Jaya Kannan, AMHERST COLLEGE, jkannan@amherst.edu
Josef G. Trapani, AMHERST COLLEGE, jtrapani@amherst.edu
Kara T. McGillicuddy, AMHERST COLLEGE, kmcgillicuddy@amherst.edu

Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry

ABSTRACT

This paper presents a case study of an immersive virtual reality (IVR) activity that the authors designed to enhance the learning experience in an undergraduate neurophysiology laboratory course. To investigate the effectiveness of this experimental approach, we analyzed student survey responses and learning outcomes from the IVR activity. We then used the Community of Inquiry (CoI) framework as a pedagogical lens for analyzing the data. This analysis using CoI enabled the examination of cognitive, social, and teaching presences in an IVR activity. The results show that the IVR activity supported student engagement and promoted the emergence of a learning community. This study contributes empirical evidence, offers a pedagogical reflection on the potential of IVR in laboratory teaching, and concludes with recommendations for classroom integration.

KEYWORDS

immersive learning, virtual reality in higher education, community of inquiry, pedagogical strategies, digital accessibility

INTRODUCTION

As immersive virtual reality (IVR) continues to evolve, its use in educational contexts is growing. Previous studies underscore the capacity of IVR to enhance knowledge building (Sitzmann 2011) and motivation (Makransky and Lilleholt 2018) in a variety of educational settings. However, the mere presence of advanced technology in the classroom cannot guarantee meaningful learning. As Lege and Bonner (2020) argue, we can only realize the true educational potential of IVR when it's supported by robust, intentional pedagogical frameworks. Despite the significant progress in IVR technology and its success in experimental and research settings, a persistent gap remains: Pedagogical strategies that are purpose-built for IVR have not kept pace with technological progress. As Scavarelli, Arya, and Teather (2021) also caution, repurposing conventional teaching methods within IVR environments misses the opportunity to leverage the affordances of the medium, such as spatial presence, embodiment, and immersive interaction. Furthermore, a recent 2025 study by Santilli, Ceccacci, Mengoni, and Giaconi found that IVR may have a positive impact on student engagement and learning but would benefit from more structured approaches, such as systematic analysis and a firmer grounding in established pedagogical frameworks. To address these approaches, we present a novel IVR case study and then use the Community of Inquiry (CoI)

CC-BY-NC License 4.0 This is an Open Access article distributed under the terms of the Creative Commons – Attribution License 4.0 International which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly attributed.

pedagogical framework in order to analyze whether instructors can effectively leverage IVR to enhance learning and foster a sense of community in an undergraduate neuroscience course.

THE COMMUNITY OF INQUIRY (COI) FRAMEWORK

An educational CoI framework aims to create an optimal learning environment that recognizes the different dimensions of learning and how they interrelate. Such a framework highlights the development of community between the students and instructors so that they may learn together through the process of inquiry. It is rooted in the social constructivist view of learning, in which individuals construct meaning when in collaboration with others. Scholars originally studied this framework in the context of online learning but eventually applied it to blended and in-person learning environments as well (Stenbom and Cleveland-Innes 2024). Given that the CoI framework emphasizes the promotion of an enriching learning environment within a community context, we applied it to our case study.

The CoI framework proposes a model for building an enriching learning environment by interconnecting three elements: social presence, cognitive presence, and teaching presence (Stenbom and Cleveland-Innes 2024). Social presence is the ability to project personal attributes, interact with others to develop a social identity, and build relationships within a learning environment; it expands on the concepts of the shared experiential learning established in Bandura's Social Learning Theory (Bandura and Walters 1977). Cognitive presence involves exploring, constructing, and resolving meaning through sustained discourse. Teaching presence encompasses the design, facilitation, and direction of the educational experience. Together, these elements create an environment conducive to meaningful learning experiences. In our opinion, the absence of even one element can diminish the capacity to provide an optimal learning environment. Thus, we designed the IVR activity described below to improve pedagogical outcomes of a long-running course, and our analysis reveals that it achieved all three CoI elements.

CASE STUDY: A NEUROPHYSIOLOGY COURSE AS A TEACHING CONTEXT

"Neurophysiology with Laboratory" (BIOL-351) is the name of an upper-level laboratory course for undergraduates majoring in biology, biochemistry, and biophysics, or neuroscience at a small liberal arts college. The laboratory component of the course emphasizes quantitative electrophysiological and biophysical concepts and focuses on student-led experiments that test novel hypotheses. Along with regular exams and problem sets, laboratory assessments include lab reports written as journal articles that introduce hypotheses proposed by students and consider the results of their experiments. As an exercise in continuous improvement of the course, the instructor recently used the first lab of the semester as a foundational step toward achieving the course learning outcomes: understanding neurophysiology core concepts, applying knowledge, mastering electrophysiology tools, strengthening teamwork skills, and developing hypotheses. To achieve this goal, the instructor leveraged the expertise of staff members from the academic technology unit of the college to help design and facilitate an IVR activity.

While certain course components and assignments connected to the course learning aspirations (e.g., through problem sets, lab group work, lab reports, and in-class paper presentations), the instructor intentionally established the IVR activity to align with specific learning goals: 1) build collaborative relationships, 2) appreciate nervous system complexity, 3) learn electrophysiology tools, and 4) develop hypothesis-testing skills. The lab began with a class of 27 students (separated into two sections); the instructor placed them into two- or three-person groups and told them that they would

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

co-learn electrophysiology hardware and software while taking part in an IVR activity designed to achieve the four learning goals above. The instructor introduced students to hypothesis design and then informed them that they would measure their heart rate, breathing rate, and grip strength before and after participation in two IVR experiences. They then formulated hypotheses based upon their predictions of how each of the IVR experiences would affect their physiological measurements.

