCSs are web-based, device-agnostic VR environments that can be accessed through a simple web link, eliminating the need for specialized hardware or advanced technical knowledge associated with the use of VR and HMDs. They promote collaborative, active learning by enabling students and educators to interact as digital avatars within simulated environments (Mystakidis, 2022). Unlike traditional VR-based methods, which rely on HMDs and necessitate technical expertise, OSCSs significantly enhance accessibility, allowing participation from any location with an internet connection. They also support real-time collaboration among multiple participants, making them more inclusive and cost-effective. OSCSs only require a web browser on standard devices such as PCs or mobile devices, minimizing financial and logistical barriers while retaining the educational benefits of traditional site visits. Several studies examined the application of OSCSs in AEC education. For example, Sun et al. (2022) compared the impact of OSCSs and Zoom© on students' learning in a construction plan reading task, finding that OSCSs provide site-specific spatiotemporal context and are effective for remote learning. Eiris et al. (2022) assessed changes in students' perceived knowledge of rail track construction before and after a railway transportation site visit using an OSCS, finding enhancements in both knowledge and engagement levels. However, no study has yet compared the educational effectiveness of OSCSs with real-world site visits. This research addresses this gap by presenting the first phase of a project focused on developing an OSCS specifically for AEC site visits and testing its feasibility. The specific study objectives are: (1) Technical Development—to create an OSCS that allows AEC students to explore, interact, and learn in a manner comparable to physical site visits; and (2) Feasibility Assessment—to evaluate students' sense of presence, perceived workload, and usability of the OSCS.

Methodology

This study examines the feasibility of using OSCSs for site visits. First, an OSCS was developed to simulate an electrical systems site visit. Then, a user-centered pilot study was conducted in which participants completed the virtual electrical systems site visit and evaluated their sense of presence, mental workload, and the usability of the OSCS. The subsections below discuss the electrical systems site visit selection, the technical development of the OSCS, as well as the experimental procedure and assessment.

Site Visit Selection

An electrical systems site visit was selected as the case study due to several factors. First, Mechanical, Electrical, and Plumbing (MEP) systems are known to be complex subjects for AEC students and are associated with the highest need for frequent physical site visits to understand their practical applications (Eiris & Gheisari, 2019). In this study, the virtual site visit in the OSCS was designed to replicate an in-person electrical systems site tour conducted in the *COSC 325: Mechanical, Electrical, and Plumbing Systems in Construction I* course in the Department of Construction Science at Texas A&M University. Specifically, one of the course assignments includes an in-person tour of the electrical systems in Francis Hall at the university. Led by the course instructor, the tour traces the flow of electrical power through the building, starting at the transformer outside and progressing to the crawl space where the cables enter. The tour then moves to the first-floor electrical room, going through the second-floor electrical room, and concluding in the top-floor electrical room. Throughout the tour, the instructor explains how power is supplied, the purpose and operation of electrical equipment in each room, and provides guidance on reading and interpreting equipment specifications, emphasizing their significance for safety and system operation.

Technical Development of the OSCS

The technical development of the OSCS followed two main steps: (1) Content Preparation and (2) Integration with OSCS (see Figure 1). First, a Building Information Model of Francis Hall was created in Autodesk© Revit and imported into Unity©. Additionally, 360° images of the electrical rooms, capturing the building's electrical systems, were collected using 360° cameras and integrated into the virtual environment within Unity©. Spatial.io© was chosen as the platform for hosting and delivering the virtual electrical systems site visit due to its accessibility, ease of Unity© integration, and minimal hardware and software requirements. Spatial.io© also provides real-time collaboration features, including avatar customization, 3D presentations, digital whiteboards, virtual pointers, voice, video, and text chat, as well as desktop and virtual tool sharing.

