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Almost Like Being There: Embodiment, Social Presence, and Engagement Using Telepresence Robots in Blended Courses

Karen G. Hickenbottom
Seattle Pacific University

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Karen G. Hickenbottom

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Approved by David Wicks ______________________________

(David Wicks, EdD, Chairperson of the Dissertation Committee)

____

(Munyi Shea, PhD)

Robin Henrikson ______________________________

(Robin Henrikson, PhD)

Program Authorized to Offer Degree: School of Education

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(Nyaradzo Mvududu, EdD, Dean, School of Education)

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Signature:

Date: February 2022

Dedication Page

This is dedicated to all those who think the work is too hard or the goal is too lofty. You won't know until you try. And to my family and friends that believed I could do it.

Acknowledgement Page

There are so many people over the last few years to thank for putting up with my constant “working on my paper/homework/assignment” excuses. I have appreciated your belief in my ability to finish this.

Thanks to Dr. David Wicks, my committee chair, whose inquiry method helped me find my scholarly “voice” and helped me realized that I have strengths to contribute to the larger conversation about educational technology and digital literacy. I appreciate you sticking with me through the dissertation process and finding time for supporting and giving feedback on my writing. Thanks to my committee members Dr. Shea and Dr. Henrikson for your valuable feedback.

Thank you to all the friends that provided distraction when I needed it, and sometimes when I did not. Just having people in my life who think what I am doing is pretty cool makes it all worthwhile.

To my Dissertation Support Group members, Dr. Liz Ebersole, Dr. Sarah Zhou, and future doctors Shannon Thiessen and Christina Bistricean, I truly do not think I could have done it without having your support, empathy, and your willingness to listen to the frustrations as well as celebrate our successes. The world needs more lady doctors like you!

To my friend Beth Glaze, another future doctor, thanks for the support, friendship, cooking classes, and the wine. I hope as you are going through the program, I can do the same for you.

And lastly, thanks to my family who probably thought I was nuts but supported me anyway. Taylor and Jadon, you get to introduce me as Dr. Mom to someone at least once. If I've taught you anything about learning I hope that I've modeled that there are no limitations if you stay curious and ask questions. There are so many fascinating things to learn in the world and no new knowledge is wasted, even if it just makes you everyone's favorite on trivia night.

Preface Page

Several people have asked me why I went back to school at 50 to get a second master's degree in Digital Education Leadership and why I pursued my doctoral degree. They aren't necessarily surprised that I would choose to do it, but don't really understand what would motivate me when the cost of the degree will never be made up in the 10 years or so that I will likely be actively working full time in education before retirement. I've never had a good answer, but I figure I'd better be able to articulate one, at least to my sons since it's unlikely they'll be getting much of an inheritance from me now.

There are number of reasons why I have wanted to have the title Doctor:

1) I have always been a learner. I love learning new things. Making connections between new ideas and old ones, or new ideas and things I do in my job, gives me energy. I thrive on the possibilities, the wonder, and the challenge of learning something new. My interests are wide, which is why learning to make cheese, experiencing sky diving, making my own cider, or trying to teach myself Spanish is equally as fulfilling as learning about educational theory and telepresence robots. I hope I continue to learn new things until the end. It keeps me interested, invigorated, and alive.
2) The idea of getting to the "end" of education, earning a terminal degree, is like winning a game. I've gotten to the top. I've completed an educational task that was challenging, fulfilling, and meaningful to me. I may never be able to pay for it in my lifetime, but I did it for me, not for anyone else, and it was worth it.
3) I believe that I can contribute to the broader field of Digital Literacy Education. I am a futuristic big picture thinker and sometimes feel like I am a little ahead of

> my time, but all the things I learn get filed away in my brain and connect and fit to the myriad details in my work life that benefit from what I've learned. I hope to help people see how vital teaching our students to be creative, responsible, and digitally literate citizens is to our future.

Friends have also asked me if I'll ask people to call me Doctor. To that I say, "hell yes!" I worked hard for the title. Beyond that, I want to show girls and young women that it is possible to become a scholar. I'd like other "seasoned" friends and acquaintances to see that it's never too late to learn, whether it is just taking an interesting class or pursuing a degree. We have something to offer younger students with less perspective and less life and work experience. We can help bridge the gap between theoretical learning and daily practice and we can model what life-long learning looks like.

Dr. Karen Hickenbottom

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Abstract

As students' online learning opportunities continue to increase in higher education, students are choosing not to come back to campus in-person for a variety of personal, health, safety, and financial reasons. The growing use of video conferencing technology during the COVID-19 pandemic allowed classes to continue, but students reported a sense of disconnectedness and lack of engagement with their classes. Telepresence robots may be an alternative to video conferencing that can provide learning experiences closer to the in-person experience, which also provides a stronger sense of embodiment, social presence, and engagement in the classroom. This study explored the use of telepresence robots in four undergraduate, humanities, blended learning courses. Sixty-nine students, 43 in-person and 26 remote students, were surveyed using the Telepresence and Engagement Measurement Scale (TEMS) and provided written feedback about their experience. The TEMS measured embodiment, social presence, psychological involvement, and three indicators of engagement: behavioral, affective, and cognitive. Embodiment and social presence were positively correlated as were embodiment and behavioral engagement. There was no significant difference between the two groups' perceptions of social presence but there was a significant difference between groups' perceptions of engagement. Qualitative data and effect sizes greater than 0.80 supported the reliability and validity of the TEMS instrument as a measurement instrument for future study of blended learning environments using remote tools such as telepresence robots. Provided that technological issues such as connectivity and audio and video quality are addressed, telepresence robots can be a useful tool to help students feel more embodied and socially present in today's blended learning classrooms.

Keywords: telepresence, embodiment, social presence, engagement, blended learning

Chapter 1: Introduction

Problem Background

Before March 2020, when many educational institutions introduced emergency remote teaching during the pandemic, only 16.6% of university and college students attended exclusively through online distance education. Another 18.7% attended in some combination of online and in-person classes (COVID-19: Stay Informed, 2021). Online learning was not the preferred learning format for most students despite the growing prevalence of online learning options available (Bouchrika, 2020). However, the relatively quick and necessary pivot to distance learning during the beginning of the COVID-19 pandemic made online learning compulsory, rather than a choice, for many of the world's students. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) reported that at the height of school closures in June 2021, over 75.4% of the world's students were affected by either the move to online learning or the lack of access to education because of school closures (UNESCO, 2021). Although many universities quickly moved to video conferencing tools for class meetings and Learning Management Systems (LMS) for homework, student access to these tools was largely dependent on the availability of reliable personal devices and broadband internet connections, which were not equitably available (McDonald, 2020; Vogels et al., 2020).

It remains to be seen if the growth of online learning will continue its upward trend post pandemic, but students pushed back about returning to campus in the short term either based on health concerns (Elfalan, 2021), refusal to wear masks or comply with vaccine requirements (Nadworthy, 2021), or general anxiety (FutureEd, 2021). In some cases, they demanded that colleges and universities continue to offer them the option of attending remotely (Elfalan, 2021). Despite the efforts of universities to offer enticements like free laptops, tuition incentives, and signing bonuses (Weissman, 2021) to attract students to attend in person, some students made long-term choices to move home for emotional and financial support, to find work, or to help take care of family members, and chose not to return to campus (Jones et al., 2021). Some students and parents found the quality of online classes to be less than satisfactory as underprepared institutions and faculty had to move quickly to a digital format (Friesen, 2021). These students did not feel they received the same college experience for their tuition dollars (N. Anderson, 2020). Regardless of whether the pandemic lingers on for years or disappears as quickly as it came, it has set in motion changes in higher education, such as the rapid adoption of new online learning strategies, the implementation and advancement of technology skills by faculty, and a shift in thinking about the value and rigor of online learning (Nworie, 2021) that will hopefully carry forward.