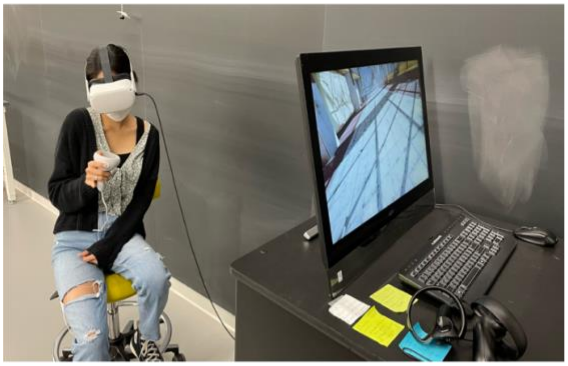
To facilitate hypothesis generation, the IVR activity intentionally included two experiences, one "passive" and the other "active" (Figure 1). For the passive experience, each student would be seated, passively watching a series of short experiences within the Oculus Dreamdeck (2016) application that ended with a large T. Rex dinosaur approaching, growling, then roaring, and finally walking over the observer. During the active experience, *Richie's Plank Experience* (2019), students physically interacted with their environment, including walking on a ten-foot long two-by-eight-inch board that served as a wooden plank. The participant began the active experience by entering a virtual elevator from the sidewalk on a city street. They then ascended to a high floor of a skyscraper. When the doors opened, the participant saw a virtual plank extending 10 feet away from the building with the exact dimensions of the real plank as well as the city street far below. A lab assistant in the physical room turned on a desktop fan focused on the participant, who was encouraged to step out from the safety of the elevator (Figure 1). While group members waited for their turn, they observed their classmates' emotional reactions to their IVR experiences. The goal of having students observe each other during the IVR activity was to foster a sense of connectedness, which research has shown supports cognitive, emotional, and self-directed learning (MacLeod, Yang, and Shi 2019). This approach aimed to strengthen connectedness and cultivate a broader learning community.

The deliberate selection of *Richie's Plank Experience* (2019) as the active experience played a pivotal and impactful role in shaping the learning experience. Multiple research studies demonstrate the benefits of using this particular IVR experience for studying the fear of heights, neuroscience concepts such as threat magnification, and its potential for reducing anxiety (Aspiotis et al. 2022; El Basbasse, Packheiser, Peterburs, Maymon, Güntürkün, Grimshaw, and Ocklenburg 2023; Krupić, Žuro, and Corr 2021; Zheng, Wang, Cao, Vidal, and Wang 2021). The instructor chose the passive experience for its thrilling nature, but the involvement of the student as a passive observer potentially limited their overall physiological reaction. The potential physiological differences between these two IVR activities therefore provided good possibilities for hypothesis development by the students.

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

Figure 1. Passive and active IVR activities in a neurophysiology lab course

A



B



C

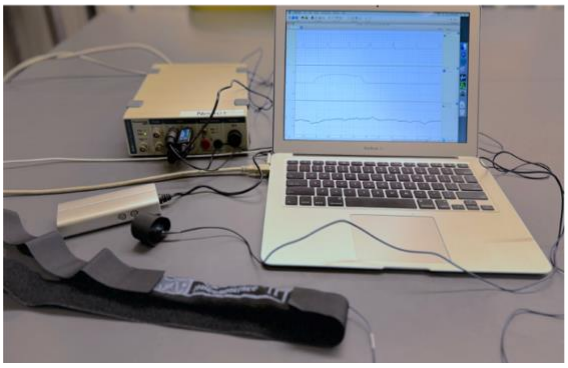


Image Credit: Josef G. Trapani 2022

Note: (Photo A) A student prepares for the approaching dinosaur in the "passive" IVR activity. (Photo B) Another student walks the plank in the "active" IVR activity. A fan creates the sensation of wind blowing as the participant exits an elevator onto a narrow platform (that has been built physically on the floor and exists virtually within the application) many stories above a city street below. (Photo C) The physiological recording setup, including an aluminum grip strength meter, finger pulse transducer, and breathing transducer strap.

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

SYSTEMATIC ANALYSIS OF THE IVR CASE STUDY

We adopted a reflective teaching practitioner's perspective to examine our IVR-based instructional case study by asking: What teaching methodologies are effective when employing IVR in the classroom? And how can those methodologies foster not just individual engagement, but a meaningful learning community? We hypothesized that engaging in a shared learning experience, rather than going through IVR in isolation, would strengthen opportunities for collaborative inquiry.

Overall, this study aimed to assess the pedagogical effectiveness of a shared IVR activity as the first laboratory of a neuroscience course through the lens of the CoI framework, whose main elements are social presence, cognitive presence, and teaching presence (Stenbom and Cleveland-Innes 2024). After presenting our case study and the results of our analysis, which included student self-reports of the lab experience, we end with four pedagogical strategies applicable to fostering a community of inquiry in the higher education classroom using IVR. Although our work focuses on a neuroscience course, we believe the described pedagogical strategies transcend disciplinary boundaries and are applicable across a wide range of academic domains.

METHODS

Procedures

Institutional review board

The Institutional Review Board (IRB) at our institution approved the IVR activity and student survey. With IRB's guidance, we constructed a consent form and shared it with the students at the beginning of the laboratory session. In addition, all authors received both Collaborative Institutional Training Initiative (CITI) training and ethics training.

Equipment and software

Each activity used one Meta Quest 2 VR headset. For the "passive" activity, the Oculus Dreamdeck (2016) application was run on a Windows PC with an NVidia graphics card and tethered by a 20-ft. USB 3 cable compatible with the Quest 2 headset. For the "active" activity, students could use the headset as standalone, since its built-in computer is capable of running *Richie's Plank Experience* (2019).

Accessibility

Through the use of the IVR activity, *Richie's Plank Experience* (2019), we intended to make the activity accessible to all users in this course, including students with disabilities and those that had accommodations. This activity included an Equally Effective Alternate Learning/Assessment Plan, or EEAAP (Harvard University Digital Accessibility Services n.d.). Using an EEAAP for this activity ensured that students with disabilities or concerns about their participation could have equal access to the learning opportunity. For example, students could choose to observe their classmates going through the IVR activity without going through the immersive experience themselves and could use that to participate in the discussion.

Measures

Surveys

The pedagogical intent behind the group reflection on an IVR activity in the first laboratory was to promote collaborative relationships, increase student appreciation of the nervous system,

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

improve facility in the use of sophisticated neurophysiology equipment, and develop the ability to design and analyze hypothesis-based experiments. To measure the effectiveness of the IVR activity, students completed a survey before participating in the IVR activities, a corresponding one afterward, and a third survey at the end of the semester.

The pre-lab survey asked students to anticipate the outcomes that they would experience in the IVR activity using eight quantitative Likert-type questions and two qualitative questions, while the post-lab survey asked the same questions as reflections on their experience. The end-of-the-semester survey consisted of two qualitative questions that differed from the ones asked in the first two surveys.

The pre- and post-lab surveys contained eight Likert-type questions focused on the four main learning goals of this lab activity outlined in the introduction. See Table 1 for the category labels used for each pair of pre- and post-lab Likert-type survey questions.

