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## The Role of Gesture and Facial Expression in Supporting Online Collaborative Learning: A Virtual HVAC Installation Learning Case

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Effective communication in the Architectural, Engineering, and Construction (AEC) domain relies on both verbal and nonverbal modalities to convey complex spatial information and support collaborative tasks. While virtual collaborative learning environments create new opportunities for online and hybrid AEC education, they often rely on avatars and provide limited support for embodied cues, such as natural hand gestures and facial expressions, that are central to face-to-face collaboration. This study explores AEC students' attitudes toward gesture and facial expression perception and examines their learning experiences in a gesture- and facial-expression-enabled virtual collaborative environment. A pilot study was conducted using FrameVR, a web-based virtual platform in which students collaboratively completed an HVAC air duct installation task while communicating through voice, text chat, and real-time webcam-based visualization of gestures and facial expressions. Post-activity surveys measured gesture perception, self-efficacy and motivation, and system usability. In addition, recorded session videos were reviewed to provide exploratory qualitative insights into students' use of facial expressions during collaboration. Results indicate positive student attitudes toward gesture- and facial-expression-supported communication and suggest that the platform effectively supported collaborative learning. These findings highlight the potential of integrating embodied cues to enhance social presence and engagement in virtual AEC learning environments.

Keywords: Virtual Collaborative Learning, Construction Education, Spatial Communication, Gesture, Facial Expression

### Introduction

In the Architectural, Engineering, and Construction (AEC) domain, effective professional practice requires not only mastery of technical knowledge but also the ability to communicate complex spatial information clearly across disciplines. This often involves describing the relationships and interactions among structural, mechanical, electrical, and plumbing systems within shared physical environments. To prepare students for these challenges, AEC education frequently employs team-based and collaborative learning approaches (Becerik-Gerber et al., 2012; Herro et al., 2021). For example, students in mechanical system courses may work in teams to interpret isometric and plan drawings of ductwork, collaboratively determining component placement and airflow paths before evaluating system performance. Throughout these tasks, students depend on both verbal and

nonverbal communication. Among nonverbal modalities, gestures allow students to reference or simulate physical components, supporting the articulation of design intent and spatial reasoning (Austin & Sweller, 2014; Maricchiolo et al., 2009). Similarly, facial expressions convey critical social cues, such as confusion, agreement, or focus, thereby fostering mutual understanding and emotional engagement during teamwork (Huang & Lajoie, 2024). In traditional classroom and laboratory settings, these nonverbal behaviors naturally enrich peer communication and group collaboration. However, in online and distance education, they are often diminished or absent. Current online AEC instruction commonly relies on video conferencing tools such as Zoom or Microsoft Teams, which allow for verbal and visual communication but fail to replicate the realism and engagement of hands-on labs or site visits, where students apply conceptual knowledge in physical contexts (Sun et al., 2022a). Virtual collaborative learning environments have been developed to address these limitations by allowing students to engage with 3D content and communicate synchronously with peers in a shared spatiotemporal context (Sun et al., 2025). Prior studies indicate that visual cues and shared reference points can enhance communication clarity and teamwork coordination. Yet, most existing virtual platforms depend on avatars and lack authentic facial expressions and natural hand gestures, key elements of real-world communication and social presence (Luo et al., 2023; Z. Zhang et al., 2023). While research in video conferencing and embodied communication highlights the importance of facial and gestural cues for engagement and comprehension, the impact of integrating these real human expressions into virtual collaborative learning environments remains largely unexplored. To address this gap, this study explores AEC students' attitudes toward gesture perception in a virtual collaborative learning environment and examines their overall learning experiences within a gesture-enabled virtual collaborative space. This study contributes to AEC education research by (1) implementing a gesture- and facial-expression-enabled virtual collaborative environment for a hands-on HVAC installation task, and (2) empirically examining students' perceptions of communication effectiveness, social presence, and usability in this embodied virtual setting.

