2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #51001

IUSE: iVisit: Situated Learning Experiences through Web-based Virtual Field Trips

Dr. Ricardo Eiris, Arizona State University
Dr. Masoud Gheisari, University of Florida

Dr. Masoud Gheisari is an Assistant Professor in the Rinker School of Construction Management at the University of Florida. I received my Ph.D. in Building Construction from Georgia Tech in December 2013. He considers himself an educator and a researcher

Danielle Oprean, University of Missouri - Columbia
Steven Marc Weisberg, The University of Texas at Arlington

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Abstract

STEM educators widely use field trips to provide situated learning experiences that promote active engagement, contextual understanding, and the application of classroom knowledge in authentic environments. Despite their instructional value, traditional field trips are increasingly constrained by logistical, financial, legal, and accessibility barriers, including limited resources, administrative burden, safety concerns, travel demands, and health risks. These constraints disproportionately affect students in large programs and restrict access to complex, remote, or hazardous learning contexts. Virtual field trips (VFTs) have emerged as a scalable alternative that can mitigate these challenges while preserving key characteristics of situated learning, such as shared visual–auditory workspaces and real-time interaction among learners and instructors. The iVisit project investigates how web-based, multi-user VFTs can support spatial communication development in Architecture, Engineering, and Construction (AEC) education. This paper synthesizes findings from three complementary efforts conducted during the first year of the project: (1) a systematic review of spatial ability research in construction education, (2) a faculty focus group examining field trip practices in construction and their transferability to VFTs, and (3) a pilot intervention using the Frame® platform using a construction setting. Collectively, the findings indicate that prior AEC research emphasizes spatial visualization, particularly mental rotation, while largely neglecting spatial communication. Focus groups highlight the importance of active learning approaches during field trips to practice spatial communication. Results from the pilot study suggest that well-designed VFTs can support both spatial understanding and communication through collaborative, situated learning activities.

Introduction

Academic disciplines in science, technology, engineering, and mathematics (STEM) require direct observation and interpretation of complex spaces to support effective communication among professionals. To develop these skills, educators use real-world environments as situated learning experiences (McGrath & Brown, 2005). Field trips are a common mechanism for delivering such experiences, promoting active learning and reinforcing spatial, verbal, and mathematical understanding. However, field trips pose substantial logistical, financial, and accessibility challenges for institutions (Zhao et al., 2020). Limited resources, administrative burdens, safety and legal concerns, travel stress, and health issues significantly reduce and constrain their use in STEM (Loizzo et al., 2019; Feig et al., 2019; Sun et al., 2022).

Virtual field trips (VFTs) have emerged as an alternative to address these barriers. Defined as multimedia representations of distant locations accessed through computing devices (Klemm & Tuthill, 2003), VFTs reduce the logistical difficulties of in-situ visits while retaining key aspects of situated learning, including real-time exchange of ideas in shared spatial workspaces (Eiris et al., 2022). Yet, interpreting and communicating about complex virtual environments requires strong spatial abilities, a developmental process that remains insufficiently understood (Freksa et al., 2017). Spatial abilities encompass cognitive skills for recognizing and manipulating objects and computing representations needed for orientation, location, and navigation (Uttal et al., 2013; Newcombe, 2018). These abilities correlate with verbal and mathematical competencies, though they are distinct (Xie et al., 2020). Spatial communication - defined as the verbal articulation of spatial and mathematical information about an environment (Lowrie, 2012; Curtin & Montello, 2023) - is recognized as critical across STEM fields (Ormand et al., 2017; Atit et al., 2021). Although digital environments like VFTs improve spatial abilities (Di & Zheng, 2022), little is known about how practicing these abilities supports spatial communication in digitally situated learning experiences.

Given the challenges of traditional field trips, their instructional value, and the need to strengthen students' spatial communication, this Improving Undergraduate STEM Education (IUSE) project aims to expand the current understanding of virtual field trips and broaden access to difficult, remote, or hazardous learning contexts. Specifically, this project advances and evaluates iVisit (i.e., web-based virtual field trip platform enabling multi-user, synchronous, situated STEM learning). iVisit focuses on improving students' spatial communication through synchronous digital environments that replicate core elements of field experiences. iVisit will explore how digital spatial representations within VFTs can enhance spatial communication. iVisit offers a pathway to transform STEM education by removing barriers to field experiences and generating new knowledge to support equitable, scalable, digitally mediated situated learning.

iVisit - Architecture, Engineering, and Construction (AEC) Context, Methods, and Results