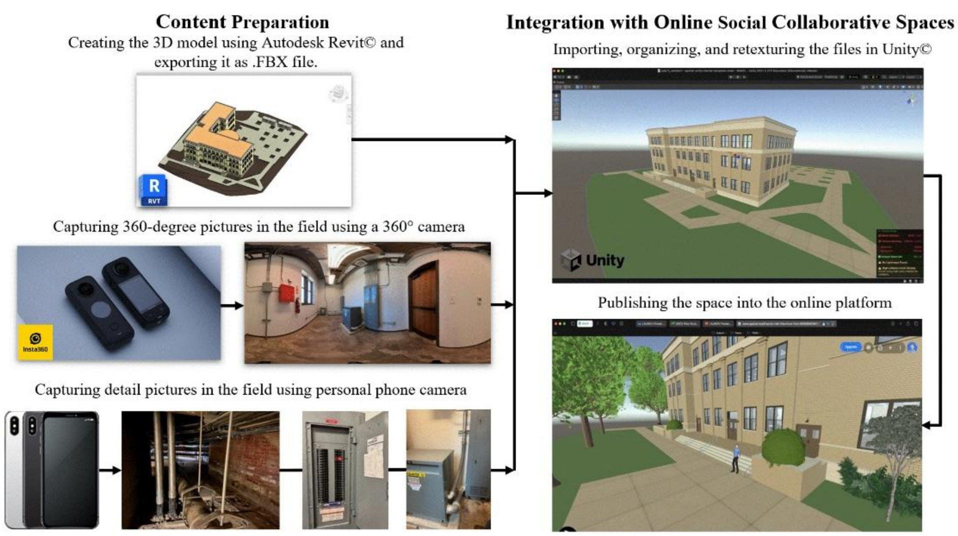

Figure 1. Technical Development Workflow

The development process involved modeling Francis Hall in Autodesk Revit©, exporting it as an .FBX file, and then organizing and retexturing it in Unity© to closely replicate its real-world counterpart. An inspection user interface (UI) was created in Unity©, incorporating 360° and two-dimensional (2D) images of various electrical components within the electrical rooms in Francis Hall. This UI allowed participants to perform realistic tasks typically performed in the real-world electrical systems site visit, such as opening and closing electrical equipment doors, accessing component details, and reviewing specifications (see Figure 2). The OSCS design and development were iterative, incorporating ongoing feedback from the course instructor to ensure content accuracy, functionality, and usability. This collaboration helped the OSCS closely replicate the physical electrical systems site visit experience. Upon completing the environment, the Spatial Creator Toolkit for Unity© SDK was used to publish the platform online on Spatial©.