## Literature Review

### *The Role of Gesture and Facial Expressions in AEC Education*

Embodied cognition has become an increasingly influential framework in cognitive development, spatial cognition, linguistics, and education (Fugate et al., 2019). Within this framework, bodily structures and actions are understood to shape not only individuals' physical interactions with the environment but also their perceptual experiences and mental representations. From this perspective, gestures serve as externalized forms of thought (i.e., bodily movement) that support reasoning and communication (Maricchiolo et al., 2009). A substantial body of research demonstrates the cognitive and communicative benefits of gesture use. Gesture facilitates speech comprehension, language acquisition, and memory, conveying meanings that may not be explicitly expressed in speech while improving conceptual clarity (Austin & Sweller, 2014). They are particularly valuable in noisy or ambiguous communication contexts, where they help listeners disambiguate verbal information (Bower & Liben, 2023). In STEM education, gestures play a vital role in supporting spatial reasoning. Stieff et al. (2016) found that gestures function as embodied strategies for spatial thinking by allowing learners to physically simulate spatial transformations. Learners frequently produce gestures while solving complex spatial problems, and students encouraged to gesture perform significantly better on spatial reasoning and mental rotation tasks than those instructed not to gesture. Collectively, these findings highlight gestures as critical tools for enhancing students' cognitive processing, communication, and engagement, especially in spatially intensive domains such as AEC. Facial expressions similarly play an essential role in communication by conveying emotions, reinforcing verbal intent, and signaling social and cognitive engagement (Frith, 2009). They serve not only as emotional indicators but also as communicative cues that establish trust, regulate conversational flow,

and signal attentiveness among team members. In collaborative learning environments, facial expressions facilitate turn-talking, promote empathy, and strengthen peer connections, all of which contribute to effective teamwork. In AEC education, the interdisciplinary and collaborative nature of construction practice demands close coordination across multiple trades and design disciplines. Effective communication, both verbal and nonverbal, is indispensable for managing design integration, field coordination, and problem-solving. Gestures and facial expressions together serve as essential communicative tools, enabling students and professionals to convey complex spatial relationships, resolve misunderstandings, and achieve shared understanding during collaborative design and construction activities.

### *Social Presence in Virtual Collaborative Environment*

Social presence is a key construct for evaluating the quality of social interaction and collaboration in online learning environment (Bulu, 2012). As online and hybrid education continue to expand globally, growing attention has been directed toward how to effectively deliver courses in disciplines such as AEC and related STEM fields, where teamwork, communication, and hands-on collaboration are fundamental. A lack of social interaction remains one of the most significant challenges in online education. Learners often report feelings of psychological distance, which can diminish engagement, satisfaction, and motivation to persist in their studies (Kim et al., 2011). Video conferencing tools such as Zoom and Microsoft Teams allow distance learners to communicate verbally and express gesture and facial cues via webcams. While these tools provide certain aspects of social presence, they fall short of replicating the experiential learning benefits found in physical labs or site visits, where students manipulate tools, materials, and systems to apply conceptual knowledge. For instance, in structural system courses, students may conduct experiments with concrete test tension and compression. In capstone courses, they frequently engage in site visits to observe real-world construction processes, materials, and equipment. These collaborative, experiential activities are difficult to reproduce in conventional online environments that rely primarily to images or prerecorded videos. To address these limitations, prior research has introduced virtual collaborative learning environments that allow students to interact with 3D content and communicate synchronously within shared spatiotemporal contexts. Studies have shown that such environments can enhance teamwork, problem-solving, and spatial understanding by providing shared visual reference points and real-time interaction (Eiris et al., 2022; C. Zhang et al., 2017). In AEC education, platforms such as Mozilla Hubs and FrameVR have been used to support online site visits, design coordination, and plan-reading activities, demonstrating improved student engagement and perceived collaboration effectiveness (Sun et al., 2022a, 2025). Despite these advances, existing virtual collaborative platforms in AEC education largely rely on avatars, voice communication, and abstract interaction tools (e.g., virtual pointers or emojis) (Andrews-Todd et al., 2023). While these approaches support basic collaboration, they often provide limited support for authentic embodied communication. In particular, real-time visualization of natural hand gestures and facial expressions, key nonverbal cues that support spatial explanation, turn-taking, and mutual understanding in face-to-face collaboration. It remains underexplored in most AEC-focused virtual learning implementations. Prior studies typically emphasize learning outcomes, engagement, or system usability, but rarely examine how the presence or absence of authentic gestures and facial expressions influences students' social presence or communication clarity in virtual collaborative tasks. This gap motivates the present study, which investigates AEC students' attitudes toward gesture and facial expression perception and explores their learning experiences in a gesture- and facial-expression-enabled virtual collaborative environment.