Table 1. Questions for the pre- and post-laboratory student surveys

#	Category label	Paired pre- and post-lab survey questions
1	Comfort participating	I feel/felt comfortable participating in this VR activity.
2	Ease of use	I anticipate that the virtual reality technology will be easy to use/The Virtual Reality technology was easy to use.
3	Collaborative relationships	This VR experience will allow/has allowed me to develop collaborative relationships with my lab partners, instructor(s), and TAs.
4	Understanding of nervous system complexity	The simulated scenarios in this VR experience will allow/have allowed me to better understand and appreciate the complexity of the nervous system.
5	Data acquisition equipment and software	This VR experience will allow/has allowed me to use, manipulate, and apply data acquisition equipment and software.
6	Hypotheses and physiological data	This VR experience will improve/has improved my ability to design hypotheses and analyze and interpret physiological data.
7	Objectives of the lab activity (lab protocol)	This VR experience will help/has helped me achieve the objectives of the lab activity (as stated in the lab protocol).
8	Learning goals of the course (course syllabus)	This VR experience will help/has helped me achieve the learning goals of the course (as stated in the course syllabus).

Analysis

We used SPSS v29 (IBM 2023) and Google Sheets (Alphabet Inc.) for statistical analysis and summarization of quantitative data.

OUTCOMES

This section combines the results of the quantitative and qualitative survey measures with a formal analysis in order to provide a more comprehensive view of the impact of the IVR activity on the student learning outcomes. Our analysis also examines the implications that arise from the results of the survey questions and uses descriptors from the Survey Instrument Characteristics that are part of the Community of Inquiry Survey Instrument (draft v14) (Appendix) in order to analyze the effectiveness of the IVR activity (Arbaugh et al. 2007).

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

Quantitative responses

We analyzed the pre-lab, post-lab, and end-of-semester surveys primarily through a qualitative lens, since quantitative analysis was limited due to a sample (N = 26) that was too small and abnormally distributed for more robust analytical approaches, such as t-tests. Further quantitative analysis was therefore restricted to comparing the separate and combined agree and strongly agree responses to the eight Likert-type questions before and after the IVR activity (Figure 2).

The total number of positive responses increased after the IVR activity for six of the eight questions. The questions that increased covered ease of use, potential for developing collaborative relationships, data use and acquisition, ability to develop hypotheses and analyze physiological data, and overall ability to achieve the learning outcomes of the course as stated in the syllabus (Figure 2). This increase in most of the questions implies that the IVR activity met or exceeded the students' expectations. It should be noted that responses to the pre-lab survey were generally very high to begin with, so the increases in these positive responses were small.

Figure 2. Total separate and combined agree and strongly agree responses before and after the IVR activity

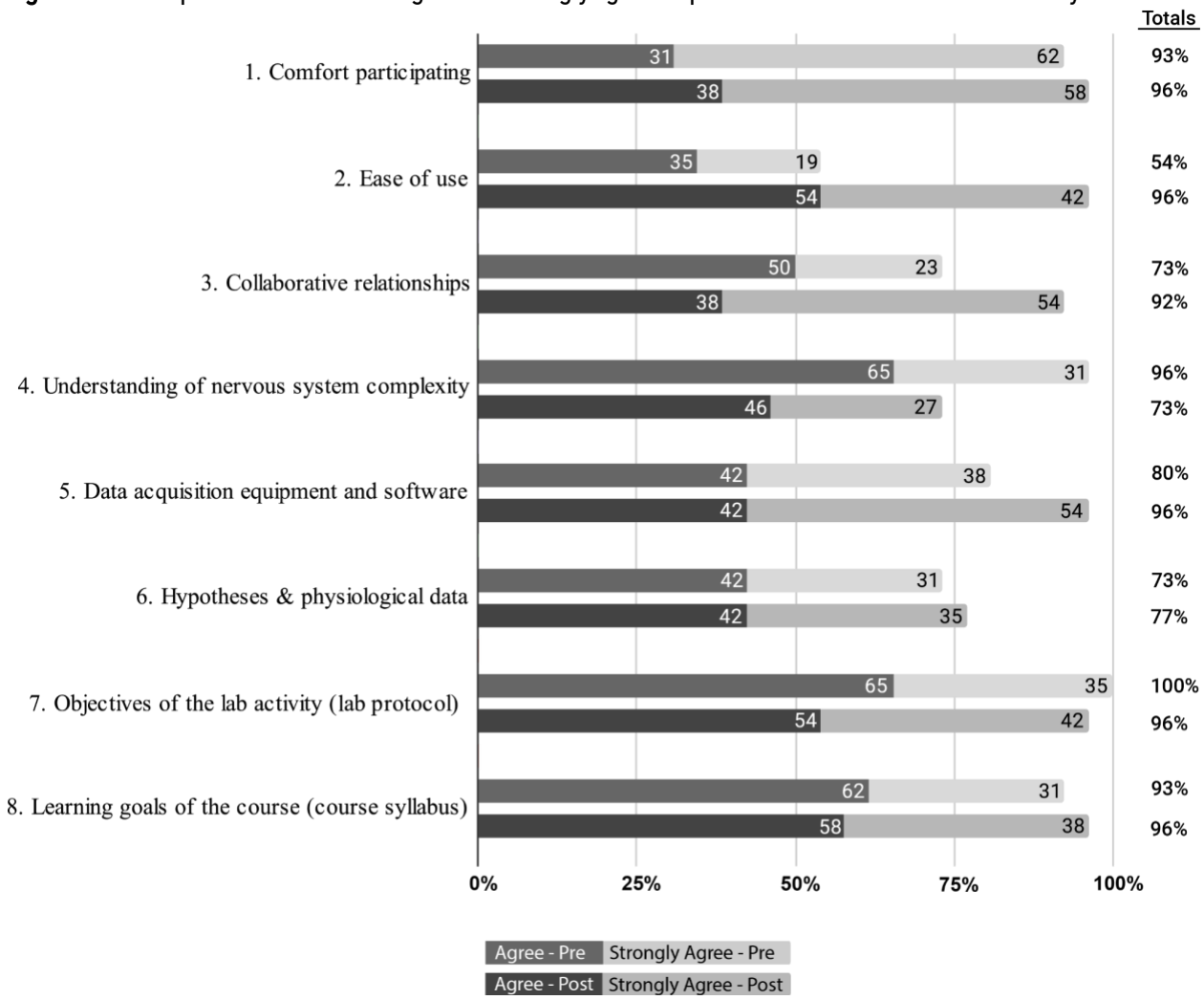


Image Credit: Kara T. McGillicuddy 2024

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

Comfort participating

Students' self-reported comfort participating in the IVR activity shifted from 93% to 96%, suggesting that students found that they were somewhat more comfortable using IVR for learning than they had expected, although expectations in this area were already rather high.

Ease of use

Positive opinions on the ease of using IVR technology increased sharply, from 54% to 96% positive (Agree or Strongly Agree) responses. This indicates that students found the IVR technology to be easier to use than they anticipated, and most of the students viewed the IVR technology as very easy to use.