The AEC domain presents a compelling context for studying spatial communication because construction sites function as hubs of multidisciplinary collaboration (Porter & Glick, 2022). Architects, engineers, construction managers, and craft workers must continuously exchange spatial information related to drawings, models, site conditions, sequencing, and safety. For students, developing these skills requires opportunities to observe real environments, interpret spatial cues, and practice articulating spatial relationships with peers and instructors (Eiris et al., 2022). Traditional field trips rarely afford sufficient time, repetition, or collaborative interaction to fully support this development, and access to all areas of a site is often restricted. iVisit addresses these limitations by providing virtual access to construction environments (typical place for AEC practices) that students can explore collaboratively, independent of physical constraints.

During the first year of the project, three studies were conducted to contextualize the design of iVisit and evaluate the potential of VFTs to support spatial communication in AEC education. Specifically, these first-year studies are centered only on the construction aspect of AEC.

<u>*(1) Assessing Construction Literature on Spatial Abilities.*</u> A systematic literature review was conducted to examine how spatial abilities have been studied within the construction education domain. Following PRISMA guidelines (Page et al., 2021), three databases were searched to perform this systematic review: Google Scholar, Scopus, and Dimensions. The search terms used within these databases were a combination of keywords and a Boolean operator. Specifically, the keywords "*Spatial Ability*", "*Spatial Cognition*", "*Spatial Reasoning*", "*Spatial Skills*", "*Spatial Perception*", "*Spatial Thinking*", "*Visuospatial Abilities*", and "*Visual Spatial Abilities*" were combined using an AND operator with the keyword "*Construction*". These search strings yielded 103 records in Google Scholar, 122 in Scopus, and 10 in Dimensions. No date restrictions were

imposed in this search. Searches were limited to peer-reviewed journal and conference publications written in English. Articles were only included in this systematic review if one of following three parameters were meet: (1) explicit focus on spatial ability as a cognitive construct; (2) examined interventions or tasks designed to affect spatial ability; (3) context of study was in construction. After following the screening and inclusion process outlined above, 32 studies meet the required criteria for final analysis.

The systematic review analysis revealed that most construction education studies focus on spatial visualization and mental rotation, often using standardized tests or task-specific performance measures. Approximately 60% of studies reported positive effects of instructional interventions - frequently involving VR (e.g., Na et al., 2022) or AR (e.g., Kim & Irizarry, 2021) and spatial performance (e.g., Williamson & Anderson, 2017). Most studies (66%) reported an increase in spatial performance. Moreover, it was found that higher spatial skills are frequently linked with stronger academic performance and better task efficiency. Commonly, digital interventions (particularly visualization-rich approaches like virtual reality or 3D models) were used to study and improve spatial abilities. However, no tools were found to be tested for assessing spatial communication, and few studies explicitly considered communication as part of spatial ability. These findings highlight a theoretical gap that motivates the focus of the iVisit project.

(2) Identifying Field Trip Practices and Transferability to VFTs. To understand how real-world field trips support spatial communication, a faculty focus group study was conducted with twelve full-time construction educators. Participants discussed field trip practices across three phases: pre-trip, during-trip, and post-trip. Thematic analysis (Braun & Clarke, 2006) revealed that pre-trip preparation emphasizes safety and logistics (e.g., PPE, waivers, transportation) as well as learning alignment, including clarifying objectives, introducing terminology, and connecting visits to assessments. During field trips, faculty highlighted the importance of safety monitoring, guided observation activities, and social interaction with site professionals. Post-trip practices focused on assessment through reflections, sketches, presentations, and discussions that link observations to course outcomes. These themes informed the practical designs of VFTs for iVisit that preserve pedagogical intent while addressing real-world constraints.

(3) Understanding VFTs for Learning Spatial Communication. A pilot educational intervention was developed using the Frame® platform to evaluate learning and usability outcomes in a collaborative experience. The platform enabled participants to navigate a virtual construction environment using avatars and featured spatial audio, shared whiteboards, laser pointers, and embedded drawing viewers. Ten students from construction programs participated as five dyads. Participants completed pre- and post-intervention knowledge assessments and a collaborative task with the following Learning Objectives (LOs): (LO1) Understand the installation sequence of drywall assemblies; (LO2) Recall and identify the terminology of drywall framing components; and (LO3) Create a framing profile with a quantitative lumber estimate. These objectives were mapped to Bloom's taxonomy to scaffold spatial cognition and communication from foundational knowledge to applied synthesis. (LO1) addressed the 'Understand' and 'Apply' levels, as learners connected the spatial configurations of the work done at the site with the theoretical for why specific steps precede others. (LO2) addressed the 'Remember' level by evaluating student accuracy of recognition for in-situ spatially-based framing components. (LO3) engaged in the 'Analyze', 'Evaluate', and 'Create' levels, requiring student to communicate and

spatially interpretant drawings, in-situ structural constraints, production of a framing profile sketch, and generation of a numeric estimate. To complete these LOs, student sessions lasted 45–75 minutes. Figure 1 illustrates the VFT designed for this pilot activity.