If higher education institutions choose to respond to the potential growth and demand for online learning by increasing their offerings, it becomes important to evaluate the various configurations, methods, and tools used to provide students with effective and successful online learning experiences that meet both the intellectual and social needs of students. Communication technologies such as video conferencing and LMS tools were useful during the emergency remote learning situation, and they mitigated some of the disruptions to the academic and social lives of students. However, online learning encompasses a vast array of options and they all come with advantages and disadvantages worth considering.

One emerging technology to consider is telepresence robots. Telepresence robots allow a user to feel present, or embodied, in a space where they are not physically present (Bell et al., 2014). Telepresence robots provide communication and remote representation conduits for human operators (Cha et al., 2017) and are worth considering as a potential tool for hybrid teaching as the robots allow remote students to participate in class with their in-person peers. This form of presence allows students the autonomy to move around the room, turn to face a speaker, have one-on-one conversations with a classmate or the instructor, and see the screen as if they were sitting in the room (Cain et al., 2016). Participating as a robot provides students with agency and an ability to be present in a classroom in a way that more closely aligns with being present in person as well as allowing for social interaction with peers more naturally. For remote students, feeling a sense of telepresence or embodiment may increase their sense of social presence and engagement within the course (Biocca et al., 2001). Instructors benefit as well by having all of their students "physically" present in front of them rather than having to attend to remote students on the presentation screen behind them (Bell et al., 2016).

Definitions

Several terms related to online learning and modes of attendance will be clearly defined during the introduction. Other terms related to embodiment, social presence, and engagement will be defined as a part of the literature review.

Video conferencing allows multiple remote participants to sign into a virtual space to communicate through video and audio. In this study, Zoom was the video conferencing tool provider for the university. The terms Zoom and video conferencing are used interchangeably throughout the study.

Synchronous learning occurs when the instructor and students are online simultaneously, and instruction is delivered directly to the students using chat or video conferencing (Taverna et al., 2015). Synchronous learning has been found to create higher levels of motivation and positive peer relationships (Roseth et al., 2013), as well as a sense of community, when it is used to promote collaborative learning (Perveen, 2016). However, some participant flexibility is lost when meeting at specific times. Synchronous learning is inequitable for students and instructors who do not have broadband internet connections or a quiet space to participate in class (Flaherty, 2020). Asynchronous learning occurs when course instruction is delivered through recorded lectures, posted resources, and interactive discussions. Students primarily work through the content independently and can move through the content with greater time flexibility because live interaction with the instructors or classmates is not required (Kurt, 2018).

Online learning has evolved in response to advancements in communications technology, beginning with distance learning, moving to e-learning, and now to online learning (R. Garrison, 2011). Although earlier versions of e-learning only allowed communication between students through discussion boards, the more recent iteration of online learning, which takes advantage of current video conferencing technology, allows students to interact both synchronously and asynchronously with the instructor, content, and other students. The addition of visual and nonverbal cues made possible by video allows students to feel more present in the online classroom both physically and socially (R. Garrison, 2011).

Today’s blended learning environments, which are also called hybrid or synchronous-hybrid, are defined as consisting of in-person and remote students receiving the same live instruction synchronously (Bower et al., 2015; Gleason & Greenhow, 2017; Hrastinski, 2019; Kurt, 2018; Olt, 2018; Szeto & Cheng, 2016; Wang et al., 2017; Zydney et al., 2019). The remote students may participate by video conference or telepresence robot, but synchronous instruction and asynchronous work are essentially the same for both groups. Blended learning environments provide both the flexibility of asynchronous learning that can be completed independently and the capacity for building community that synchronous environments offer (King & Arnold, 2012; Malik et al., 2017). LMS tools often serve as the hub of asynchronous learning environments where resources, readings, assignments, and text-based discussions are housed. Increasingly, LMS tools are also the connection point for synchronous learning in the form of links to Zoom meetings. These synchronous meetings can also be recorded for later viewing, making them available to students who could not attend a particular class meeting.

An alternative blended model provides lectures to in-person students that are concurrently live-streamed to a largely passive remote audience through Zoom. These lectures may be recorded and watched asynchronously by a third group of students. While this model provides flexibility, one study found it left students feeling disconnected from other students and faculty, and not all faculty were enthusiastic about using that method (Rossouw, 2018). This type of hybrid learning seems to have more in common with asynchronously posted lectures as it does not allow for the interactivity of other types of blended synchronous models. One additional model related to blended learning is called HyFlex and combines both synchronous and asynchronous paths for the same course. Students choose to attend the course in-person, fully remote, or some combination of both (Wright, 2016). These configurations have advantages and disadvantages for students and faculty regarding flexibility, access to resources, face-to-face interaction, access to faculty, and quality of the learning experience (Raes et al., 2020). Each configuration may require multiple iterations to develop the right balance and create a quality online learning experience (Binkley, 2020).

The model used for this study was a blended model which consisted of weekly asynchronous work with scheduled synchronous meetings that included the opportunity for students to interact verbally or nonverbally with each other and their instructor. Blended models such as these seem to come closest to providing both in-person and remote students with the most similar learning experience. It also allows one professor to teach two sections concurrently to avoid the added workload of teaching two similar sections at separate times. But even this method can come with challenges.

Combining video conferencing and in-person participants can be challenging for faculty who must manage both groups of learners simultaneously or who may need to redesign courses to address the needs of both (King & Arnold, 2012). The video conferencing students can feel disconnected from the in-person students (Flaherty, 2020). Audio or video configurations may make it difficult for students to hear and see the in-person students. Online students' faces may be out of the direct line of sight of the instructor. Room design and placement of cameras and microphones become critical to the success of a synchronous-hybrid course (Bell et al., 2016). Technical challenges around internet bandwidth, both at the school and in a student's home, still pose challenges to equitable access (Nworie, 2021). Hands-on labs, active group projects, and other activities that require high interaction are challenging to replicate in an online environment. Alternative activities or technologies may need to be developed for online and remote students to have similar experiences as their in-person peers (Chatterjee, 2020). Technologies like video conferencing and telepresence robots can provide remote students with a more natural experience of feeling physically and socially present as part of a learning community, but they can come with challenges for learners and faculty that in-person instruction does not. The technical challenges of connection, quality video and audio, and juggling multiple modes of attendance alone can be daunting factors in attending or teaching blended courses.