## **Methodology**

This study explores AEC students' attitudes toward gesture and facial expression perception and examines their learning experiences in a gesture- and facial-expression-enabled virtual collaborative learning environment. Specifically, it investigates how real-time webcam-based hand gestures and facial expressions, as distinct but complementary nonverbal communication modalities, influence students' perceptions of communication effectiveness, social presence, and collaboration during virtual hands-on learning activities. To achieve this goal, the study pursues two primary objectives: (1) to develop a virtual collaborative learning platform that integrates webcam-captured facial expressions and hand gestures, allowing students to communicate naturally and synchronously within a shared spatiotemporal context; and (2) to implement a collaborative hands-on activity involving air duct installation to assess students' perceived communication effectiveness, social presence, and learning experiences while using the gesture-enabled environment.

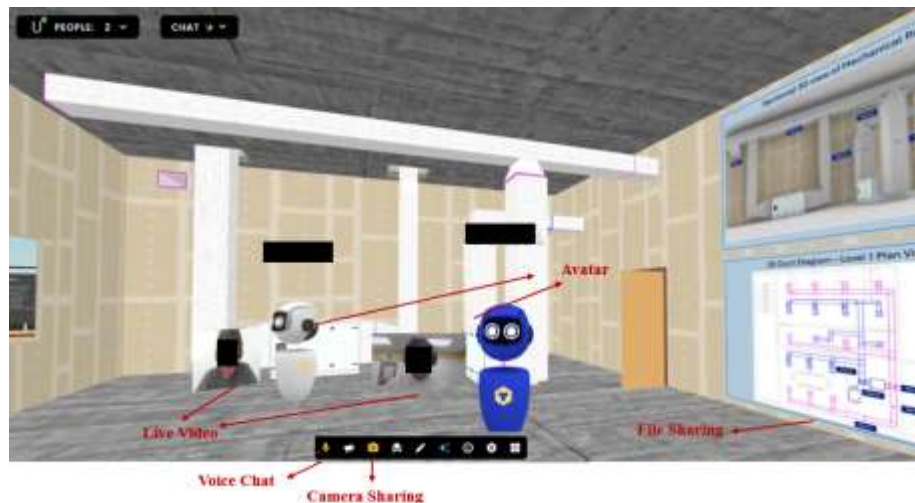
#### *Virtual Collaborative Platform Development*

In this study, the virtual platform was designed around an air duct system installation task to provide students with opportunities to collaboratively engage in a hands-on, problem-solving activity. The learning experience required students to coordinate a series of spatial actions, such as pointing, selecting, and aligning components, while communicating with peers to complete the installation process. To ensure accessibility for both students and instructors, FrameVR, a web-based virtual collaborative platform, was used to develop the environment. FrameVR supports multiple collaborative communication affordances essential for teamwork, including text and voice chat, virtual pointer, file sharing, and webcam streaming. Two scenes were created within the platform: introduction scene and hands-on activity scene. Introduction scene is designed to familiarize students with the virtual environment, this scene provided a guided orientation on how to navigate the space, use communication tools, and manipulate 3D objects. Hands-on activity scene replicated a lab-like environment where students collaboratively completed the HVAC duct installation tasks. Participants used various affordances to communicate spatial decisions and coordinate actions in real time. The architectural and mechanical models of the building facility were created in Autodesk Revit, exported in .rvt format, and converted to .glb format using Blender®. To enhance visual realism, textures and materials were refined in Rhinoceros 3D® before import into FrameVR. Within the virtual environment, students' avatars appeared alongside a live webcam feed positioned near their avatar, enabling peers to view facial expressions and natural hand gestures.