Collaborative relationships

The degree to which students felt the experience could help them build collaborative relationships with their lab partners, instructor(s), and TAs also increased from 73% to 92% positive responses overall, especially in the number of Strongly Agree responses which went from 23% to 54%. This shift revealed that students felt the IVR activity allowed them to develop collaborative relationships to a greater extent than they had expected.

Understanding of nervous system complexity

Positive responses to the question of whether the IVR activity would support understanding of nervous system complexity decreased from 96% to 73%. It is possible that this discrepancy occurred because it was the first lab of the semester, and students are still in the early stages of their educational journey.

Data acquisition equipment and software

Student perspectives on the ability of the IVR activity to help them learn how to use data acquisition equipment and software increased appreciably (80% to 96% positive), indicating that students felt the IVR activity provided a greater opportunity for development in these skills than they had anticipated.

Hypotheses and physiological data

The degree to which the students expected the IVR activity to help them learn how to design hypotheses and analyze physiological data increased a very small amount, from 73% to 77%; this suggests that most students recognized the first lab's hypothesis-brainstorming activity as a helpful foundation for developing their hypothesis-building throughout the course.

Objectives of the lab activity (lab protocol)

Student perception that the IVR activity helped them achieve the lab objectives decreased slightly, from 100% to 96%. This change in perception is almost negligible and may reflect the adjustment period typical after a first lab, when students recalibrate their expectations and are developing a basis for comparison in relation to the rest of the course.

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

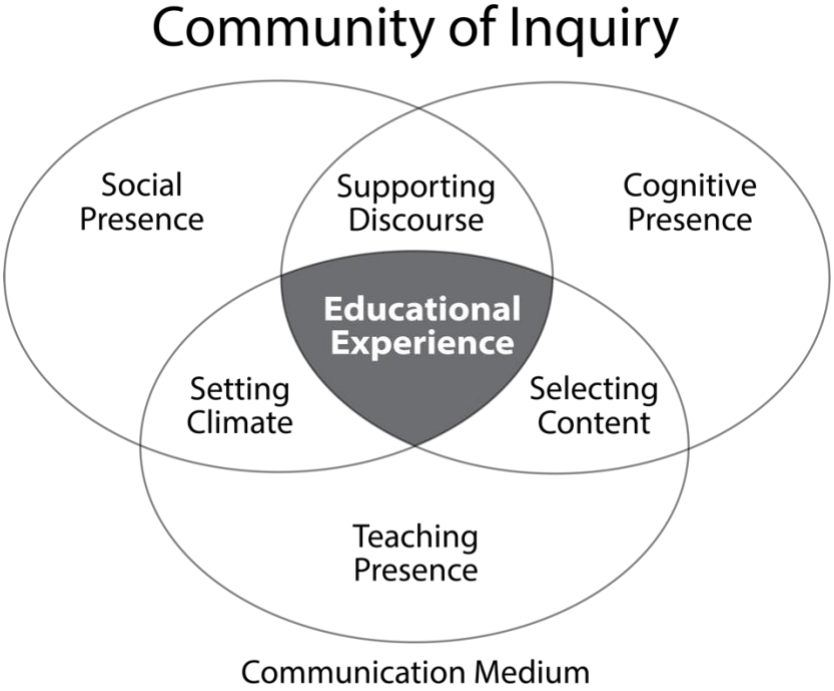
Learning goals of the course (course syllabus)

Student opinion on whether the IVR activity helped them achieve the learning goals as stated in the course syllabus increased from 93% to 96%. The net gain in positive feedback suggests that for some students, the IVR activity exceeded their expectations in helping them achieve the course learning goals.

Qualitative responses analyzed using the CoI framework

The use of the CoI framework highlights the potential applications of IVR for improving course learning outcomes and promoting a learning community. Our case study examines the three elements of the CoI framework described in the introduction, namely social presence, cognitive presence, and teaching presence (Figure 3). Arbaugh and colleagues (2007) developed a survey instrument to measure the effectiveness of the CoI framework (draft v14). The instrument includes specific descriptors for each element of the framework, which we used as guideposts for our analysis (Appendix). However, we did not administer the Survey Instrument itself as part of the IVR activity.

Figure 3. Holistic view of the Community of Inquiry framework



Note: The three elements of the CoI framework (Social Presence, Cognitive Presence, and Teaching Presence) come together in a Venn diagram where their individual and overall overlap provides specific pedagogical outcomes. Image Credit: Garrison, Anderson, and Archer 1999 (used with permission)

Social presence

Based on the student survey results, students experienced both excitement and anxiety, engaged openly with peers and instructors, and observed one another's participation as part of a social group. According to the descriptors in the CoI Survey Instrument (draft v14) (Appendix), three factors acted as determinants of social presence within the student learning experience: open

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

communication, affective expression, and group cohesion (Arbaugh et al. 2007). We now discuss the student survey results using these three factors as analytic lenses.

Open Communication: Group interaction in the IVR activities turned learning into an open communication exercise with the potential to foster belonging. Abrica, Lane, Zobac, and Collins (2022) showed that IVR intervention in STEM programs can nurture a sense of belonging. O'Connor (2018) also demonstrated that IVR could foster a community of problem solvers. Survey comments noted how peer interaction created a sense of connection, thus laying the foundation for collaborative knowledge building from the first week of lab. Two responses in particular captured this desire for connection. One student commented that "...working in groups will also be nice so that we can troubleshoot together." Another student stated that they "...hope to also have a good collaborative environment where I feel comfortable enough to share my ideas and discuss my findings with my lab group."

Affective Expression: According to Meta (n.d.), "Richie's Plank experience was designed to invoke the strongest possible emotions in the shortest possible time," making it logical for studying and discussing neuroscience concepts, such as the fight-or-flight response. Student responses from our survey show that this intentional low-stakes design of the IVR activity, which aimed to tap into their emotions, effectively heightened students' affective responses. This emotional engagement in turn fostered a sense of bonding among classmates. One student's survey comment captures this link between the emotions generated by the activity and the perception of connection with their lab partner, stating "... me and my lab partner quickly bonded. I think there are two reasons… 1) We got to experience something exciting … together. This shared experience and common rush of adrenaline brought us together in a fun way that is usually not achievable in classical lab/lecture setting. 2) [The] lab session was low stress - gave us time and space to share and to get to know each other."

Group Cohesion: Placing this social activity early in the learning sequence contributed to the development of the students' intellectual community. As the students shared their emotional reactions (such as enthusiasm, excitement, fear, or anxiety) with their peer groups, a collaborative inquiry process developed. The "passive" IVR activity evoked some emotional reactions. As students compared and contrasted it with the "active" experience, this further grounded discussion and created space for comparing hypotheses, which in some cases predicted these differences.