Online Learning

The various combinations of asynchronous and synchronous learning with in-person and remote learners are primarily organizational considerations when developing the best learning environment for students. However, it is also important to consider how students learn online. Online learning has evolved as the technology for learning has evolved, mainly based on the changes being brought about by video conferencing and virtual reality (Lombard et al., 2015). Although there is still no unifying definition of online learning theory (T. Anderson, 2011; Picciano, 2017), the most widely cited theories have three distinguishing features in common: the content, the teacher, and the learner. Three types of interaction between these three features of online learning were first defined by Moore (1989). He described these interactions as Learner-Teacher, Learner-Content, and Learner-Learner. In today’s blended learning models, these interactions still apply although the mode of interaction can now occur in video and audio-rich environments that were not possible in the late 1980s. Moore’s (1989) work was followed by the development of the Community of Inquiry Framework by Garrison et al. (2000), which suggested that the educational “transaction” in computer-mediated instruction includes the interaction of three components: cognitive presence, social presence, and teaching presence (Garrison et al., 2000). Learning is a primary goal of the higher education experience, and cognitive presence involves the ability for students to collaboratively construct new meaning for themselves as part of a community of learners (D. R. Garrison et al., 2001). Social presence, or the ability for a student to project their personality and individualism to the group in a way that makes them real to others in the online environment, is important as a supporting mechanism for the cognitive work being done by the learner. A social experience with other learners may lead to more enjoyable learning and contribute to more successful cognitive outcomes. Teaching presence includes the design, facilitation, and instruction of an online learning environment that successfully enhances the social and cognitive presence that leads to positive educational outcomes (R. Garrison et al., 2000).

It could be argued that models such as these are just models of good teaching practice, regardless of their delivery method, and that theories of online learning are just enhancements to the best practices of learning (Mayes & De Freitas, 2004). The value that technology brings to online learning is not that it can recreate the in-person learning experience but that it can offer opportunities for teaching and learning in different ways. If technology is only used to help remote learners learn in a similar fashion as their in-person peers then we may not be offering a new way of teaching but rather using a tool to enhance our current teaching methods (Mayes & De Freitas, 2004). The use of technologies, such as video conferencing and telepresence robots, may offer practical solutions to providing blended learning environments to students. Both come close to offering the same learning experience to both in-person and remote students but may not substantially change the ways students are taught.

Research on successful online students has identified strong independent learning skills and self-direction (Kerr et al., 2006), motivation (Kim & Frick, 2011), and executive functioning skills (Dabbagh, 2007) as keys to their success. The flexibility and convenience of online learning options can be especially attractive to busy working students (Lorenzo, 2012). Other factors such as the quality of engagement from the online instructor (Sun et al., 2008), the student’s peer-group interactions and social involvement (Tinto, 1998), and the student’s sense of social and cognitive presence (R. Garrison et al., 2000) are factors in the student’s success in online courses. Garrison et al. (2000) also suggested that the increased use of online networks and communication tools has shifted online learning toward more collaborative and interactive modes of learning, which required students to be more socially present as they learn together online.

However, online learning participants have reported feelings of social isolation, which negatively affects their well-being and how they function in the online environment (Hortulanus et al., 2006). Social isolation has been described as a lack of meaningful social contacts and is a factor in the attrition of college students (Ali & Smith, 2015). Technology allows quick and efficient communication in online learning environments, but it has also resulted in students completing degrees with little interaction with faculty or other students (Ali & Smith, 2015). One contributing factor to social isolation is a lack of direct contact (Priego & Peralta, 2013). Although video conferencing does provide some social interaction it can sometimes feel awkward as the students cannot rely on the usual verbal and nonverbal cues of other students to know when they can take a turn to talk, ask a question, or contribute an idea (Nicandro et al., 2020). Video conferencing students, for assorted reasons, often choose to turn off their cameras during synchronous learning. One reason posited for this has been “Zoom fatigue” which may partly be caused by increased screen time during the pandemic. This fatigue feeling may come from the mental energy necessary to interpret meaning when there is a lack of body language and of other nonverbal cues in a video conferencing discussion (J. Lee, 2020; Nicandro et al., 2020). The choice to turn off cameras is also related to students’ self-consciousness about themselves and their living environments (Nicandro et al., 2020). Students may choose to participate via chat or other ways, but they may be stepping back from having a strong social presence by not letting the group see their faces on the screen. Faculty may perceive these turned-off cameras as a lack of engagement by students (K. Lee, 2020).

Engagement has been studied at many different levels, from the institutional to the course or activity level (Skinner & Pitzer, 2012), and has several definitions. Studies of computer-mediated engagement, however, have often focused on the combinations of three subcomponents because they are easily observed and measured: behavioral engagement (observable behaviors of how one participates with others in the learning environment), emotional engagement (reactions to others and willingness to do the work), and cognitive engagement (investment and effort in learning) (Fredricks et al., 2004). These categories of engagement will be used with the current study as they have been used in previous research closely tied to the social presence theories central to this study.

Problem Statement

Telepresence robot use in higher education has been relatively sparse and is in the early stages of research. Recent studies have focused on the physical and technical aspects of telepresence robots (Cha et al., 2017; Gallon et al., 2019; Liao & Lu, 2018; Ahumada-Newhart & Olson 2019; Tanaka et al., 2014). Research focused on the students, such as their sense of embodiment, social presence, and engagement and how the three are connected, are of more interest to the current study (Bamoallem et al., 2014; Bell et al., 2016; Cain et al., 2016; Fitter et al., 2020; Gleason & Greenhow, 2017; Jaber & Kennedy, 2017; Lei et al., 2019).

Higher education institutions may look at telepresence robots as a viable option for students to attend courses remotely, but it will be important to determine if the robots can help remote students feel more socially connected to their classmates and instructors as well as more engaged in learning. Exploring ways in which the remote experience can more closely replicate the in-person experience may be one way to improve the remote students' connectedness and engagement.

The purpose of this study was to examine students' perceptions of their embodiment, engagement, and social presence in a blended course that included in-person students and students attending as telepresence robots. All students participated live in the same classroom and received the same instruction (Wang et al., 2017). In this research study, both in-person and telepresence robot students were surveyed to examine how their perceptions of social presence and engagement differed, and how they thought the opposite group perceived them. Telepresence robot students were also studied for what part embodiment played in their perceptions of social presence and engagement.

Undergraduates have been underrepresented in previous studies of telepresence robots, which have primarily included graduate or doctoral students. Samples sizes for previous studies involving telepresence robots have included 17 students or less (Cain et al., 2016; Fitter et al., 2020; Gleason & Greenhow, 2017; Lei et al., 2019). The current study included both in-person and telepresence robot students in undergraduate humanities courses and yielded a larger sample size (82 participants) with a broader mix of student perspectives. Participants included first through fourth-year students with a wide range of experience with online learning.

Research Questions

The focus of this study was to measure undergraduate in-person and telepresence robot students' feelings of embodiment (a sense of being physically present in the room), social presence (a sense of being present with others) and engagement (ability to interact with others and the content) in a blended learning environment to explore whether telepresence robots provided similar experiences to attending in-person. The following questions were the focus of this study:

1. Is there a relationship between the telepresence robot students' sense of embodiment and their perception of social presence?
2. Is there a relationship between the telepresence robot students' sense of embodiment and their perception of engagement?
3. Is there a difference in the sense of social presence reported by the in-person students and the students attending by telepresence robot?
4. Is there a difference in the sense of engagement reported by the in-person students and the students attending by telepresence robot?

5. What are the instructors' experiences with telepresence robots?

Summary

At the time of writing, some students were choosing not to return to in-person learning at colleges and universities during the COVID-19 pandemic for a variety of personal, financial, and health reasons. It may be incumbent on colleges and universities, who want to retain students, to adapt to student needs by continuing to offer, or expand, online offerings. Blended learning, where in-person and remote students attend the same instruction synchronously and receive additional asynchronous independent work, holds some promise as a model to meet the needs of in-person and remote students and reduce the need for faculty to teach separate courses for the two groups.