#### *Pilot Study – A HVAC Hands-On Lab Activity*

The HVAC air duct installation task was intentionally selected as the learning activity for this study because it demands intensive spatial reasoning, sequential assembly, and collaborative decision-making. These processes that naturally elicit both verbal and nonverbal communication. HVAC installation requires students to interpret 2D drawings and 3D spatial configurations, coordinate component placement, and communicate spatial relationships such as direction, alignment, and clearance, all of which frequently involve hand gestures and facial expressions in face-to-face settings. In addition, HVAC installation is a common hands-on laboratory activity in AEC and construction management curricula, making it a representative and authentic context for examining collaborative learning behaviors in virtual environments. A pilot study was conducted to evaluate the effectiveness of the gesture- and facial-expression-enabled virtual collaborative platform in enhancing AEC students' spatial communication clarity and social presence. The task replicated a Building Mechanical Systems laboratory exercise in which students collaboratively installed an HVAC air duct system within a virtual mechanical room. As illustrated in Figure 1, the environment included duct components and live webcam feeds positioned alongside avatars to support embodied communication. In the virtual space, students located a mechanical room containing two air-handling units (AHUs),

one preinstalled and the other requiring installation. Working in pairs, participants installed the second AHU by connecting five duct components (Parts A, B, C, D, and E) based on a provided 2D duct layout diagram and a corresponding 3D sectional view. Throughout the activity, students interpreted spatial information, communicated design decisions, and coordinated actions using the collaborative affordances available in FrameVR. Each experimental session began with participants completing an informed consent form and a demographic survey, followed by the collaborative HVAC installation task in the virtual environment. After completing the activity, students responded to a post-survey administered through Qualtrics to assess their perceptions of social presence, communication effectiveness, and system usability. Screen and voice recordings were also collected for subsequent analysis of spatial communication behaviors and interaction quality. This study was approved by the University of Southern Mississippi Institutional Review Board (IRB #25-0589). Although the HVAC installation activity was conducted in a virtual environment, the task was designed to simulate the key cognitive and collaborative aspects of physical ductwork installation rather than simply interfacing with computer hardware or software. Students were required to identify spatial constraints within the mechanical room, determine appropriate component orientation and sequencing, and collaboratively align and connect duct segments within a shared virtual space. During this process, gestures and facial expressions played a functional role in communication: students used hand gestures to indicate duct direction, alignment, clearance, and relative positioning, while facial expressions signaled uncertainty, confirmation, or the need for clarification. The live webcam feed displayed alongside each avatar enabled peers to observe these embodied cues in real time, supporting turn-taking, spatial explanation, and collaborative problem-solving. Rather than replicating physical exertion, the virtual task emphasized the spatial reasoning, coordination, and communication demands that precede and guide real-world HVAC installation.



**Figure 1.** Virtual Collaborative Hands-On Lab Environment

### *Study Metrics*

This study collected quantitative survey data to examine students' attitudes, learning experiences, and perceptions of the gesture-enabled virtual collaborative environment. The self-Rating Scale for Gesture Perception and Production (Nagels et al., 2015) was used to assess students' attitudes toward using and interpreting gestures in communication. This instrument provided insights into how students perceive the role of gestures in supporting understanding and interaction during the collective

activity. To evaluate learning experience, the Self-Efficacy and Motivation Scale (Lee et al., 2016; Sun et al., 2024) was administered to measure students’ confidence in completing spatially complex tasks and their motivation to engage in the virtual hands-on lab. Finally, the System Usability Scale (SUS) (Brooke, 2013) was included to assess students’ perceptions of the system’s ease of use, functionality, and overall satisfaction with the gesture-enabled virtual environment. Descriptive statistical analyses were conducted to summarize students’ experiences in the virtual environment, with results reported using mean and standard deviation (SD). The selected measures focused on students’ attitudes toward gesture and facial expression use, perceived learning experiences, and system usability because the primary objective of this exploratory study was to examine students’ perceptions of embodied communication and social presence in a gesture- and facial-expression-enabled virtual collaborative environment. Given the preliminary and exploratory nature of this study, additional learning-related factors such as perceived workload or cognitive load were not included.