Some student comments provided evidence that the primary goal of the laboratory activity, to offer a personalized immersive experience within a shared learning context, was largely achieved. For example, a student noted the experience "[w]as a really great way to learn the computer part and build trust with my partner." However, one student commented that " … although we all took turns using the equipment, it still felt more 'individual' since we weren't going through the experience together," which highlights an opportunity to further enhance the balance between individual and shared experiences in future iterations of the course.

Cognitive presence

Cognitive presence refers to constructing meaning through sustained communication (Garrison, Anderson, and Archer 2001). IVR's inherent immersive and interactive features can elicit a significantly heightened cognitive presence among students. According to the descriptors in the CoI Survey Instrument (draft v14) (Appendix), three factors acted as determinants of cognitive presence within the student learning experience: triggering event, exploration, and integration and resolution (Arbaugh et al. 2007). Through the examination of the results of our three student surveys and our observations of student learning, we found that the IVR activity effectively achieved these three

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

factors as it sparked interest, encouraged exploration, and showed the emergence of integration within their learning.

Triggering Event: The pre-survey results revealed enthusiasm for IVR, indicating a strong sense of curiosity among the students. Upon experiencing the sensory-rich IVR activity, some students expressed their belief that it would aid in their comprehension of neuroscience concepts. This outcome suggests a link between curiosity and student motivation to engage with content-related questions, which aligns well with the idea of initiating cognitive presence. As a whole, comments indicated that learning motivation was very high, and the majority of student responses mentioned the terms "fun" or "excitement." Multiple students felt the IVR activity improved their understanding of course goals and the concept of neuroscience. For example, one student commented that they "… found it amazing how easily we can trick our brains into believing that we are somewhere other than where are [sic] physical bodies actually are."

Exploration: Class discussions and pre- and post-survey data indicated that the IVR activity positively impacted student understanding of neuroscience concepts. They anticipated that the hands-on and visual nature of IVR would expand their learning approaches beyond traditional lectures and expressed excitement about its educational potential. This was clear evidence of their willingness to try a new approach, as compared to traditional lab settings that do not use IVR. For example, multiple comments alluded to the potential for visual learning of the materials, including a student who stated, "I think the VR will make it easier for me to visualize the concepts being introduced to me."

Integration and Resolution: At the end of the course, students expressed varied opinions on whether the IVR activity impacted their learning. The degree of integration was uneven among students and, as noted in the quantitative responses section, positive responses to the question of whether the IVR activity would help them "better understand and appreciate the complexity of the nervous system" dropped from 96% before the lab activity to 73% after. Some students did not connect the IVR learning experience to the remainder of the course, and one student commented, "I liked doing the lab, but throughout the rest of the semester I didn't really think about it at all or connect any of the lecture topics to that particular lab." In contrast, another student mentioned that they brainstormed possible ways to apply IVR to other neuroscience courses, such as the Consciousness of the Brain course, commenting, "I was thinking that VR would be helpful to test if different color adaptations would work."

Moore, Miller, and Diaz (2023) advise educators to consider that students may still be in the early stages of exploration and may not have reached advanced levels of thinking. When this is the case, instructors need not worry if integration and resolution stages are not immediately evident in course discussions. Rather, the goal should be to align course objectives with the students' current level of cognitive presence. By the end of the semester, all students demonstrated proficiency in utilizing neurological data acquisition equipment. Furthermore, the iterative hypothesis-based writing assignments throughout the course showcased students' ability to construct new meaning, a process that the IVR activity initially facilitated. According to the instructor, all student work related to hypotheses development was markedly improved compared to previous iterations of the course, supporting the positive impact of the IVR activity on course learning outcomes.

Teaching presence

Teaching presence involves guiding cognitive and social processes toward meaningful learning outcomes (Anderson, Liam, Garrison, and Archer 2001). Collaborative effort between the

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

instructor and technologists, blending technical knowledge with pedagogical expertise, was essential in creating a quality lab experience for students. According to the descriptors in the CoI Survey Instrument (draft v14) (Appendix), the three factors that act as determinants of teaching presence are: 1) design and organization, 2) facilitation, and 3) direct instruction (Arbaugh et al. 2007).

Design and organization: Framing the learning activity as low-stakes and offering students the choice to opt out encouraged them to assert control over their learning process. All the students declined the option to opt out and voluntarily participated in the IVR, despite their unfamiliarity with the activity. Furthermore, some students noted that this IVR activity's design differed fundamentally from their regular labs, as one student noted, "Since it's not a wet lab setting, it won't be too overwhelming and we can focus on understanding the material more than making sure we're doing each step correctly and safely." Some student comments touched on the effectiveness of the design and also suggested ways to improve clarity ("I would say some more guidance on how to record and analyze the data collected would have been helpful.") and time allowance ("It felt a bit rushed and I do not think that I got out of it as much as I could've.").

Facilitation: Written handouts containing detailed step-by-step instructions for equipment use and data measurement, as well as their integration into small group discussions, offered valuable instructional support to students. Most post-lab survey respondents found the activity guidelines were clear. One representative survey comment stated, "The pace of the lab was not stressful as we weren't chased for time, and we got to fully enjoy the VR experience without having to worry about any graded assignments." A key pedagogical outcome was the recognition that student engagement and meaningful learning in IVR environments depend heavily on the clarity of instructional framing. The findings indicate that IVR, while immersive, does not inherently support learning unless it is situated within a communicated and coherent pedagogical motive.

Direct instruction: Our case study established teaching presence by clearly communicating the purpose of the IVR activity to the students. Students stated in their survey responses that they recognized the objective of exploring innovative approaches to conducting lab work. The post-lab survey showed overwhelmingly positive responses, such as "It was a fun and unique experience!" and "I thought it was cool!" More specific positive comments touched on comfort and design, while some noted room for improvement in terms of explaining the hypothesis formulation. For example, one student suggested that "[t]here could have been a little more support in discussing the formulation of the hypotheses specific to this lab, but all the other instructions were very clear and easy to follow."

Analyzing our case study with the CoI framework revealed pedagogical outcomes and highlighted the critical role of teaching presence in fostering an engaged learning community. Reflections from the students emphasized not only the novelty and excitement of the IVR activity, but also a sense of comfort and clarity from the intentional design and facilitation. Students specifically alluded to a "safe environment," "a lot of support," that it "was designed really well," and was "easy to follow and easy to perform." One student in particular stated that "[i]t made me more open to the lab work we did in class and set the tone that lab was going to be fun/less traditional than in previous STEM courses."