Video conferencing has been helpful during this period of remote teaching, but some students are still challenged by a lack of social connection and are becoming disengaged in the learning. Telepresence robots may provide an alternative to video conferencing that offers students a stronger sense of presence in the physical classrooms. That sense of embodiment may provide the supports needed to develop a sense of social presence in the community of learners and help students stay engaged with the learning. This study will examine the embodiment, social presence, and engagement experiences of both telepresence robot learners and in-person learners in a blended learning environment, to explore the robots' ability to provide a similar experience for remote learners to that of their in-person peers.

Chapter 2: Literature Review

Introduction

The concept of telepresence was first described by Marvin Minsky (1980) as the use of robots whose feedback systems could make the operator feel that the machine and their hands were one and the same. He referred to the experience of interacting with a physical object located in a remote environment that reacted to the user in such a way that it felt like an extension of their body (K. M. Lee, 2004). Further research and the development of much more sophisticated tools and virtual environments have led to additional characteristics of telepresence that are important to understand in any study using telepresence robots. The literature review will touch on the three areas of presence needed for a person to experience a virtual environment fully: telepresence (also referred to as spatial or physical presence), self-presence (embodiment or co-presence), and social presence (Ijsselsteijn & Riva, 2003; K. M. Lee, 2004; Oh et al., 2018). A strong sense of presence in a virtual body that is interacting socially with others contributes to a higher sense of behavioral engagement with cognitive tasks (Biocca, 1997). Although online learning theories such as Moore’s Interaction Types (Moore, 1989) and the Community of Inquiry Framework (R. Garrison et al., 2000) also include cognitive and teaching interactions or presences, they are not as directly related to the use and experience of the telepresence robot user. The focus of this study was to look more closely at the concepts of telepresence (as related to physical and social presence) and engagement in the context of blended learning environments in higher education. In addition, faculty who organize and create collaborative online learning environments are also affected by the challenges of teaching online and in hybrid formats. The potential use of telepresence robots would need to serve the needs of faculty as well as students.

Telepresence/Spatial Presence

A person's sense of physical presence in the world is a complex combination of multisensory data and cognitive processes and it is not something one regularly questions (Ijsselsteijn & Riva, 2003). A human consciousness defaults to the sense of "being there" based on sensations of the physical environment they are standing in (Biocca, 1997). Since 1980, when the concept of telepresence was first defined, the increasing sophistication of technology has allowed users to become immersed in virtual environments to the point they almost forget they are not physically in that world (Biocca, 1997; Haans & Ijsselsteijn, 2012; Hartmann et al., 2015; K. M. Lee, 2004; Oh et al., 2018). This sense of environmental presence is enhanced by the "extent to which the environment itself appears to know your existence and react to you" (K. M. Lee, 2004, p. 44). When the user can feel and influence objects and people in their environment, whether virtual or real, the more solidly they feel present in that environment (Haans & Ijsselsteijn, 2012).

The concept of presence is central to the user's experience with computer- or technology-mediated environments (K.M. Lee, 2004). It is determined by the amount of sensory information available to the participant, their level of control, and their ability to modify their environment (Sheridan, 1992). The medium's ability to provide interactivity and vividness can determine the robustness of the telepresence experience. Interactivity is the extent to which the user can alter the sensory input or make modifications to the virtual world. Vividness refers to the depth of detail as well as the number of senses engaged (Steuer, 1992). Hartman et al. (2015) suggest that interactivity partly depends on the ability of the technology to map itself into natural pathways of sensory stimulation in the mind in real-time. For example, video conferencing offers users visual and auditory vividness to the extent of the quality of the equipment and the internet bandwidth, which allows users to interact with others. Telepresence robots offer similar visual and auditory stimuli but add the perceived kinesthetic control of the virtual robotic body. Users can control which direction they look and hear from and where they are situated in the room, and they can mimic some human movement like turning toward a speaker or "nodding" a virtual head in agreement (Bell et al., 2016). The vividness of the user's auditory and visual stimuli is still dependent on equipment quality and internet bandwidth. Newer interactive qualities such as haptic feedback, depth cues, and enhanced audio quality have shown positive relationships to users' sense of social presence because of the saturation of the sensory input (Oh et al., 2018). Telepresence can be considered a measure of the quality of the immersion in the virtual experience. The more vivid the telepresence experience, the more immersed the user feels in the virtual environment (Haans & Ijsselsteijn, 2012). Biocca (1997) suggests that "telepresence is about the telecommunication of the body" (p. 18) into the remote or virtual space through the transmission of sensory and motor data, which he calls the sense of "being there."

Self-Presence/Embodiment

Part of the development of a sense of telepresence is the ability for the human to incorporate mental models into their experience in the mediated environment. Human perceptions of the world are embodied through the patterns of energy that the body senses (Biocca, 1997). Those patterns are translated into three different levels of embodiment:

body schema, body morphology, and body image (Haans & Ijsselsteijn, 2012). Body schema helps the mind keep track of the body in time and space as well as the environment around the body. Body morphology refers to beliefs about capacity and limits of the virtual body. Robots would be perceived to have capabilities and limits based on how they are built and what parts they have. You would not expect a robot to be able to pick things up without having some sort of hand. Body image is the perception of the robotic body or avatar which includes how a person experiences the body and sees themselves as part of that body. For example, in one study, robot users reported worrying about how they were perceived by the live students in the room, or about moving the robot, because they did not know if the robot was making noise when it moved and they did not want to disrupt others (Bell et al., 2016). A person's actions are closely related to their construction of meaning and perceptions of the world (Hartmann et al., 2015). As their sense of self-presence increases, their level of cognitive performance increases (Biocca, 1997).

The mental models of embodiment allow the user to self-identify with the whole or part of the robot, which is a representation of their body (K. M. Lee, 2004). As the sensory feedback from the robot or virtual environment comes closer to naturally mimicking feedback from the real environment, the more closely the user identifies with the representation of their body and the more they feel a stronger sense of self-presence (Biocca, 1997; Hartmann et al., 2015). Telepresence involves not just the sense of being in the body of the robot but may also entail a sense of ownership over the virtual body parts of the robot (Haans & Ijsselsteijn, 2012).

Behavioral realism, or the extent to which the action of the robot body mimics real human behaviors in real-time, is a predictor of social presence, especially if the user perceives the presence of another human intelligence in their virtual space (Oh et al., 2018). Users may begin to act in an egocentric reference frame in which they react to others as if they were present in the robotic body, which increases social presence (Hartmann et al., 2015; K. M. Lee, 2004). The robots provide a first-person viewpoint in which the users perceive others as separate from themselves. The robots have agency to move toward or away from others and interact as if they were in the room. Video conferencing does not provide users the same sense of agency to control one's "body" within a virtual environment. A sense of embodiment, determined by one's spatial or physical presence, does not exist alone. As social beings, the most common purpose of physical presence is to increase the sense of social presence (Biocca et al., 2001).