### Results and Discussion

A total of 14 students (7 pairs) participated in the virtual lab activity. Table 1 shows their demographic information.

**Table 1.** Participant demographic information

Parameters		Responses Number (Percentage)
Gender	Females	7 (50%)
	Males	7 (50%)
Educational background	Architectural Technology	10 (72%)
	Construction Management	2 (14%)
	Others	2 (14%)
Previous experience with VR technologies	Never used VR before	4 (28%)
	Tried VR once or twice	9 (65%)
	Occasionally used VR	1 (7%)
	Used VR regularly	0 (0%)
	Had extensive experience with VR	0 (0%)

Table 2 shows results from the Self-Rating Scale for Gesture Perception and Production (Nagels et al., 2015) indicated generally positive attitudes toward gesture use among participants (overall Mean = 3.58). Most of students agreed that they frequently used gestures to make themselves better understood (Mean = 3.50) and appreciated peers who gestured during communication (Mean = 3.50). Similarly, gestures were perceived as helpful in noisy or cognitively demanding contexts (Mean = 3.75), suggesting that participants view gestures as an effective tool for reinforcing communication. In contrast, negatively worded statements such as “I find it very annoying when peers gesture a lot” and “It looks silly when I see peers gesturing” received low agreement scores, reflecting a general acceptance of gesture use in collaborative communication. These findings align with prior research suggesting that gesture facilitates speech comprehension and enhance social engagement during collaborative tasks (Austin & Sweller, 2014). Also, participants reported moderate agreement on using gestures to reinforce communication as non-native speaker (Mean = 3.25), underscoring gestures’ compensatory role in supporting understanding across linguistic and cultural contexts (Maricchiolo et al., 2009). In addition to the survey results, the research team reviewed recorded session videos to gain a general understanding of students’ interaction behaviors during the activity. Although facial expressions were not systematically coded or analyzed, informal observations suggested that students occasionally used facial expressions, such as nodding or visible hesitation, to signal understanding, uncertainty, or agreement while collaborating. These observations are exploratory in nature and are reported to provide contextual insight rather than empirical evidence.

Future studies will incorporate structured behavioral coding schemes to systematically examine the role of facial expressions in virtual collaborative learning.

**Table 2.** Self-rating scale for gesture perception and production

<b>Likert scale: 1 = strongly disagree, 5 = strongly agree</b>	<b>Mean (SD)</b>
1. I usually use gesture when I talk to make myself better understood	3.50 (0.926)
2. I like talking to people who gesture a lot when they talk	3.50 (0.535)
3. I've been told before that I gesture a lot when I talk.	2.25 (1.488)
4. I find it more difficult to understand my peers when they gesture a lot. *	1.63 (0.744)
5. When talking in noisy condition, I used gesture a lot to make myself understood over the noise	3.75 (0.886)
6. I find it very annoying when I'm talking to peers who gestures a lot during the conversation. *	1.63 (0.744)
7. I feel amazed by peers who are able to gesture a lot when they talk.	2.75 (0.886)
8. When I'm non-native speaker, I do a lot of gesturing to reinforce what I'm saying.	3.25 (1.389)
9. During this activity, it's very distracting to me if peers gesture a lot. *	1.50 (0.535)
10. When I see peers gesturing a lot, I often wonder if I would have used the same gestures	3.13 (0.835)
11. It looks silly when I see peers is gesturing a lot. *	1.88 (0.641)
12. I like my hands free when I have a discussion with someone.	3.50 (1.069)
<b>Overall</b>	<b>3.58 (1.101)</b>