A strong teaching presence helped create an environment where students felt encouraged, included, and open to participation. This environment contributed to a positive shift in attitudes toward lab work, which may provide evidence that intentional learning design can shape collaborative and motivated learning communities.

Although we conducted this study in a STEM course, other learning domains can use IVR activities to improve learning goals and build community. To facilitate such use, we next provide a set

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

of strategies and suggested guidelines that are intended to provide support and points of reflection for teaching practitioners who intend to use IVR in their classroom.

PEDAGOGY STRATEGIES

Our analysis of this case study highlights the advantages of IVR technology and its potential for building learning communities. However, the use of IVR alone cannot guarantee successful learning outcomes; the combination of instructional design knowledge and intentional use of IVR is necessary to promote educational enrichment. Drawing upon the lessons learned from our case study, we have identified four pedagogical strategies for the effective application of IVR. These strategies are interrelated and essential for optimal learning: learner motivation; learner autonomy; learning content; the technological ecosystem that facilitates learning; and the paramount need for inclusivity (i.e., encouraging the engagement of every student in the classroom). We believe that educators can adopt a holistic approach to strengthen student learning through a combination of these strategies. Notably, scholars in all academic disciplines across STEM, Social Science, and Humanities can replicate and implement these strategies.

Strategy One — To strengthen learner motivation, ensure that the design of the IVR activity aligns meaningfully with the course goals and consistently highlight its relevance throughout the course.

The outcomes of our case study demonstrated that the pedagogical approach of replacing a traditional lab with an IVR activity was effective and well received by the students. The neurophysiology course's initial lab activities provided an opportunity to bolster motivation and foster community. Furthermore, small groups cultivated a sense of community through shared observation and interaction.

The work of Belanger, Joshi, Fuesting, Weisgram, Claypool, and Diekman (2020) demonstrated that strong connections with peers and the instructor can enhance motivation in lab activities. It may not be an exaggeration to state that failing to prioritize community building early in a course might be detrimental to learner engagement. This IVR activity provided a model for prioritizing early community building and its positive influence on learner engagement.

Strategy Two — To promote learner autonomy, design immersive learning experiences that prioritize student agency and are situated within a collaborative learning context.

Developing hypothesis statements throughout the course enhanced students' critical thinking skills. Later laboratory activities built upon their initial IVR-based hypothesis activity. Two factors influenced the emergence of learner autonomy in this case: the student's individual experience within a peer group discussion setting and the opportunity to refine their thinking through multiple iterations of the hypothesis creation activity.

Learner autonomy is defined as the "learner's ability to take charge of his or her [or their] own learning" (Holec 1979), and it is well established that learner autonomy flourishes when students operate within a social construct (Turula 2017) and a networked learning environment (Drexler 2010). This IVR activity empowers students with personal control over the learning environment, fostering self-reflection on course concepts throughout their individual experiences (Johnson-Glenberg 2018).

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

Strategy Three — IVR learning materials must be suitable for the teaching and learning context.

Richie's Plank Experience (2019) proved particularly effective for the IVR activity due to its immersive and emotionally engaging nature, which successfully captured students' attention. This underscores the importance of thoughtfully selecting IVR learning materials, since the choice can significantly enhance or hinder the student learning experience.

IVR learning materials should facilitate an inclusive approach as well as collaborative learning in the classroom. One way to achieve this is to ascertain whether IVR can accommodate physical and learning differences by applying the Universal Design for Learning (UDL) framework as established by Center for Applied Special Technology (CAST n.d.). Another vital aspect to consider is technological ease, such as whether a first-time user can navigate through the immersive experience with minimal guidance in a way that ensures accessibility and a smooth learning process.

Strategy Four — Leverage the technological affordances of IVR to enhance student learning.

In our case study, adding a real plank and a desktop fan enhanced the immersive nature of *Richie's Plank Experience* (2019). These intentional additions to the activity showed that designing for maximum impact requires an understanding of the IVR platform's built-in features and strategic use of thoughtful design additions.

After a comprehensive review of 151 IVR-related studies within the information systems domain, Dincelli and Yayla (2022) identified five key affordances: embodiment, interactivity, navigability, sense-ability, and create-ability. They state that while IVR inherently provides these technological affordances, achieving effective user experiences necessitates a nuanced understanding of how to strategically apply these features; mere possession of these technological capabilities is insufficient (Dincelli and Yayla 2022).

For example, in this study, the improved usability of modern head mounted devices (HMDs) shaped the decision to design group activities instead of individual sessions. A deeper understanding of the technological features is key to effective design of the lab activity, thereby enhancing the learning experience.

LIMITATIONS AND FUTURE DIRECTIONS

Our analysis of this case study has several limitations that future research could address. The first limitation is the small dataset, which resulted in an abnormal distribution of data and thus precluded more robust statistical analysis techniques. We also only used the IVR activity at the start of the course. Multiple iterations of the activity that integrated student feedback throughout the duration of the course could have strengthened the impact of the quantitative and qualitative tools. Other future work might include larger cohorts or establishing IVR activities across a series of different courses within and outside of STEM.

The qualitative responses from our survey data indicate positive outcomes from the use of IVR to enhance student learning, and they highlight the potential to build a strong classroom community. Nevertheless, future case studies should consider using a longitudinal design, as well as a larger sample size, to enhance the quality of the measured data and avoid some of our case study's limitations.

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58

Lastly, we recognize the potential impact of factors, such as the level of enthusiasm shown by the instructor, TAs, or other lab members, which might influence student responses, as well as the inherent lack of generalizability in studies that use student-only samples. Additionally, the novelty of new technologies, such as IVR, can interfere with the measurement of other factors and should be controlled for in any future experimental studies (Miguel-Alonso, Checa, Guillen-Sanz, and Bustillo 2024).

CONCLUSION

The integration of IVR technology into the first laboratory of an advanced undergraduate neuroscience course shows that learning and community building can be enhanced in a meaningful way that motivates and excites students. Further, we demonstrate that the potential of IVR to enhance socio-cognitive aspects of learning depends upon effective pedagogical design. Finally, we used CoI as an analytical tool for our case study. Based on the results of this analysis, we arrived at four pedagogical strategies for the use of IVR in order to create an enriching learning experience.

The goal of experimenting with IVR as a pedagogical method was to move beyond traditional didactic lectures and provide students with an opportunity to engage in experiential learning. IVR inherently enhances a sense of presence by narrowing focus and minimizing external distractions, thereby enabling learners to process information more deeply. In our lab setting, the IVR activity heightened cognitive focus; grounding that focus in the course content offered students an opportunity to make meaningful connections. As Philippe, Souchet, Lameras, Petridis, Caporal, Coldeboeuf, and Duzan (2020) explained, a key advantage of IVR in education is its ability to allow students to explore content from multiple perspectives and to situate learning in authentic contexts (424).