Social Presence Theory

Early social presence theory was defined as the degree to which one is perceived as "real" in a computer-mediated environment, and the realness of the interpersonal relationships in that environment (Short et al., 1976). Much of Short, Williams, and Christie's (1976) social presence work focused on the capacity for the technology to transmit nonverbal cues that were related to communication and relationship building. If visual channels were taken away, such as in early audio-only conference calls, they found it disturbed the affective interactions between participants. As nonverbal cues were removed in interactions, it changed conversational behavior (more pauses and interruptions), affected interpersonal attitudes, and reduced the feedback cues of personal communication. The outcome of their research was the concept that the media itself defined the strength of the perception of social presence. The quality or strength of social presence did not influence the task; instead, users would choose the media based on the amount of social presence needed to complete the task (Short et al., 1976). Tasks like information sharing, which required very little interaction from participants, could be done efficiently in writing, but tasks that required strong personal interaction, such as negotiating, would be better served by video communication. A mismatch between task and social presence could cause the user to feel uncomfortable. For example, matching an impersonal or less social technology (i.e. discussion boards) with an interactive task that required relationship building (group work) might cause the user to feel a sense of disconnectedness. Social presence contributes to the intimacy of the relationships which includes trust, acceptance by others, and the ability to risk (R. Garrison, 2011; Short et al., 1976), and immediacy defines the social distance, from casual to formal, that one puts between themselves and others depending on the circumstances (Short et al., 1976). Often these two factors are seen in verbal and nonverbal cues that include gestures, expressions, and tone of voice (Gunawardena & Zittle, 1997). Oh et al. (2018) suggested that in much of the current research, users' sense of social presence is higher when some form of visual representation is available.

As communications technology entered the education field, social presence theory shifted away from the media and task to the user's perceptions of the media. Gunawardena (1995) began to notice students in text-based online communities developing friendships and creating recognizable impressions of their personalities within the group through written messages that included verbal or textual cues. There was a perception of them being “real” to others in the community (Biocca et al., 2003;

Gunawardena, 1995). Constructivism was beginning to influence online learning design at this time. Social constructivism (Vygotsky, 1978) especially highlighted the importance of social interaction as part of the development of the mental models created as learning occurs. Social presence then becomes an important part of learning collaboratively and building knowledge (Gunawardena, 1995). Students organically began to create communities without the benefit of nonverbal cues, but the conditions for developing community were still influenced by the instructor's ability to create the climate for social presence to develop (Gunawardena, 1995).

Although social presence can be looked at solely as the feeling of being present with others, it cannot be experienced alone and requires interaction with other intelligences, whether real or virtual (Biocca, 1997; R. Garrison, 2011; K. M. Lee, 2004; Oh et al., 2018). It is the sense of being together with others, or co-presence, that has become even more immersive with technology such as telepresence, virtual reality, and gaming (Oh et al., 2018). Biocca et al. (2003) suggested that co-presence relies on a certain level of physical or sensory awareness of others. However, a physical sense of another person is not enough to feel a strong sense of social presence. What is needed is also a sense of psychological involvement, the sense that there is another mind that can be interacted with (Biocca et al., 2003). A strong social presence is a highly sought-after attribute for hardware and software developers who want the user's experience to be as real and natural as possible. It is also a desirable state in the classroom. If a person successfully enculturates themselves into a remote learning experience, they increase their social presence and their chances of participating in the group (Gunawardena, 1995).

Visual representation of others has been found to be an important quality for higher reported measures of social presence. Speaking with a real person, or an avatar of a person, increases social presence, especially if the person or avatar shows an awareness or responsiveness to one's presence. Interactivity is also positively associated with social presence (Oh et al., 2018). Social presence is a subjective experience that is influenced not only by the technological medium but also by the physical and psychological distance between those interacting in the medium. An important trait that influences social presence is the presence of social cues in groups. Participants reported a higher sense of social presence when communicating with multiple remote partners by telepresence robot than with a single partner (Choi & Kwak, 2017), which may be related to the sense of being part of a community or social group.

Finally, social presence is an important part of establishing a collaborative community in which learning can happen through discourse, contribution of ideas, and critical thinking (R. Garrison, 2011). The development of social presence contributes to the trust and respect building necessary for discourse in a community of learners in a constructivist online environment. Garrison (2011) refined the definition of social presence as "the ability of participants to identify with the group or course of study, communicate purposefully in a trusting environment, and develop personal and affective relationships progressively by way of projecting their individual personalities" (p. 34). The reflection of personalities can happen in text-based environments, but the sense of being present with others is enhanced by the students' feelings of presence in the remote environment (Biocca, 1997).

Measurement of social presence has proved challenging and is generally done either from an objective or subjective perspective (Cui, 2013; Slater, 2002). Objective studies generally measure behavioral or observable responses such as responses to others and physiological reactions (Bamoallem et al., 2014). Subjective measures have been used more widely. Short, Williams, and Christie’s (1976) seven-point bipolar scale of adjectives measured the strength of social presence based on the strength of personal, sensitive, warm, and social features. Gunawardena and Zittle (1997) modified that scale down to a 17 item five-point bipolar scale which was used widely in social presence research but was not specifically built for general students (Cui, 2013). In the development of the Networked Minds measure of social presence, Biocca et al. (2001) developed an item bank to measure co-presence, psychological involvement, and behavioral engagement, which they believed were key dimensions of social presence. This measure was one of the first to include not only the user’s feelings but their perception of other participants’ feelings. Co-presence could be seen as a continuum of the degree of sensory, or embodied, awareness of another. It is not an either-or measure as every situation may result in different levels of the presence of others (Biocca et al., 2003). The sense of co-presence involves not only sensing the presence of another but also the sense that the person has a mutual sense of awareness of the user. In turn, this sense of another intelligence includes a certain level of psychological involvement on the part of the users who attach certain mental models to the other intelligence. Users’ sense of social presence can be higher when they are in a context that includes social cues indicating that they are in a social context, such as a discussion or group (Oh et al., 2018). There have been some indications that users who value social interaction or who are more oriented toward other people experience higher levels of social presence (Oh et al., 2018; Short et al., 1976). Biocca et al. (2003) also suggest that all social interaction includes levels of behavioral engagement which manifest in actions that are interactive and reactive to others. In the Networked Minds model, higher levels of social presence include indicators of behavioral engagement (Biocca et al., 2001).

Social presence in this study will be measured based on a combination of the users' perception of social presence (how present they feel with others in the group) and psychological involvement (how involved they feel with group members as other intelligent beings).

Engagement

Engagement has been considered a predictor for student achievement and success in education, but there have been varied ways researchers have approached measuring the concept (Fredricks et al., 2004; Redmond et al., 2018). It has become a general term used to refer to a variety of behaviors related to learning and engagement and can sometimes be used as a noun instead of a verb in that it becomes a task to complete or a battle to fight, as opposed to being an active, positive experience with new learning in the company of other engaged learners (Krause, 2005). The difficulty lies in the complex variety of definitions and measurements used to determine engagement. Engagement as a concept can include time spent, effort, persistence, attendance, performance, and even interpersonal engagement (Henrie et al., 2015; Krause, 2005; Pittaway, 2012). It can also focus on types of social institutions, involvement in school, and larger institutions (Skinner & Pitzer, 2012). Another form of engagement involves access by underserved populations to resources, social groups, and support in the efforts to increase equity (Krause, 2005).