\*Statement 4, 6, 9, and 11 are worded negatively

Results from the self-efficacy and motivation survey indicated that students generally exhibited strong confidence and engagement during the gesture-enabled virtual collaborative activity (overall mean = 4.05). Across self-efficacy items, students reported high levels of confidence in mastering the knowledge taught in this activity (Mean = 4.21) and in overcoming challenges when the task was difficult (Mean = 4.05). These findings suggest that the virtual lab effectively supported students' perceptions of competence, which is an essential factor in fostering intrinsic motivation and persistence in learning (Bandura, 2001). In terms of engagement, participants expressed strong attention and active participation (Mean = 4.00), as well as positive attitudes toward collaboration (Mean = 4.14). For example, a student reported, *"I liked this system well and would like to see the other applications that could be achieved."* Meanwhile, low mean scores for negatively worded statements, such as *"I feel bored when I'm learning this knowledge"* (Mean = 2.07), indicated that students found the activity engaging and stimulating. The high rating for reflective learning behavior, such as asking questions to ensure understanding (Mean = 4.43) further demonstrates active cognitive engagement during the task. These results align with prior studies suggesting that immersive and interactive virtual environments can enhance students' motivation and learning engagement (Sun et al., 2024).

**Table 3.** Self-efficacy and motivation

<b>Likert scale: 1 = strongly disagree, 5 = strongly agree</b>	<b>Mean (SD)</b>	
Self-efficacy	1. I'm sure I can become really good at the knowledge taught in this activity	4.21 (0.699)
	2. I'm sure I can figure out almost all the work in the activity	4.14 (0.864)
	3. Even though the work in the activity is hard, I can learn it	4.50 (0.650)
Engagement	4. I pay attention to all of the learning activities	4.00 (0.784)
	5. I get in trouble in the activity*	2.57 (1.505)

6. I feel bored when I'm learning this knowledge*	2.07 (1.207)
7. I like being in the collaborative activity	4.14 (1.292)
8. When I learn new knowledge, I ask myself questions to make sure I understand what I am learning about	4.43 (0.756)
9. If I don't understand what I learn in this activity, I go back and watch it over again	3.64 (1.216)
<b>Overall</b>	<b>4.05 (1.057)</b>

\*Statement 5 and 6 are worded negatively

The SUS results indicate that the usability of the developed system falls between the “Good” and “OK” range, with an overall low-marginal level of acceptability (Bangor et al., 2009). This outcome is comparable to findings from previous studies that examined the usability of virtual collaborative environments in educational contexts (Brooke, 2013; Sun et al., 2022b). Although the overall usability rating was modest, student feedback highlighted the platform’s potential to enhance learning engagement and collaboration. For example, another student said, “*I loved it! It was a very engaging project, and I felt like I could learn through that.*” The web-based virtual collaborative environment used in this study, developed in FrameVR, has been validated in prior research as a user-friendly and easily customizable tool for supporting online teamwork and communication. Importantly, the integration of real-time webcam capture, which presented students’ facial expressions and gestures to introduce an additional communication modality, did not negatively affect the system’s usability. These findings suggest that incorporating embodied communication features, such as gesture and facial expression, can enrich interaction and presence in online collaborative learning environments without compromising usability.

Table 4. System Usability Scale

<b>Likert scale: 1 = strongly disagree, 5 = strongly agree</b>	<b>Mean (SD)</b>
Q1: I think that I would like to use this system frequently	3.29 (1.326)
Q2: I found the system unnecessarily complex*	2.57 (1.399)
Q3: I thought the system was easy to use.	3.71 (0.611)
Q4: I think that I would need the support of a technical person to be able to use this system*	2.07 (0.917)
Q5: I found that the various functions in the system were well integrated.	3.79 (0.893)
Q6: I thought there was too much inconsistency in this system*	2.21 (1.369)
Q7: I would imagine that most people would learn to use this system very quickly	4.00 (0.961)
Q8: I found the system very awkward to use*	2.36 (1.082)
Q9: I felt very confident using the system	3.29 (1.383)
Q10: I needed to learn a lot of things before I could get going with this system*	2.36 (1.393)
<b>Overall Usability Score (Bangor et al., 2009) :</b>	<b>66.3/100</b>