ACKNOWLEDGMENTS

Thank you to Andy Anderson, David Yang, and Luis E. Guzman-Clavel for assistance with setting up and facilitating the IVR technology for the neuroscience lab activity. Thank you also to Andy Anderson for providing feedback on our manuscript.

AUTHOR BIOGRAPHY

Jaya Kannan (United States) is director of technology for curriculum and research at Amherst College. She partners with faculty to advance effective teaching and learning using emerging technologies. Her digital pedagogy research explores strategies for promoting learner autonomy and learning communities.

Josef G. Trapani (United States) is a professor of biology in the biology department and neuroscience program at Amherst College. His research focuses on understanding sensory encoding using the zebrafish model system.

Kara T. McGillicuddy (United States) is a senior academic technology specialist at Amherst College. She is the primary administrator for the college's learning management system and provides support for other academic technologies. Her research examines the intersection of communication, pedagogy, and technology.

DISCLOSURES

The authors have no conflicts of interest to disclose. We did not use AI at any stage of the manuscript's development or writing process.

ETHICS

The Institutional Review Board (IRB) at Amherst College approved this research.

DECLARATIONS

Availability of data and materials: The dataset analyzed during the current study, as well as the full survey instrument used, are available from the corresponding author upon reasonable request.

REFERENCES

Abrica, Elvira J., Tonisha B. Lane, Stephanie Zobac, and Elizabeth Collins. 2022. "Sense of Belonging and Community Building within a STEM Intervention Program: A Focus on Latino Male Undergraduates' Experiences." *Journal of Hispanic Higher Education* 21 (2): 228–42. https://doi.org/10.1177/1538192720974884.

Anderson, Terry, Rourke Liam, D. Randy Garrison, and Walter Archer. 2001. "Assessing Teaching Presence in a Computer Conferencing Context." *Journal of Asynchronous Learning Networks* 5 (2): 1–17. https://doi.org/10.24059/olj.v5i2.1875.

Arbaugh, J. B., Martha Cleveland-Innes, Sebastian R. Díaz, D. Randy Garrison, Philip Ice, Jennifer C. Richardson, Peter Shea, and Karen P. Swan. 2007. "Community of Inquiry Survey Instrument (draft v14)." *Community of Inquiry Survey.* https://www.thecommunityofinquiry.org/coisurvey.

Aspiotis, Vasileios, Andreas Miltiadous, Konstantinos Kalafatakis, Katerina D. Tzimourta, Nikolaos Giannakeas, Markos G. Tsipouras, Dmitrios Peschos, Euripidis Glavas, and Alexandros T. Tzallas. 2022. "Assessing Electroencephalography as a Stress Indicator: A VR High-Altitude Scenario Monitored through EEG and ECG." *Sensors* 22 (15): 5792. https://doi.org/10.3390/s22155792.

Bandura, Albert, and Richard H. Walters. 1977. *Social Learning Theory*. Vol. 1. Prentice Hall.

Belanger, Aimee L., Mansi P. Joshi, Melissa A. Fuesting, Erica S. Weisgram, Heather M. Claypool, and Amanda B. Diekman. 2020. "Putting Belonging in Context: Communal Affordances Signal Belonging in STEM." *Personality and Social Psychology Bulletin* 46 (8): 1186–1204. https://doi.org/10.1177/0146167219897181.

CAST (Center for Applied Special Technology). n.d. "Universal Design for Learning." Accessed October 3, 2025. https://www.cast.org/what-we-do/universal-design-for-learning.

Dincelli, Ersin, and Alper Yayla. 2022. "Immersive Virtual Reality in the Age of the Metaverse: A Hybrid-narrative Review based on the Technology Affordance Perspective." *The Journal of Strategic Information Systems* 31 (2): 101717. https://doi.org/10.1016/j.jsis.2022.101717.

Drexler, Wendy. 2010. "The Networked Student Model for Construction of Personal Learning Environments: Balancing Teacher Control and Student Autonomy." *Australasian Journal of Educational Technology* 26 (3). https://doi.org/10.14742/ajet.1081.

El Basbasse, Yasmin, Julian Packheiser, Jutta Peterburs, Christopher Maymon, Onur Güntürkün, Gina Grimshaw, and Sebastian Ocklenburg. 2023. "Walk the Plank! Using Mobile Electroencephalography to Investigate Emotional Lateralization of Immersive Fear in Virtual Reality." *Royal Society Open Science* 10 (5): 221239. https://doi.org/10.1098/rsos.221239.

Garrison, D. Randy, Terry Anderson, and Walter Archer. 1999. "Critical Inquiry in a Text-Based Environment: Computer Conferencing in Higher Education." *The Internet and Higher Education* 2 (2-3): 87–105. https://doi.org/10.1016/S1096-7516(00)00016-6.

Garrison, D. Randy, Terry Anderson, and Walter Archer. 2001. "Critical Thinking, Cognitive Presence, and Computer Conferencing in Distance Education." *American Journal of Distance Education* 15 (1): 7–23. https://doi.org/10.1080/08923640109527071.

Harvard University Digital Accessibility Services. n.d. "Creating an Equally Effective Alternate Access Plan (EEAAP)." https://accessibility.huit.harvard.edu/creating-equally-effective-alternate-access-plan-eeaap

Holec, Henri. 1979. *Autonomy and Foreign Language Learning*. Pergamon.

IBM Corp. Released 2023. IBM SPSS Statistics for Macintosh, Version 29.0.2.0 IBM Corp.

Johnson-Glenberg, Mina C. 2018. "Immersive VR and Education: Embodied Design Principles That Include Gesture and Hand Controls." *Frontiers in Robotics and AI* 5: 81. https://doi.org/10.3389/frobt.2018.00081.

Krupić, Dino, Barbara Žuro, and Philip J. Corr. 2021. "Anxiety and Threat Magnification in Subjective and Physiological Responses of Fear of Heights Induced by Virtual Reality." *Personality and Individual Differences* 169: 109720. https://doi.org/10.1016/j.paid.2019.109720.

Lege, Ryan, and Euan Bonner. 2020. "Virtual Reality in Education: The Promise, Progress, and Challenge." *Jalt Call Journal* 16 (3): 167–80. https://doi.org/10.29140/jaltcall.v16n3.388.

Makransky, Guido, and Lau Lilleholt. 2018. "A Structural Equation Modeling Investigation of the Emotional Value of Immersive Virtual Reality in Education." *Educational Technology Research and Development* 66: 1141–64. https://doi.org/10.1007/s11423-018-9581-2.

