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COMPARING COLLABORATIVE LEARNING IN VARIOUS LEARNING MODALITIES

Ashma Suwal[1], Wei Wu[2], and Yupeng Luo[2]
[1]California State University, East Bay, Hayward, California, USA
[2]California State University, Fresno, Fresno, California, USA

Abstract

Due to the increasingly dispersed project team composition, the architecture, engineering, and construction (AEC) industry has been practicing remote collaboration long before the COVID-19 global pandemic. On the other hand, higher education went through a deep learning curve in adapting to online teaching and learning. As a result, there are uncertainties about best practices to prepare students for redefined project team collaboration in the post-pandemic AEC industry. Therefore, this research explores and compares three different modalities, i.e., face-to-face, Zoom, and web-based social virtual reality (VR), in teaching students about collaboration using project-based learning. A mixed-method approach was utilized to capture perceptual and behavioral data to help understand the characteristics and effectiveness of collaboration in these different modalities. The results suggested comparable outcomes in project progress, but the patterns in time use, team dynamics, and perceptions of team collaboration indicated unique features of each modality.

Introduction

While online learning and the technological infrastructure to support it has improved over the last decade, issues persisted for faculty in higher education during the pandemic (Martin et al., 2022). In disciplines like architecture, engineering, and construction (AEC), where learning takes place in both individual and collaborative settings, faculty find it challenging to effectively engage students and deliver a stimulating learning experience using asynchronous (e.g., learning management systems such as Canvas) or synchronous (e.g., web conferencing systems such as Zoom) formats.

The use of emerging technologies such as web-based social Virtual Reality (VR) platforms that synthesize the strengths of VR and web conferencing produces a new modality that holds the promise of enabling students to be more visually aware of their classmates and can converse in real-time with them while collaborating in learning activities and course assignments. They can also receive immediate feedback from the instructor and gain a sense of being present in the same place as their peers despite their remote physical locations. The shared virtual environments also facilitate the whole class's simultaneous viewing of learning materials and allow them to actively participate in group discussions about the learning content simultaneously.

As many higher education institutions are transitioning back to in-person instruction, it is intriguing to investigate how innovations such as web-based social VR remain relevant. The research team is particularly interested in understanding how social VR would be integrated to enhance learning, especially collaborative learning, in AEC disciplines, compared with brick-and-mortar classrooms and synchronous online classes. Specifically, this research aims to explore the unique characteristics of social VR-enabled virtual collaboration in comparison with traditional collaboration, identify the factors that may influence the learning experience and outcomes from virtual collaboration, and understand how emerging social VR platforms may facilitate virtual collaboration, thus enhancing these learning experiences and outcomes.

Background

Collaborative Learning

Koehn (2001) described collaborative learning as "an intellectual endeavor in which individuals act jointly with others to become knowledgeable of some particular subject matter." In practice, collaborative learning often incorporates team-based and project-based pedagogy in which students work in small teams to achieve a common objective to motivate the student from a passive learner to an active participant in the educational process (Bransford et al., 2000). It allows students to sharpen communication skills, develop teamwork and social skills, and hone their conflict-resolution capacities (Prichard et al., 2006).

Key to the success of collaborative learning is the design of such experience so that group projects are not simple social interactions but encourage students to develop cognitive involvement through social interactions (BouJaoude, 2016). Simply having students work on a group project does not automatically result in students' development of deep thinking and construction of knowledge (Garrison, 2016). Various instructional design models for collaborative learning include student-centered design (Prichard et al., 2006), knowledge-centered design (Bransford et al., 2000), assessment-centered design (Sluijsmans et al., 1998), and community-centered design (Schwier, 1999).

Recent advancement in educational technology and digital learning solutions has enabled unprecedented learner-to-learner, learner-to-instructor, and learner-to-content interaction and offers ample opportunities for learners to collaborate, within or beyond the traditional boundary of a classroom (Lowyck and Pöysä, 2001). The specific properties of technology determine both the kind of information that can be exchanged and the easiness of the communication process, though its effectiveness highly depends on how the properties are used. Technologies that facilitate collaborative learning can be situated on various dimensions, each of which triggers a decision from the instructional designer. The combination of these decisions determines the outlook of the instructional support delivered (Lowyck and Pöysä, 2001), directly affecting the learners' experience, knowledge construction, and skill development.