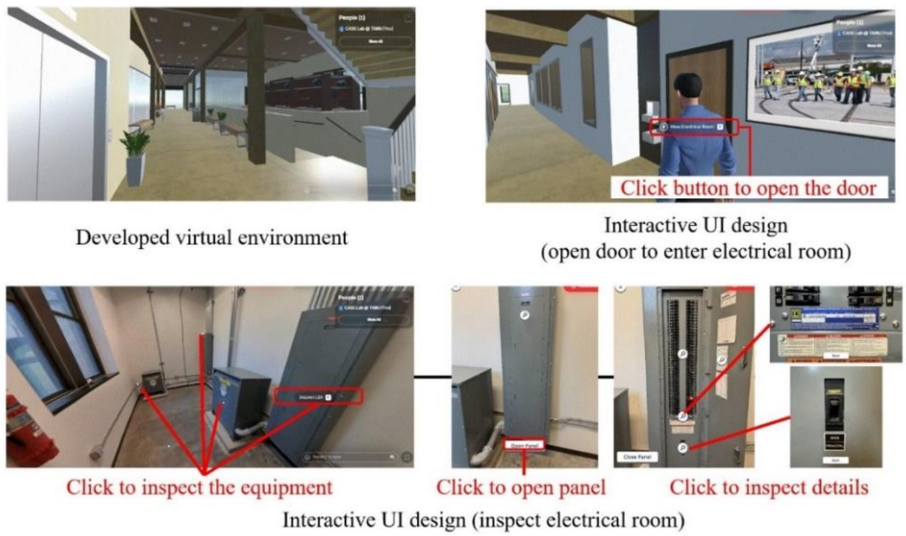

Figure 2. Developed environment and interactive UI

Experiment Procedure and Assessment

Participants were first provided an online link via Qualtrics© to complete a demographics questionnaire. After completing the questionnaire, they were given another link within Qualtrics© to access the OSCS in Spatial.io©. In the OSCS, a trained researcher—who had been guided by the class instructor responsible for moderating these electrical systems site visits in the real world—served as the session moderator to replicate the site visit experience. Prior to the experiment, this researcher was also trained to lead the virtual site visit in Spatial.io. The virtual electrical systems site visit mirrored the procedure of the in-person visit, guiding participants through the entire electrical system of Francis Hall, from the outdoor transformer to the top-floor electrical room. Detailed explanations of all electrical equipment were provided, ensuring consistency with the physical tour.

After completing the virtual electrical systems site visit, participants worked in pairs to answer a set of questions designed to assess their knowledge of the electrical concepts covered. However, test scores were not analyzed or presented, as the primary goal of this study was to test the feasibility of the OSCS. Participants were also asked to complete three validated and widely used questionnaires: (1) the Igroup Presence Questionnaire (IPQ) to assess their perceived sense of presence in the developed OSCS virtual environment (Schubert et al., 2001); (2) the NASA Task Load Index (NASA-TLX) to measure their perceived cognitive load after completing the tour in the OSCS (Hart & Staveland, 1988); and (3) the System Usability Scale (SUS) to evaluate their perceived usability of the OSCS (Brooke, 1996). Additionally, an open-ended feedback question, posed after completing all three questionnaires, allowed participants to share their overall experiences with the collaborative space.

Results and Discussion

Demographics

Ten students participated in the study, evenly divided by gender (five males and five females), with an overall average age of 23.20 ± 4.45 years (see Table 1). Participants were split between undergraduate (N=6, 60%) and graduate students (N=4, 40%). Their educational backgrounds included Engineering (N=4, 40%), Construction (N=3, 30%), Architecture (N=1, 10%), Bioinformatics (N=1, 10%), and Computer Science (N=1, 10%). Within the Engineering sector, the distribution across majors was as follows: civil engineering (N=2, 50%), electrical engineering (N=1, 25%), and mechanical engineering (N=1, 25%). The majority of participants (N=8, 80%) had at least some prior experience in the AEC industry, with experience ranging from 1 month to over 2 years; however, most reported being no more than slightly familiar with electrical systems. All participants (N=10, 100%) had at least some familiarity with video games and digital environments.

Table 1. Participant Demographics

Parameters	**N (%)**	**Parameters**	**N (%)**
Gender		AEC Experience	
Males	5 (50%)	None	2 (20%)
Females	5 (50%)	1-6 months	3 (30%)
		0.5-1 year	1 (10%)
		1-2 years	1 (10%)
		2+ years	3 (30%)
Age		Familiarity with Electrical Systems	
≤20	4 (40%)	Not familiar at all	4 (40%)
21-25	4 (40%)	Slightly familiar	4 (40%)
26-30	1 (10%)	Moderately familiar	1 (10%)
31-35	1 (10%)	Very familiar	0 (0%)
		Extremely familiar	1 (10%)
Educational Level		Familiarity with Video Games	
Undergraduates		Not familiar at all	0 (0%)
Freshmen	0 (0%)	Slightly familiar	3 (30%)
Sophomore	1 (10%)	Moderately familiar	3 (30%)
Junior	3 (30%)	Very familiar	1 (10%)
Senior	2 (20%)	Extremely familiar	3 (30%)
Graduates			
Master’s	1 (10%)		
Doctor of Philosophy	3 (30%)		
Educational Background		Familiarity with Digital Environments	
Construction	3 (30%)	Not familiar at all	0 (0%)
Architectural	1 (10%)	Slightly familiar	2 (20%)
Electrical Engineering	1 (10%)	Moderately familiar	3 (30%)
Civil Engineering	2 (20%)	Very familiar	2 (20%)
Mechanical Engineering	1 (10%)	Extremely familiar	3 (30%)
Other	2 (20%)		