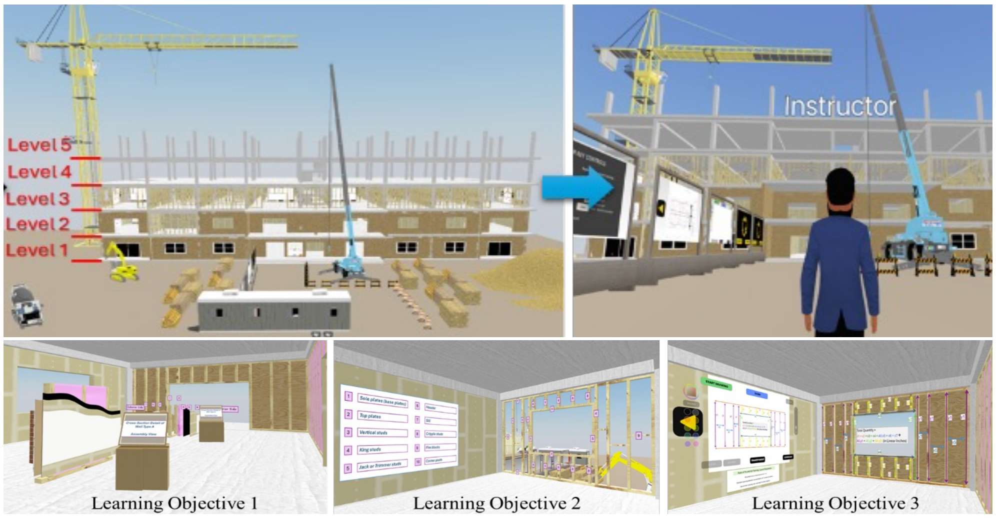

Figure 1. Pilot VFT for Wood Platform Framing Construction

Results indicate an overall learning gain. Mean (LO1) scores (Max = 5; Min = 0) increased from 2.6 (SD = 2.3) to 3.8 (SD = 3.1), showing improvement in spatial understanding of the installation sequence of a drywall (with some variability for this task). (LO2) scores (Max = 10; Min = 0) increased from a mean of 6.1 (SD = 2.7) to 8.3 (SD = 1.6), with no observed declines in the in-situ identification of framing components. (LO3) accuracy (Max = 100%; Min = 0%) ranged from 63% to 97% across dyads (M = 83.6%, SD = 12.9%). These results for (LO3) demonstrated significant variability in student communication and spatial interpretation. From the five dyads, three reported high accuracies (97%, 90%, 91%) and two reported low accuracy (63%, 77%). Further study is required to understand the causes of these low spatial communication performance. For usability, the iVisit system was measured using the System Usability Scale, with an average score of 69.5 (SD = 20.6). This resulting usability score for iVisit is slightly above the benchmark for usability by Bangor (2009) (reported a minimum of 68 points for acceptable usability levels). These findings suggest that while collaborative VFTs can support spatial cognition learning and communication, some usability friction still requires to be minimized.

Conclusion and Future Project Steps

This paper reports the first-year findings from the iVisit project, integrating theoretical, practical, and empirical perspectives on virtual field trips for AEC education. The literature review demonstrates that while spatial abilities are widely studied, spatial communication remains underexplored. Faculty focus groups highlight the importance of structured preparation, active engagement, and reflective assessment in field-based learning. The pilot VFT study provides preliminary evidence that web-based, collaborative virtual environments can support spatial communication learning outcomes and acceptable usability.

Future research will examine how specific VFTs affordances support spatial communication using mixed-methods approaches grounded in established spatial cognition frameworks. Additional AEC content areas and classroom-scale implementations will be explored to assess scalability and transferability. Through these efforts, iVisit aims to establish virtual field trips as a rigorous and equitable component of situated STEM learning.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Awards No. 2336507, No. 2336508, and No. 2336509. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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