Social VR

Social VR, also called immersive virtual worlds or multiuser virtual environments (MUVEs), constitutes three-dimensional computer-generated virtual reality spaces instrumental to social or psychological immersion (Mystakidis et al., 2021). Social VR is accessible through computer technology, while some can also be experienced through head-mounted displays or mobile, hand-held devices. Over 150 publicly available systems are cataloged in Schulz's blog about social VR (Schultz, 2022), including widely used event and work collaboration platforms such as Artspace VR, ENGAGE, Horizon Workrooms, and Spatial.io. Two key traits, which form the foundation of collaboration in social VR environments, include the support of nonverbal communication and the sense of presence (Moustafa and Steed, 2018). Nonverbal communication, such as gaze and movement, helps convey subtle social dynamics among collaborating users, and the sense of presence, including both "place presence" (Sheridan, 1992) and "plausibility illusion" (Slater, 2009), reinforces the authenticity of users' experience in the social VR environments.

The increased interest in social VR among the AEC higher education community stems from the limitations identified from the research literature that documents the current use of VR simulation and Internet technologies, which include: offline simulation without the collaboration of educators; traditional construction education approaches have not taken advantage of the virtual simulation; the low interaction and expression level between users; the limitation of spaces and students in some virtual room education; and the simplicities in nature with limited features (Le et al., 2014). In contrast, social VR is expected to facilitate meaningful interaction and support enhanced human-human collaboration and human-computer co-creativity (Merrick and Gu, 2011). As reviewed by Mystakidis et al. (2021), a few studies present the potential of and progress on how social VR reshapes learning in higher education communities. This paper examines social VR in the context of collaborative learning as the research team believes a default merit of social VR is facilitating meaningful and multimodal learner interaction and knowledge cogeneration.

Methodology

The comparison of collaborative learning in the three modalities, i.e., In-person, Zoom, and social VR (using ENGAGE with Quest 2), was conducted via a simulated team design project of a backyard cottage. Three teams, each consisting of three undergraduate students with a background in construction management and architectural studies, were recruited and randomly assigned with a specific modality and stick with the same modality throughout the project. A series of iterative design tasks were integrated for each design session to necessitate analysis, communication, and implementation. The process enabled students to engage in essential activities such as identifying the problem, brainstorming solutions, conducting feasibility studies to evaluate and screen the ideas, and creating preliminary designs based on promising ideas. Three design sessions were conducted, each lasting ~90 minutes. Due to students' schedule differences, each team had separate meetings, and the complete simulation took four to six weeks for all three teams to complete the three design sessions. In addition, for ease of assessment, the research team also developed preliminary templates (slide decks) that the teams could use to produce required deliverables, including brainstorming, conceptualization, design prototyping, presentation/report out, and reflection.

Amid the simulation, the research team conducted both formative and summative assessments. Short pre- and post-surveys were given to individuals at the beginning and end of each design session to document individuals' experiences throughout the project. A group interview was conducted at the end of the third session when final deliverables were submitted for each project team. In addition, direct observation of each team was made by a student assistant who also served as a facilitator of the simulation. For the team assigned with social VR, the assigned student assistant provided necessary training on Quest 2 and the ENGAGE social VR application. The research assistant would answer general requests for information, clarification, or technical issues but would not interfere with the team's design decision-making. All design sessions were video recorded during this design collaboration to capture individual team members' behavior and team dynamics. **Figure 1** provides an overview of the research design and data collection plan.

Results and Findings

Direct Observations

The direct observation of each team through the simulation provided firsthand insights into how individuals embarked on the project and navigated through team-building, eventually collaborating on completing the design tasks. The direct observation was summarized via the narration by the facilitators assigned to each student team. It furnished the research team with desired context information of each student team and supplemented the video recording data.