Sense of Presence

The average scores (M: mean; SD: Standard Deviation) of participants on a 7-point Likert scale (from -3 to +3) are presented in Table 2 for each of the four factors—Presence, Spatial Presence, Involvement, and Experienced Realism—of the IPQ. IPQ was analyzed using the -3 to +3 scale, which aligns with the scale used in benchmark studies in the literature. This choice allows for direct comparison of the study's findings with previously established results, ensuring consistency and contextual relevance in interpreting the data. Overall, the results suggest that participants experienced acceptable levels of presence. In terms of *Presence*, participants reported a moderate-to-high sense of 'being there' and immersion in the OSCS (Q1, M = 1.50, SD = 1.72). Compared to established benchmarks in the literature, which analyzed over 9,000 responses across 229 studies using the IPQ (Tran et al., 2024), the *Presence* score (M = 1.50, SD = 1.72) was at the threshold between the 'Moderate' and 'High' ranges, which reflects a moderate-to-high sense of presence among the participants.

Regarding *Spatial Presence*, participants indicated a moderate sense of engagement and connection with the OSCS. They reported neutral feelings about the virtual world 'surrounding' them (Q2, M = 0.60, SD = 2.12), and expressed moderate-to-high feelings of acting within the OSCS rather than operating it from outside (Q5, M = 1.40, SD = 0.70). Additionally, they felt moderately-to-highly present in the OSCS (Q6, M = 1.50, SD = 1.08), somehow disagreed with perceiving the OSCS as mere pictures (Q3, M = -0.80, SD = 2.20), and reported slightly reduced feelings of detachment from the virtual space (Q4, M = 0.80, SD = 1.69). It is important to note that the calculated overall average score for *Spatial Presence* (M = 1.02, SD = 1.11) falls within the 'Moderate' range according to literature benchmarks (Tran et al., 2024), indicating acceptable levels of physical presence within the OSCS compared to other environments.

For *Involvement*, participants reported a moderate level of engagement with the OSCS, reflecting their varying degrees of focus on the virtual environment. They indicated moderate awareness of the real world surrounding them during navigation (Q7, M = -0.80, SD = 2.04) but slightly disagreed with being entirely detached from their real environment (Q8, M = -0.80, SD = 1.69). Participants also noted some continued attention to real-world elements, as reflected by their moderate agreement with paying attention to their surroundings (Q9, M = 1.10, SD = 2.13). Additionally, they expressed a moderate sense of being captivated by the virtual environment (Q10, M = 0.60, SD = 1.96). These findings suggest that while participants were somewhat immersed in the OSCS, they maintained a connection to their physical surroundings, indicating a balance between involvement in the OSCS and awareness of the real world. It should be noted that the overall average *Involvement* score of -0.53 (SD = 1.16) fell within the 'Low' range according to benchmarks (Tran et al., 2024). The low Involvement score may be attributed to the web-based, PC format of the OSCS, which lacks the immersive qualities of HMDs that promote more focused and less distracted interactions, providing a more engaging experience. Additionally, as this was participants' first time using the OSCS, they may have required time to adapt to the environment and navigation controls, which could have limited their initial engagement. External distractions common in PC-based setups, such as notifications or awareness of physical surroundings, may have further impeded their ability to fully immerse in the virtual OSCS experience.

In terms of *Experienced Realism*, participants perceived the virtual environment as quite realistic, reporting a moderate-to-high degree of realism compared to the real world, as suggested by participants' answers to both "how real did the virtual world seem to you" questions with high averages of -1.60 ± 1.58 (Q11) and 0.60 ± 2.12 (Q13), as well as high consistency with real-world experiences (Q12, M = 2.20, SD = 1.03). However, the virtual world was perceived as less real than the actual world (Q14, M= -1.50, SD = 1.84), suggesting an overall authentic but not exaggerated experience of realism. The overall *Experienced Realism* average score (M = 0.73, SD = 1.23) fell within the 'Very High' range when compared to benchmark thresholds reported in the literature (Tran et al., 2024), suggesting the OSCS was perceived as highly realistic. It should be also noted that participants did not provide any presence-related comments in their responses to the open-ended feedback question.