\*Statement 2, 4, 6, 8, and 10 are worded negatively

### Conclusion and Future Work

This preliminary study explored AEC students’ attitudes toward using gestures and facial expressions in a virtual collaborative learning environment. The findings suggest that integrating real-time webcam-based gestures and facial expressions can enrich communication and engagement in online collaborative tasks without negatively affecting system usability. Although the overall usability score indicated a low-marginal but acceptable level, students expressed positive perceptions of the platform’s potential to improve interaction, teamwork, and learning effectiveness. These findings

align with prior research emphasizing the importance of multimodal communication in supporting collaboration and spatial understanding in virtual learning environments. Unlike previous studies that relied primarily on avatars to represent learners, this research introduced authentic, real-time human expressions, contributing to ongoing efforts to strengthen social presence and spatial communication in virtual AEC education. However, this study has several limitations. The small sample size, single-group design, and reliance on self-reported measures limit the generalizability of the findings. Additionally, behavioral data such as gesture frequency or communication sequences were not captured, preventing deeper analysis of how gestures influenced collaboration quality or spatial reasoning. Future work will extend this preliminary exploration by systematically comparing gesture- and facial-expression-enabled conditions with avatar-only and face-to-face learning settings. Subsequent studies will incorporate additional measures, including workload and cognitive load, to provide a more comprehensive understanding of learning processes and outcomes. Further development will focus on creating a gesture-enabled virtual collaborative laboratory that integrates real-time hand tracking to support natural spatial interaction with 3D objects. While this study focused on a hands-on HVAC laboratory activity, future research will examine the application of gesture- and facial-expression-enabled virtual collaboration across a broader range of construction courses. Potential applications include plan reading, construction safety, scheduling and sequencing, design coordination, and interdisciplinary project-based courses, where spatial explanation and collaborative communication are critical. Examining these applications will help evaluate the scalability and instructional value of embodied virtual collaboration across the construction curriculum. The ultimate goal is to design an accessible, browser-based platform that enables AEC and STEM students to engage in authentic, embodied, and collaborative learning experiences that more closely mirror real-world teamwork.

### Reference

- Andrews-Todd, J., Jiang, Y., Steinberg, J., Pugh, S. L., & D'Mello, S. K. (2023). Investigating collaborative problem solving skills and outcomes across computer-based tasks. *Computers & Education*, *207*, 104928. <https://doi.org/10.1016/j.compedu.2023.104928>
- Austin, E. E., & Sweller, N. (2014). Presentation and production: The role of gesture in spatial communication. *Journal of Experimental Child Psychology*, *122*, 92–103. <https://doi.org/10.1016/j.jecp.2013.12.008>
- Bandura, A. (2001). Social Cognitive Theory: An Agentic Perspective. *Annual Review of Psychology*, *52*(1), 1–26. <https://doi.org/10.1146/annurev.psych.52.1.1>
- Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, *4*(3), 114–123.
- Becerik-Gerber, A. M. A., Ku, K., & Jazizadeh, F. (2012). BIM-Enabled Virtual and Collaborative Construction Engineering and Management. *Journal of Professional Issues in Engineering Education and Practice*, *138*(3), 234–245. [https://doi.org/10.1061/\(ASCE\)EI.1943-5541.0000098](https://doi.org/10.1061/(ASCE)EI.1943-5541.0000098)
- Bower, C. A., & Liben, L. S. (2023). Instructors' Gestural Accuracy Affects Geology Learning in Interaction with Students' Spatial Skills. *Journal of Intelligence*, *11*(10), 192. <https://doi.org/10.3390/jintelligence11100192>
- Brooke, J. (2013). *SUS: a retrospective Display design for fault diagnosis View project SUS: A Retrospective*. *8*, 29–40.
- Bulu, S. T. (2012). Place presence, social presence, co-presence, and satisfaction in virtual worlds. *Computers & Education*, *58*(1), 154–161. <https://doi.org/10.1016/j.compedu.2011.08.024>
- Eiris, R., Sun, Y., Gheisari, M., Marsh, B., & Lautala, P. (2022). *VR-OnSite—Online Site Visits Using Web-Based Virtual Environments*. 100–109. <https://doi.org/10.1061/9780784483985.011>