Team 1 (Zoom Team)

For Team 1, all three design sessions were conducted remotely using Zoom and recorded using a built-in recording function. Even though all three students used Zoom during the pandemic, a brief training on Zoom's support for work collaboration, such as screen-sharing and Whiteboard, was provided to Team 1 students.

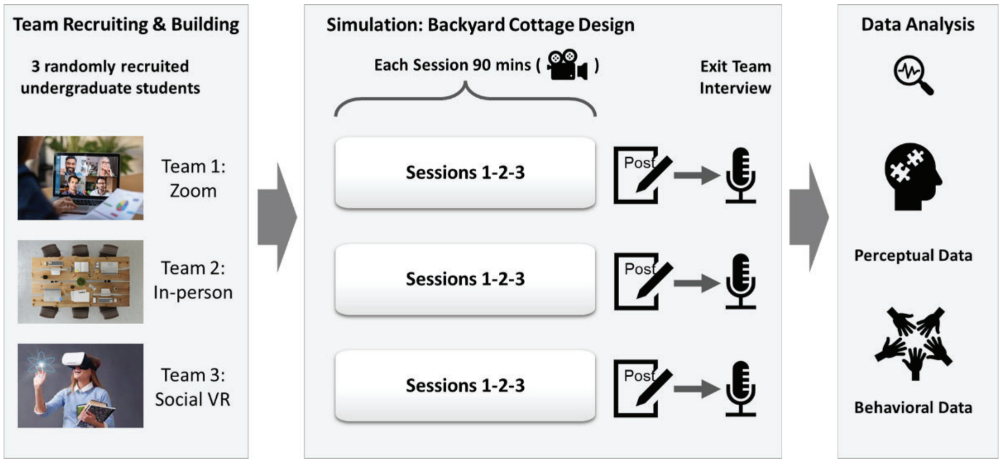

Figure 1: Research design and data collection plan

- Session 1: At the first meeting on Zoom, the students were unfamiliar with each other, so they hesitated to interact with each other in the first session. They tried to collaborate but had problems sharing their screens with their teammates. They used software like Bluebeam and Google Maps. They completed the prescribed tasks for Session 1 in 45 minutes.
- Session 2: Collaboration between the students was good during the second session. Everyone gave their opinion and displayed effective team dynamics. One student had issues with Zoom when sharing the screen. The team used Bluebeam and Revit to work on the tasks, and they completed all tasks for Session 2 in 40 minutes.
- Session 3: As students got familiar with each other, they demonstrated efforts to complete the design project as a real team. The frequency of verbal communication was remarkably high. The level of participation and effectiveness of communication was excellent. They used Autodesk Revit and MS Excel for the tasks prescribed. The final presentation of the whole design project went well. They completed the final session in 70 minutes.

Team 2 (In-person Team)

Team 2 conducted all three design sessions as if they were in a regular course project by meeting physically in a collaborative lab space. The space was equipped with a projector and movable furniture, ideal for a design collaboration project. All three sessions were recorded with the help of a GoPro 6.

- Session 1: As the session started, two team members dominated over the third team member. Two team members were working on the same laptop, but the third member was less interactive. They used Autodesk Revit and Google Maps to work on tasks of Session 1. The team completed the tasks of the session in 76 minutes.
- Session 2: The team members showed their problem-solving and analytical skills in the second meeting. All team members collaborated and interacted well with each other. They could see each other's efforts on the design project and helped each other to move the project forward. They completed all tasks of the session in 60 minutes.
- Session 3: In the third meeting, the students discussed with each other their individual undertakings and team deliverables for the project and used a projector to give the presentation. The presentation was good as it was very lively. The team was also satisfied with the outcome. They completed the tasks of the session in 20 minutes.