Table 2. IPQ (Mean and SD reported on a 7-point Likert scale: -3 to +3)

Questions		Mean ± SD
Presence		
Q1.	In the computer-generated world, I had a sense of "being there" (-3 = not at all, 3 = very much).	1.50 ± 1.72
Spatial Presence		
Q2.	Somehow, I felt that the virtual world surrounded me (-3 = fully disagree, 3 = fully agree).	1.02 ± 1.11
Q3.	I felt like I was just perceiving pictures (-3 = fully disagree, 3 = fully agree).	
Q4.	I did not feel present in the virtual space (-3 = not felt present, 3 = felt present).	
Q5.	I had a sense of acting in the virtual space, rather than operating something from outside (-3 = fully disagree, 3 = fully agree).	
Q6.	I felt present in the virtual space (-3 = fully disagree, 3 = fully agree).	
Involvement		
Q7.	How aware were you of the real world surrounding while navigating in the virtual world (i.e. sounds, room temperature, other people, etc.) (-3 = extremely aware, 3 = not aware at all)?	-0.53 ± 1.16
Q8.	I was not aware of my real environment (-3 = fully disagree, 3 = fully agree).	
Q9.	I still paid attention to the real environment (-3 = fully disagree, 3 = fully agree).	
Q10.	I was completely captivated by the virtual world (-3 = fully disagree, 3 = fully agree).	
Experienced Realism		
Q11.	How real did the virtual world seem to you (-3 = completely real, 3 = not real at all)?	0.73 ± 1.23
Q12.	How much did your experience in the virtual environment seem consistent with your real-world experience (-3 = not consistent, 3 = very consistent)?	
Q13.	How real did the virtual world seem to you (-3 = as real as an imagined world, 3 = indistinguishable from the real world)?	
Q14.	The virtual world seemed more realistic than the real world (-3 = fully disagree, 3 = fully agree).	

Perceived Workload

Participants' raw NASA-TLX scores (range: 0-20) across the six workload dimensions (Mental, Physical, Temporal, Performance, Effort, and Frustration) are presented in Table 3. When broken down into the six workload dimensions, participants indicated that the virtual electrical systems site visit, conducted through the developed OSCS, required a moderate level of mental effort (Mental Demand: M = 11.90, SD = 4.53), suggesting that while the task involved some cognitive engagement, it was not overly challenging. Physical demand was minimal (Physical Demand: M = 3.60, SD =

3.13), as expected in a virtual setting similar to the OSCS where physical movement is limited. Temporal demand was also low (Temporal Demand: M = 4.60, SD = 2.63), likely because the self-paced nature of the task allowed participants to proceed at their own speed, reducing any perceived time pressure. When evaluating their own performance, participants rated it relatively good (Performance: M = 6.40, SD = 5.15), indicating a strong sense of accomplishment during the task. Effort was rated as moderate (Effort: M = 11.30, SD = 5.95), reflecting that task completion required some effort but was manageable overall. In terms of frustration, participants reported moderate levels (Frustration: M = 10.10, SD = 6.14), suggesting that while the experience was generally smooth, occasional issues were encountered. Participants' responses to the open-ended feedback provided insight into potential sources of frustration. For instance, one participant expressed enjoyment of the experience but highlighted a technical issue: *"the avatars (my colleagues and I) were clustered together in the electrical room"*, referring to how all participants appeared in the same location within the 360° view. This overlap may have been somewhat distracting, briefly disrupting the immersive experience and potentially contributing to participants' frustration ratings. The calculated overall average NASA-TLX score (range: 0-100) (M = 39.92, SD = 13.94) was comparable to benchmark scores obtained from a meta-analytic review of 556 studies using NASA-TLX. Specifically, the obtained score was similar to those reported for computer-enabled virtual environments (M = 43, SD = 14) (Hertzum, 2021), suggesting that the workload experienced by participants was within an acceptable range relative to other virtual environments.