Krause (2005) suggests that engagement goes hand in hand with disengagement, although she prefers the term “inertia” when referring to undergraduate students who do not take advantage of opportunities to engage with courses, peers, and instructors. This may in part be caused by lack of self-motivation or executive function skills on the part of the student or perhaps by lack of good course design and instructor facilitation, but regardless, it contributes to the dropout and success rates of students in higher education institutions (Krause, 2005). Research on the Community of Inquiry framework (R. Garrison et al., 2000), used as a model for online learning, found that online students engaged in less interactive ways but had higher levels of convergent thinking, while face-to-face interactions resulted in more divergent thinking. This seems to argue the need for instructors to incorporate opportunities for both types of learning in their online courses. Instructors play an important role in designing engaging learning environments of the type that is defined as an investment of time, energy, and attention, with peers and with the cognitive tasks of learning (R. Garrison et al., 2000).

One meta-analysis of engagement found that few researchers had actually committed to creating a definition of engagement (Henrie et al., 2015). This meta-analysis focused on engagement in online learning and found a wide variety of methods, measures, instruments, and outcomes related to engagement in online learning. Most studies used surveys as the most efficient method of collecting quantitative data but suggested that certain frequency and log data, as well as qualitative observations, were useful in exploratory studies (Henrie et al., 2015).

Many measures of engagement rely on observation of behaviors or require a setting where students have agency to make physical choices with their bodies, like raising hands (Henrie et al., 2015; Lei et al., 2019), and measuring the same types of engagement in computer-mediated environments is more challenging. Video tools have made observing engagement in online learners a possibility, but not all students choose to engage by video even when it is available (Castelli & Sarvary, 2021).

One focus of this study is to explore relationships between embodiment and engagement and differences between measures of engagement between in-person and telepresence robot users. The engagement definitions that best fit the needs of the study are the ones that have been operationalized into three main categories: behavioral, cognitive, and emotional (affective) (Fredricks et al., 2004). Behavioral engagement measures engagement based on what students do in class, such as hand raising, attentiveness, completing assignments, and the number, quality, or frequency of completed tasks. Cognitive behavior, or what students think about, is measured by the quality of students' analysis of content, elaboration, explanation of concepts, focus, or use of higher levels of Bloom's Taxonomy (Bloom, et al., 1956). Emotional or affective engagement, which is what students feel in class, encompasses measures of boredom, anxiety, collaboration, enthusiasm, and fun (Bell et al., 2017; Henrie et al., 2015). Engagement, especially in online learning, has also focused on the interaction of the learner with instructors, peers, and the learning content using digital technology (Bell et al., 2017; Cain et al., 2016; Fredricks et al., 2004; Henrie et al., 2015).

Online Learning and Telepresence

The final category of research is explicitly focused on the sense of these different presences related to online learning, whether through computer-mediated interaction, synchronous-hybrid, or blended courses, or the use of video conferencing and telepresence robots (Henriksen et al., 2014; Lei et al., 2019). Some courses in recent studies involve combinations of face-to-face students and video conference students, with the addition of telepresence robots in some cases (Fitter et al., 2020). Recent studies (Cain et al., 2016; Fitter et al., 2020; Lei et al., 2019) found that students prefer in-person attendance over both video conferencing and robotic attendance although they did prefer robotic participation over video conferencing. Students felt a statistically significant and higher sense of social presence and engagement as robotic participants than as video conference attendees. These studies, however, were done with small sample sizes (11, 18, and seven respectively), and the participants were graduate students in engineering/technical programs or doctoral technology education programs. A review of the literature did not result in any telepresence robot studies done with undergraduates or with students who may not have strong initial levels of experience with technology.

The Telepresence and Engagement Measurement Scale (TEMS) was developed and used in a mixed methods study of graduate students (Bell et al., 2017). The course had two “live” students who did not participate in the study, and of the 10 other students who attended as robots or on stationary video conference stands, only seven participated in the survey. This is not an ideal mix of students and robots to test social presence in a synchronous-hybrid course as they were not able to include the perspectives of the in-person students.

The ratio of in-person students to telepresence robot students has often been determined by the capacity of the network in the building (Bell et al., 2016). Telepresence robots use three times the bandwidth of a group video conference call (A. Chau, personal communication, April 29, 2021). Wi-Fi usage of in-person students on phones or laptops during the course also needs to be considered. It will be important to understand both the in-person and telepresence students' perspectives about how socially present and engaged they both feel with each other. That sense of being present with others should be experienced by in-person and remote students if telepresence robots can be considered viable methods for remote class attendance after the pandemic.

Searching for studies related to telepresence robots and the measurement of social presence and engagement in higher education in large databases such as Academic Search Complete and Research Library Complete yielded very few useful results. Instead, similar terms were used in Google Scholar. The term telepresence robot was initially combined with social presence, engagement, and various forms of higher education, such as college, university, etc. Tools like video conferencing fall under a broader category called computer-mediated communication (Georgakopoulou, 2011). Other names for telepresence robots included robot-mediated communication (Gleason & Greenhow, 2017) and mobile robotic telepresence systems (Kristoffersson et al., 2013; Lei et al., 2019). Using these terms widened the search to other studies.

Telepresence robots themselves have been used and studied in both health (Shaw et al., 2018) and business fields (M. K. Lee & Takayama, 2011; Standaert et al., 2013), but in education, robots have been expensive enough that their use has often been limited to one robot per class (Newhart & Olson, 2017). These have most often been used for students who, for medical reasons, were not able to attend classes (Cheung et al., 2018; Melendez, 2017; Newhart & Olson, 2017; Newhart, 2018). Additionally, telepresence robots have been used in education with English Language Learners to connect small groups of students to one telepresence robot instructor (Liao et al., 2018; Tanaka et al., 2014).

Several pilot studies have been done using telepresence robots in higher education settings, which focused on usability and feasibility for use with remote students. These included studies on the credibility of a teacher teaching remotely (Edwards et al., 2016), communication quality (Cha et al., 2017), how schools manage robots (Newhart & Olson, 2017), the effect of the appearance of robots (Fitter et al., 2018) and tested various types of robots for use with special populations (Reis et al., 2019). In some cases, articles were based on feasibility reports from pilot studies which involved one or two robots. They were focused on the user experience and attractiveness of attending class by robot (Dimitoglou, 2019). However, more recent research has shifted focus to the students' experience and how the robot can help them feel more present in the classroom, enabling them to be socially present with their peers and therefore more engaged with the learning environment.

Literature Selection and Review Methodology of Recent Studies

The search for studies in the literature was limited to those that measured both social presence and engagement using telepresence robots in hybrid or blended courses that occurred in the last five years. Studies prior to that time were focused more on technical aspects of the robots. Synchronous-hybrid courses included in-person and remote students simultaneously which met concurrently with the professor at predetermined class times (Wang et al., 2017). Four studies combined either quantitative or qualitative measures of social presence and engagement and used telepresence robots, and they are discussed in chronological order below.

Bell et al. (2016) studied online learning experiences by comparing the same courses taught in two different modes: in-person, and remotely taught in a newly created online program. Their initial efforts led them to feel that the classes were similar but not equal to each other (Bell et al., 2016). Still, they wanted to create an experience for the remote students that more closely replicated the in-person experience. They did not have the staff or resources to teach two separate classes for one subject, so they combined them into a single course. However, when in-person and remote students learned together, the remote students indicated they did not feel that they were part of the course but felt secondary to what was happening in the live class. This led the researchers to experiment with various configurations of remote learning, including telepresence robots.