Team 3 (Social VR Team)

Team 3 conducted the complete design collaboration via the ENGAGE social VR platform with the Quest 2 headsets. Quest 2 can run as a standalone headset with an internal, Android-based operating system, or it can be tethered (via USB or Wi-Fi) with the Oculus Link to run Oculus-compatible VR applications (e.g., Steamers applications) through an external computing device such as a laptop. The students in the VR team were new to VR and had not used it before for any prudent reason.

ENGAGE is an advanced social VR Platform with ideal features for conferences, education, simulated training, and virtual events and can be used globally as an alternative to video-based communications such as Zoom. ENGAGE's user interface (UI) is intuitive and requires little to non-technical expertise. During the simulation, a team member cast the UI of ENGAGE onto a laptop and screen-recorded all three design sessions.

- Session 1: The students were introduced to using VR and ENGAGE. One student had already used VR once, but the other two were completely unfamiliar. A few technical issues occurred when students were trying to access ENGAGE, and after some troubleshooting, students became comfortable with the UI and tools available for collaboration (Figure 2). The team used features such as *Whiteboard*, a built-in tablet, and 3D pens to document the discussion and brainstorming. They completed the tasks of Session 1 in 90 minutes. Nobody reported any motion sickness or dizziness.

Figure 2: Design collaboration in ENGAGE

- Session 2: The session started with good team collaboration. The students sometimes got distracted by the other features of VR. They discussed the tasks at hand and enjoyed the virtual environment. They used the whiteboard feature again, and everyone worked on the same board and contributed ideas and opinions. They completed the tasks of the Session within 80 minutes. No motion sickness or dizziness was reported.
- Session 3: The frequency of verbal communication was very high in the third session. Students showed team dynamics by equally contributing to the design project. The presentation was done using the screen-sharing option on ENGAGE. They were all familiar with joysticks, so they had no problem using various application features. They completed the project deliverables in 85 minutes. No motion sickness or dizziness was reported. As VR was the only team that had experienced all three learning modalities, their final group interview was significantly important.

Behavioral data analysis

Among various indicators that could reflect the extent and effectiveness of collaborative learning and collaboration, the research team focused on the time consumption of team members in various activities during the three design sessions. We categorized time into two broad groups: *production time* and *idling time*. Production time was tallied if the activities were contributing to the collaborative tasks, regardless of if team members were working on the same thing or tasks assigned to individuals. Production time was value-adding. In contrast, *idling time* was tallied if the activities were taking breaks, troubleshooting, or chit-chatting among team members. Idling time was non-value-adding.

Based on the video recordings, the research team reviewed and tagged time durations when the teams were in active production mode. Then the total production time duration in each project team session was summarized, as shown in Table 1. Given that all three teams could complete prescribed tasks in each of the three collaborative sessions, each team's actual allocation of time in each session was drastically different. Team 1 (Zoom Team) had the most consistently high ratio of production time, while Team 3 (Social VR Team) had a significant variance from session to session. Team 3 suffered major idling/troubleshooting in Session 2 when no immediate solutions were available to allow them to produce architectural design like the other teams with Autodesk Revit. Team 2 (In-person Team) was the only team that achieved a perfect 100% production time ratio in their final session.

Table 1: Summary of time allocation per team per session

Team	Session	Production %	Idling %
Zoom	1	96%	4%
	2	85.4%	14.6%
	3	96.9%	3.1%
In-person	1	87.3%	12.7%
	2	85.7%	14.3%
	3	**100%**	0
Social VR	1	83.8%	16.2%
	2	63.3%	**36.7%**
	3	90.7%	9.3%

Perceptual data analysis

A post-session survey was conducted on all members of the three teams at the end of each design session. This short survey facilitated participants' reflection upon their collaborative learning experience with four open-ended questions:

1. Were you able to complete all assigned tasks?
2. What was your contribution?
3. What was your teammates' contribution?
4. How were the team dynamics?

By repeating the same questions over three sessions, the challenges and success each team experienced started to show individual patterns.