Table 3. NASA-TLX Questionnaire

Workload Dimensions	**Mean ± SD**
Mental Demand (0 = Low, 20 = High)	11.90 ± 4.53
Physical Demand (0 = Low, 20 = High)	3.60 ± 3.13
Temporal Demand (0 = Low, 20 = High)	4.60 ± 2.63
Performance (0 = Good, 20 = Poor)	6.40 ± 5.15
Effort (0 = Low, 20 = High)	11.30 ± 5.95
Frustration Level (0 = Low, 20 = High)	10.10 ± 6.14
Overall Average NASA-TLX Score (0 = Low – 100 = High)	39.92 ± 13.94

System Usability

Participants' SUS scores are summarized in Table 4. Overall, participants had a mixed yet moderately favorable perception of the OSCS platform usability. They rated anticipated frequency of use as somehow neutral (Q1, M = 2.40, SD = 1.26), suggesting limited interest in repeated use. Complexity was a noted aspect, with participants somehow agreeing that the system felt unnecessarily complex (Q2, M = 3.40, SD = 0.70) and that a technical person's support is needed to use the OSCS (Q4, M = 3.30, SD = 0.82). Nevertheless, participants found the system's functions to be reasonably well integrated (Q5, M = 3.50, SD = 0.85) and felt that most people would learn to use it relatively quickly (Q7, M = 3.50, SD = 0.71). Ease of use and confidence also received neutral-to-positive ratings (Q3, M = 3.10, SD = 1.29; and Q9, M = 3.10, SD = 0.99), and while the system was rated as somewhat awkward (Q8, M = 3.20, SD = 0.92), initial setup requirements were seen as slightly demanding but manageable (Q10, M = 3.20, SD = 0.79). The overall average SUS score was 81.00 ± 13.60, placing the system between 'Good' and just below 'Excellent' usability according to SUS benchmarks (Bangor et al., 2009). This indicates that participants found the system generally usable, though there are areas for improvement. For instance, two participants noted *"difficulties in reading specifications on some equipment"*, suggesting the need for an image enlargement feature in the OSCS. Additionally, the technical issue of avatars clustering in the electrical room caused some frustration. These issues should be addressed to enhance usability and improve the learning experience.

Table 4. SUS Questionnaire

Questions (1: Strongly Disagree – 5: Strongly Agree)	**Mean ± SD**
Q1. I think that I would like to use this system frequently	2.40 ± 1.26
Q2. I found the system unnecessarily complex	3.40 ± 0.70
Q3. I thought the system was easy to use.	3.10 ± 1.29
Q4. I think that I would need the support of a technical person to be able to use this system.	3.30 ± 0.82
Q5. I found that the various functions in the system were well integrated	3.50 ± 0.85
Q6. I thought there was too much inconsistency in this system.	3.70 ± 0.48
Q7. I would imagine that most people would learn to use this system very quickly.	3.50 ± 0.71
Q8. I found the system very awkward to use.	3.20 ± 0.92
Q9. I felt very confident using the system.	3.10 ± 0.99
Q10. I needed to learn a lot of things before I could get going with this system.	3.20 ± 0.79

Conclusion

The aim of this study was to develop and evaluate the feasibility of an Online Social Collaborative Space (OSCS) as a tool for conducting virtual site visits. A pilot study was conducted, involving a virtual electrical site tour within the OSCS, where participants assessed their sense of presence, perceived workload, and system usability. The results indicate that participants experienced acceptable levels of presence, suggesting the OSCS effectively simulated aspects of a physical site visit. Perceived workload scores fell within acceptable ranges, indicating that participants could navigate and engage with the environment without excessive cognitive or physical demand. System usability was also rated favorably. However, several technical issues were identified, such as clustered avatars and limited image enlargement capabilities, which impacted user experience and immersion. In addition, this study is limited by the small sample size, which constrains the generalizability of findings, as well as the focus on electrical systems, leaving other AEC disciplines unexplored. The absence of a direct comparison with physical site visits also limits conclusions about the relative effectiveness of OSCS. Future research is warranted to address these limitations by refining the OSCS based on participant feedback, expanding the sample size, incorporating diverse AEC disciplines, and conducting comparative studies. These efforts aim to further validate the OSCS's potential as a scalable, accessible, and effective alternative to traditional site visits in AEC education.

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