The study explored social presence as a measure of a successful online learning experience. Social presence included co-presence, psychological involvement, and behavioral engagement (Biocca et al., 2003) as measures of remote participants' feelings of being valued and present in the same way in-person students are. Three graduate courses in education were chosen for the study. The courses were selected because they were taught by one instructor who lacked availability to instruct in-person and online versions of each course separately. Courses had between six and 20 students. They used pre- and post-surveys as well as focus groups that included both face-to-face and remote students. A qualitative research design was used because it was determined that the courses were dissimilar enough to not easily be compared using quantifiable data.

Initially, they created classrooms where online students were projected on a large screen in front of the room while the instructor and in-person students sat in a half circle facing the screen. They called this their 2D mode of learning because the online and in-person students experienced the online students as flat two-dimensional figures on a screen. The study described successes and failures with audio and video and how the online student displays and cameras were moved to various parts of the room to make these students feel more like they were in the classroom. The instructor found it challenging to pay attention to both the in-person and online students simultaneously. Online students reported that, depending on the placement of the cameras, it was difficult to tell who was speaking to them because there was no eye contact (Bell et al., 2016). The study included two additional iterations of telepresence, a view of the video conference participant on an iPad that could be set at various parts of the room, and an iPad attached to a Node chair that could be moved around the room and would show an individual student's face.

The various experiments brought to light some interesting results. Students who had an individual presence in the room using the Node chairs felt a greater sense of co-presence. The groups set more natural paces of discussion, and individuals interrupted each other with additions to an idea as in a typical in-person class discussion, which demonstrated higher behavioral engagement. When the online students' faces were individually added to the class on their own screens, the in-person students reported feeling like the online students were more a part of the class than when they were on a video conference screen.

The next iteration of the study introduced Kubi devices, which are stationary tabletop robotic devices that allow a user to pivot the screen left to right as an in-person student would face a speaker, and two Double robots that were fully mobile telepresence systems. The researchers found that the remote students reported a much higher sense of presence in the classroom (Bell et al., 2016). The ability to control certain aspects of the robot or screen gave students a sense of autonomy. Because the devices had their own cameras, the students could tell when the instructor looked directly at them, allowing for eye contact and a feeling of connectedness lacking with the video conference setup.

Although the article shared comments from students and instructors, there was no report of any data, nor did they report any coding of qualitative data. However, it is an important study in that it had a clear goal of increasing the similarity of the experience for both in-person and online students. The researchers systematically experimented with different iterations of online systems, evaluated students' feedback, and then tried new equipment setups or devices to move the experience continuously closer to the goal. Although the online students liked certain aspects of the Double robots, they did experience some anxiety about driving the robots and the robots falling. The in-person students felt some anxiety about the robots and their personal space.

This study laid a solid groundwork for the current research in that it highlighted many of the technical issues that had to be considered. It was hoped that a dedicated Wi-Fi access point and robots with more robust cameras and audio systems would help alleviate some of the challenges faced by the students and instructors in Bell et al.’s (2016) study. It is also hoped that the current study will reinforce the findings of stronger social presence when a stronger sense of embodiment is present.

The Gleason and Greenhow (2017) study examined whether using robots would affect a student's sense of social presence and embodiment in a synchronous-hybrid course. A key finding of this study was that having remote students use telepresence robots in a course contributed to the sense of embodied communication that facilitates social presence.

Researchers used an educational technology doctoral course that included 11 online students and one face-to-face student. One of the authors was the course instructor. A survey (unidentified; although the study included sample questions), focus groups, and student-written reflections were used as qualitative data. Students completed a survey and participated in a focus group that concentrated on three areas: perceptions of social presence, embodiment, and transactional distance (Gleason & Greenhow, 2017).

Focus groups of three to four people (*N*=11) were asked questions to extract details related to trends in the survey data. Conversations were recorded and transcribed and then a thematic analysis was used (Glesne, 2016) and categorized by advantages and disadvantages related to the focus areas.

The instructor had previously taught the same course using video conferencing, with remote students on wall-mounted displays up above eye level and a camera on the table where the in-person students were sitting. It was difficult for students to know where to look (at camera or display). The study course was a hybrid class where students worked asynchronously during the week to prepare for synchronous discussions every other week. One synchronous meeting method was for the face-to-face student, the instructor, and one teaching assistant (who provided technical support) to meet in a classroom while remote students attended via video conference or robot. Other synchronous meetings used the same in-person students, but remote students only participated through video conferencing. The article did not include how often students met in different modes. Two types of robots were used: Kubi and Double robots. Kubi robots were table mounted. Remote students could use their keyboard to move the Kubi screen/camera to see parts of the room or the discussion table. Remote students could move the Double robots around the room using keyboard controls.

The researchers explored the nature of students' embodiment, social presence, and classroom experience in robot-mediated learning (Gleason & Greenhow, 2017). Student focus group data were analyzed. All 11 online students reported a sense of embodiment and physical presence when using a robot. Students reported that it was easier to see the people in the room and felt they were being seen more naturally. Challenges with using robots for learning included a narrow field of view of the robot cameras and difficulty hearing the instructor and other students. Students expressed having a sense of social presence. Researchers found that most students reported that participating by robot facilitated communication, interaction, and set the stage for potential collaboration and construction of ideas. "Social robotics telepresence systems can enable hybrid students' sense of embodiment in a synchromodal class, which may support their social presence, or sense of connection and belonging" (Gleason & Greenhow, 2017, p. 171). Researchers also noted that instructors might need to reimagine how they are approaching teaching with robots and need to have a high tolerance for risk to be successful.

This study was a small-scale qualitative study. Researchers did not collect observational data to verify their results. They collected data from one discussion-based class. The audio quality of the robots for use in small group discussions was problematic because students could hear other groups' meetings. Audio quality issues have been reported in all cited studies and were considerations when designing the current study.

The Gleason and Greenhow study (2017) provided a valuable lesson about balance for the current study. The ratio of 11 robots to one in-person student seemed lacking in the perspective of the in-person experience. It might not be unheard of in the future for most of a class to be made up of telepresence robot students, but it seems unlikely that a university would have the resources to make that the norm. Also, the audio systems on the robots in both this study and the current study were unidirectional, and the robots do not turn quickly. Those issues made it difficult for large numbers of robotic students to determine who was speaking and then turn the robot quickly enough to line up the microphones and speakers to hear more easily. In the current study, the robots were scattered through the room to allow for social distancing of the in-person students and help the robot students better judge who was speaking.

The two previous studies included video conferencing and telepresence robots, but another recent study chose to separate those two experiences. Fitter et al. (2020) compared student experiences attending classes by distance learning tools (DLT) such as video conferencing or telepresence robots with in-person attendance. The study had a small sample size (N= 18) and used a three-level within-subjects design.

Participants were selected from four engineering classes. Two to three participants were selected from each class. Each participant attended two weeks of class in each mode (in-person, DLT, and robotic) except for two students who did not live close to campus and only participated in the DLT and robot trials. The researchers chose engineering courses because they hoped the students were already familiar or comfortable with the technology used in the study. Lecture courses were used, although instructors were encouraged to include student engagement. The article did not discuss what student engagement might look like using telepresence robots nor did the researchers report any differences between the courses in terms of instruction.