Team 1 (Zoom Team) Survey Summary

Members of the Zoom team were very conscientious. They appreciated each other and worked on all tasks with equal load and contribution. The verbal communication among team members was weak initially but kept improving session by session. The team dynamics were excellent, and each member seemed to learn something from others. The confidence level of individual members enhanced tremendously as the project proceeded. Zoom as a platform seemed to be effective in furnishing the team with desired tools and channels of communication to collaborate in this type of design project. The survey results matched the facilitator's direct observation presented earlier.

Team 2 (In-person Team) Survey Summary

The in-person team maintained a very lean but effective collaboration style. Team members worked out a plan to allocate individual responsibilities and executed it very well. The reflection indicated that everyone was noticeably clear about each other's contribution and their role in this collaborative project. Team dynamics were reflective of their communication style: concise but effective. The survey results matched the facilitator's direct observation.

Team 3 (Social VR Team) Survey Summary

The social VR team members enjoyed working with the technology and each other. Tasks were distributed, but members supported each other when needed. The team dynamics were very positive from the very beginning. The survey results matched the facilitator's direct observation.

In addition to the short surveys, a final exit interview was also conducted for each team at the end of Session 3. The exit interview encouraged the students to relate the modality they were assigned with the perceived outcomes and experience they obtained from this collaboration. The exit interview also only asked four questions:

1. How was your overall experience? Was it collaborative?
2. Did this modality help you with various collaborative team tasks? What worked well and what did not work so well?
3. What do you wish to improve?
4. Was it your preferred modality to work on a group project? How did this compare to other modalities you had?

Students in all teams seemed to be eager to engage in collaboration, and some were highly communicative. Peer collaboration played a vital role in student engagement with task activities. When asked what they wished to improve in their respective modalities of learning, the students from Team 1 (Zoom) felt some awkward silence, overlapping each other in communication, and poor internet connection were some of the issues they wished to improve. Team 2 (In-person) suggested that trying to manage the same time for everyone and coming to meetings on time could be improved. Similarly, Team 3 (Social VR) noted that ENGAGE's technical troubleshooting and graphics quality should be improved.

Almost all students preferred in-person as the first option for team projects and collaborative learning. In terms of time and efficiency, they considered in-person learning the best option. Then as an alternative, they would prefer learning in social VR as their second option, as everybody could be actively involved in the social VR platform and naturally interact with each other. Learning via Zoom would be the least preferred option. Students might not actively participate in the work by hiding behind their web cameras and muting themselves. Communication seemed to be awkward and unnatural if teammates chose not to respond.

Additionally, learning via social VR could be an excellent alternative in the future, as suggested by Team 3. Students enjoyed the social VR environment and mentioned it as somewhat realistic regarding "being present." However, students also noted that current social VR platforms still lag in many ways, such as it requires good quality Internet connection and high-resolution computer graphics, which were still quite cost-prohibitive.

Discussion and Limitation

As an exploratory study, this research did not aim to make statistically significant claims that favor one specific modality over the others. The interest resides in a better understanding of the pros and cons of each modality that will likely coexist in future collaborative learning in higher education. In addition to the limitation of a small sample size, the research team also realized the undefined role that the types of learning activities and assessment activities might play in verifying the specific affordances of each learning modality. In other words, further research is needed to develop a clear understanding of how instructional design should clearly account for the unique affordance of each modality and the potential synergy among them when mixed modalities are utilized to achieve optimal outcomes.

Conclusions

This research study investigated and compared how undergraduate students collaborate on a design project in three different modalities. The objective is to understand if and in what ways different modalities might impact the student's ability to collaborate and the outcomes of such collaboration. Based on direct observations and perceptions collected in this research study, most students still prefer in-person collaboration, even though the overall project outcome was comparable across the three modalities. Nevertheless, the social VR approach has great potential to enable effective and communicative collaboration in a project setting if certain technical deficiencies and computer graphics could further improve.

In the post-pandemic higher education community, there is a coexistence of conventional and emerging new learning modalities. For educators in AEC programs, this coexisting multimodality offers an untapped potential to design innovative, collaborative learning spaces that may better prepare students for professional collaboration in the workplace.

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