MacLeod, Jason, Harrison Hao Yang, and Yinghui Shi. 2019. "Student-to-student Connectedness in Higher Education: A Systematic Literature Review." *Journal of Computing in Higher Education* 31: 426–48. https://doi.org/10.1007/s12528-019-09214-1.

Meta. n.d. "Richie's Plank Experience." https://www.meta.com/experiences/richies-plank-experience/1642239225880682.

Miguel-Alonso, I., David Checa, Henar Guillen-Sanz, and Andres Bustillo. 2024. "Evaluation of the novelty effect in immersive Virtual Reality learning experiences." Virtual Reality 28 (27): 1–23. https://doi.org/10.1007/s10055-023-00926-5.

Moore, K. Page, R. Craig Miller, and Sebastian Diaz. 2023. "Utilizing the Community of Inquiry Survey to Inform Student Satisfaction and Sense of Belonging in a Community College Environment." *Journal of Applied Research in the Community College* 30 (1): 91–108.

O'Connor, Eileen A. 2018. "Developing Community and Building Knowledge Online Using a Virtual Reality Environment and Student-Created Videos." *Journal of Educational Technology Systems* 46 (3): 343–62. https://doi.org/10.1177/0047239517736874.

Oculus Dreamdeck. [Meta Quest Software]. 2016. Meta Quest. https://www.meta.com/experiences/pcvr/oculus-dreamdeck/941682542593981/.

Philippe, Stéphanie, Alexis D. Souchet, Petros Lameras, Panagiotis Petridis, Julien Caporal, Gildas Coldeboeuf, and Hadrien Duzan. 2020. "Multimodal Teaching, Learning and Training in Virtual Reality: A Review and Case Study." *Virtual Reality & Intelligent Hardware* 2 (5): 421–42. https://doi.org/10.1016/j.vrih.2020.07.008.

Richie's Plank Experience. [Meta Quest Software]. 2019. Toast Interactive. https://toastinteractive.com/richiesplankexperience/.

Santilli, Tommaso, Silvia Ceccacci, Maura Mengoni, and Catia Giaconi. 2025. "Virtual Vs. Traditional Learning in Higher Education: A Systematic Review of Comparative Studies." *Computers & Education* 227: 105214. https://doi.org/10.1016/j.compedu.2024.105214.

Scavarelli, Anthony, Ali Arya, and Robert J. Teather. 2021. "Virtual Reality and Augmented Reality in Social Learning Spaces: A Literature Review." *Virtual Reality* 25: 257–77. https://doi.org/10.1007/s10055-020-00444-8.

Sitzmann, Traci. 2011. "A Meta-analytic Examination of the Instructional Effectiveness of Computer-based Simulation Games." *Personnel Psychology* 64 (2): 489–528. https://doi.org/10.1111/j.1744-6570.2011.01190.x.

Stenbom, Stefan, and Martha Cleveland-Innes. 2024. "Introduction to the Community of Inquiry Theoretical Framework." *In The Design of Digital Learning Environments: Online and Blended Applications of the Community of Inquiry*, edited by Martha F. Cleveland-Innes, Stefan Stenbom, and D. Randy Garrison. Routledge.

Turula, Anna. 2017. "Teaching Presence in Telecollaboration. Keeping an Open Mind." *System* 64: 21–33. https://doi.org/10.1016/j.system.2016.12.001.

Zheng, Runze, Tianlei Wang, Jiuwen Cao, Pierre-Paul Vidal, and Danping Wang. 2021. "Multi-modal Physiological Signals Based Fear of Heights Analysis in Virtual Reality Scenes." *Biomedical Signal Processing and Control* 70: 102988. https://doi.org/10.1016/j.bspc.2021.102988.

APPENDIX

Survey Instrument Characteristics for the CoI Framework from Community of Inquiry Survey Instrument (draft v14) (Arbaugh et al. 2007)

Social presence	
Area	**Outcomes as observed by instructor**
Affective expression	Participants' sense of belonging, ability to form distinct impressions of others and the perception of communication as conducive to social interaction.
Open communication	Participants' comfort and ease in engaging in discussions and interacting with other course participants.
Group cohesion	Participants felt comfortable expressing disagreement while maintaining trust, having their viewpoints acknowledged by others, and perceiving discussions as conducive to collaboration and teamwork.
Cognitive presence	
Area	**Outcomes as observed by instructor**
Triggering event	Participants' interest in course issues is heightened through encountering problems, engaging in course activities that pique curiosity, and feeling motivated to explore content-related questions.
Exploration	Participants demonstrate their engagement by utilizing diverse information sources to tackle course problems, resolving content-related questions through brainstorming and information gathering, and gaining insights from discussions to understand various perspectives effectively.
Integration	Participants develop their learning process by integrating new information to address course questions, constructing explanations and solutions through learning activities, and deepening their understanding of fundamental concepts through reflection on course content and discussions.
Resolution	Participants demonstrate their ability to apply and test the knowledge gained in the course by describing methods for application, developing practical solutions to course problems, and applying the acquired knowledge to real-world scenarios, including work or other non-class related activities.
Teaching presence	
Area	**Outcomes as observed by instructor**
Design and organization	Participants felt the instructor effectively communicated essential course topics and goals, provided clear instructions for participation in learning activities, and ensured clarity regarding important due dates and time frames for course activities.
Facilitation	Participants felt the instructor facilitated learning by identifying areas of agreement and disagreement on course topics, guiding the class toward understanding to enhance clarity of thought, and encouraging exploration of new concepts. Their actions also fostered a sense of community and engagement among course participants, reinforcing productive dialogue and learning.
Direct instruction	Participants felt the instructor focused the discussion on relevant issues, provided timely feedback, and helped the learner become aware of their strengths and weaknesses relative to course objectives.

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. "Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry." *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58


Copyright for the content of articles published in *Teaching & Learning Inquiry* resides with the authors, and copyright for the publication layout resides with the journal. These copyright holders have agreed that this article should be available on open access under a Creative Commons Attribution License 4.0 International (https://creativecommons.org/licenses/by-nc/4.0/). The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited, and to cite *Teaching & Learning Inquiry* as the original place of publication. Readers are free to share these materials—as long as appropriate credit is given, a link to the license is provided, and any changes are indicated.

Kannan, Jaya, Josef G. Trapani, and Kara T. McGillicuddy. 2026. “Immersive Learning Using Virtual Reality: Pedagogical Strategies for Building a Community of Inquiry.” *Teaching & Learning Inquiry* 14: 1–20. https://doi.org/10.20343/teachlearninqu.14.58