- Frith, C. (2009). Role of facial expressions in social interactions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1535), 3453–3458. <https://doi.org/10.1098/rstb.2009.0142>
- Fugate, J. M. B., Macrine, Sheila L., & Cipriano, C. (2019). The role of embodied cognition for transforming learning. *International Journal of School & Educational Psychology*, 7(4), 274–288. <https://doi.org/10.1080/21683603.2018.1443856>
- Herro, D., McNeese, N., O'Hara, R., Frady, K., & Switzer, D. (2021). Exploring graduate students' collaborative problem-solving in engineering design tasks. *Journal of Engineering Design*, 32(9), 496–516. <https://doi.org/10.1080/09544828.2021.1922616>
- Huang, X., & Lajoie, S. P. (2024). A scoping review on effective measurements of emotional responses in teamwork contexts. *Current Psychology*, 43(31), 25661–25682. <https://doi.org/10.1007/s12144-024-06235-7>
- Kim, J., Kwon, Y., & Cho, D. (2011). Investigating factors that influence social presence and learning outcomes in distance higher education. *Computers & Education*, 57(2), 1512–1520. <https://doi.org/10.1016/j.compedu.2011.02.005>
- Lee, C. S., Hayes, K. N., Seitz, J., DiStefano, R., & O'Connor, D. (2016). Understanding motivational structures that differentially predict engagement and achievement in middle school science. *International Journal of Science Education*, 38(2), 192–215. <https://doi.org/10.1080/09500693.2015.1136452>
- Luo, L., Weng, D., Ding, N., Hao, J., & Tu, Z. (2023). The effect of avatar facial expressions on trust building in social virtual reality. *The Visual Computer*, 39(11), 5869–5882. <https://doi.org/10.1007/s00371-022-02700-1>
- Maricchiolo, F., Gnisci, A., Bonaiuto, M., & Ficca, G. (2009). Effects of different types of hand gestures in persuasive speech on receivers' evaluations. In *Speech Accompanying-Gesture*. Psychology Press.
- Nagels, A., Kircher, T., Steines, M., Grosvald, M., & Straube, B. (2015). A brief self-rating scale for the assessment of individual differences in gesture perception and production. *Learning and Individual Differences*, 39, 73–80. <https://doi.org/10.1016/j.lindif.2015.03.008>
- Stieff, M., Lira, M. E., & Scopelitis, S. A. (2016). Gesture Supports Spatial Thinking in STEM. *Cognition and Instruction*, 34(2), 80–99. <https://doi.org/10.1080/07370008.2016.1145122>
- Sun, Y., Albeaino, G., Gheisari, M., & Eiris, R. (2022a). Online site visits using virtual collaborative spaces: A plan-reading activity on a digital building site. *Advanced Engineering Informatics*, 53(April), 101667. <https://doi.org/10.1016/j.aei.2022.101667>
- Sun, Y., Albeaino, G., Gheisari, M., & Eiris, R. (2022b). Virtual Collaborative Spaces for Online Site Visits: A Plan-Reading Pilot Study. *ASC 2022*, 688–678. <https://doi.org/10.29007/d14v>
- Sun, Y., Bhadaniya, P., Eiris, R., & Gheisari, M. (2025). Applying Systematic Learning Progression in Online Construction Site Visits. *Proceedings of Associated Schools of Con*, 6, 279–288.
- Sun, Y., Gheisari, M., & Jeelani, I. (2024). RoboSite: An Educational Virtual Site Visit Featuring the Safe Integration of Four-Legged Robots in Construction. *Journal of Construction Engineering and Management*, 150(10), 04024126. <https://doi.org/10.1061/JCEMD4.COENG-14779>
- Zhang, C., Lu, Y., Xu, R., Ye, X., Shi, Y., & Lu, P. (2017). An Educational Tool based on Virtual Construction Site Visit Game. *Modern Applied Science*, 11(8), 47. <https://doi.org/10.5539/mas.v11n8p47>
- Zhang, Z., Fort, J. M., & Giménez Mateu, L. (2023). Facial expression recognition in virtual reality environments: Challenges and opportunities. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1280136>