The researchers administered a pre-study survey, post-class surveys each week, a post-condition survey after each method, and milestone surveys every two weeks to see how perceptions changed over time. No measure was explicitly named so it is assumed that the study designers created the survey. Free response and 7-point Likert scale items were based on previous work on self-ownership and self-presence in virtual environments (Fitter et al., 2020). The researchers included shortened descriptions of the questions when they reported the ratings of the various questions, such as “Felt present,” “Felt Like in a Classroom,” and “Could Interact with Others.” They also created a coding rubric for their qualitative data based on prior survey tools for usability heuristics and video conferencing recommendations. Semi-structured interviews were done with students and instructors at the end of the study. Participants were paid $200 for participating and for completing all surveys. The researchers demonstrated the use of robots and administered the pre-test. The milestone surveys coincided with the completion of each two-week experience in one attendance format. The researcher limited all surveys to five questions to avoid survey fatigue.

The study included three hypotheses: 1) in-person instruction will lead to better learning outcomes, 2) telepresence robots will feel more “in-person” than video conference, and 3) students and instructors will prefer robot attendance over video conference attendance if unable to attend class.

T-tests and ANOVAs were used to analyze the data. Researchers created a coding rubric for the free-response portions of surveys. It was based on Nielsen's usability heuristics and Logitech's video conferencing recommendations (Fitter et al., 2020). Fitter et al. (2020) coded data as positive or negative based on five factors: ease of use, technical robustness (e.g., audio/video quality), affordances offered by technology (e.g., playback, control, and flexibility), interaction facilitation (e.g., ability to communicate in class), and content delivery capabilities (e.g., ability to learn presented content). Bonferroni's test was used to adjust for the family-wise error rate across multiple comparisons (Fitter et al., 2020).

The researchers found no changes in perceptions of technology. Only one of 18 participants showed a preference for the robot. Eight chose video conferencing and nine chose in-person learning. Issues with the quality of the video and audio on the robots may have affected the results. There were significant results in post-class surveys in several areas (presence, appearance in classroom, ability to express oneself, awareness, and engagement). Milestone surveys showed significant differences in frustration and immersive and social ratings but not on the other 10 characteristics. In the post-condition survey, researchers compared DLT and telepresence robot users' experiences. Significant differences were found in: "feeling like one could reach into the classroom" and "feeling like attendance method was part of one's own body" (Fitter et al., 2020, p. 5). Students were more comfortable with distance learning technology. There was no noticeable difference in their ability to participate. Students indicated feeling more present when using robots.

Suggestions for future study included giving students more practice on robots prior to the study, maintaining strong network and broadband reliability and charged batteries for robots, enabling users to comprehend how loud they are speaking, and improving the spatial awareness and visual acuity of the robot cameras to help reduce stress. Finally, providing richer nonverbal cues (expressing confusion, enthusiasm, questioning, etc.) could help participants and instructors feel more engaged.

This study helped inform the considerations for training used in the current study where opportunities for both the instructors and the students to become familiar with the controls for the robot prior to the first day of the term were offered.

In the final study, the focus was on how the sense of embodiment was related to students' sense of engagement with both robot and in-person students (Lei et al., 2019). The course was a graduate-level educational technology class with two in-person students and 12 telepresence robot students. The two in-person students and two of the telepresence robot students chose not to participate in the study and only seven completed the survey. The course consisted of a mixture of alternating asynchronous and synchronous weekly meetings.

The data were collected on one day midway through the term. The researchers administered the TEMS (Bell et al., 2017), collected video recordings from various perspectives around the room of the one 3-hour class meeting, and made observational notes.

The researchers' hypotheses centered around exploring the idea of engagement and embodiment. They wanted to know how robotic students used their "bodies" to interact with learning and how they perceived social presence, embodiment, and engagement, and they wanted to observe how these students were engaging in the course.

The researchers determined the internal reliability of the TEMS instrument and generated Cronbach's scores for each sub-scale. Embodiment ($\alpha = 0.660$) and behavioral engagement ($\alpha = 0.694$) did not reach the reliability scores of $\alpha > 0.80$ that were preferred, although the social presence, affective, and cognitive engagement scores were over the threshold. The researchers suggested that testing with larger sample sizes could give a more definitive measure of reliability. Z-scores were used to test for outliers and calculate the first and third quartile for each item. Based on the quartiles, they identified responses as either high, moderate, or low. They also computed the mean scores of all seven participants and the standard deviations for each sub-scale. The sample size of seven participants was small and the in-person student chose not to participate in the survey process. Therefore, it made sense to focus on sub-scale scores rather than individual items. They also compared the quantitative data to the observations of actual behaviors and needed quartile scores in both the quantitative data and the coding of the observational data to standardize their comparisons. The lack of a similar sized in-person sample made comparisons between the two groups impossible.

As for the qualitative data, the researchers coded the frequency of engagement actions from the video into three categories: cognitive, affective, or behavioral engagement. These included items such as asking questions, verbal and nonverbal attention seeking, and expressing themselves. After two rounds of coding using multiple coders, they generated quartile scores based on frequency of the various behaviors coded. They then compared the quartile scores for each participant.

The researchers discovered some disparity between students' perceived sense of engagement and the actual numbers of engagement behaviors or observed behaviors. Although the sample was small, embodiment was a significant predictor of self-reported cognitive engagement, $F(1,6) = 7.499$, $p < .041$ (Lei et al., 2019).

There was concern about the small sample size, and that the instructor required all students to participate as robots. Individuals' observed engagement varied but was almost two times higher when the robots were used for small rather than whole group discussions. Studying differences in engagement between large and small group discussions may be useful but was not included in the current study.

Faculty Experience

Although embodiment, social presence, and engagement for students are the focus of the current study, it is important to include the experience of the instructors. They construct the conditions for online learning and often create the opportunities for social presence to develop (R. Garrison et al., 2000; Gunawardena, 1995). Garrison et al. (2000) called this important component “teaching presence” and considered it the crucial piece that brought social and cognitive presence together in an online learning environment. However, the original concept of teaching presence was based on research done on asynchronous text-based communication in online courses and focused on learning design and organization, direct instruction, and facilitating discussion (T. Anderson et al., 2001). The reality of all instructors having to move their teaching online highlighted the challenges of establishing that teaching presence.

The current blended video-conference-based courses brought new challenges for instructors that were only exacerbated by the emergency move to remote teaching.

Instructors during the pandemic had to make an almost overnight shift to online learning using technology tools they may not have been familiar with, and some lacked the pedagogical knowledge needed to design a successful learning environment online (Rapanta et al., 2020). Previously used strategies for building community in person may not have translated well to the online environment. Those interactions may have become more formal when fully online because some of the spontaneous interactions between participants were lost (Rapanta et al., 2020). Blended learning added the element of building collaborative communities when part of the class was remote and part in-person. Instructors in one study noted that lack of participation in class, less student understanding of content, lack of video screen usage, and academic integrity all significantly influenced their preference for in-person instruction over remote teaching (Bonsangue & Clinkenbeard, 2020). Students turning their screens off during synchronous meetings had been perceived as a lack of engagement by faculty and had led to feelings by both groups that the educational experience was diminished (Castelli & Sarvary, 2021; J. Lee, 2020). Students attending remotely reported that it is difficult to engage with the instructor because they cannot tell who the instructor is making eye contact with, and they have lost of some of the social cues that support discussion (Bell et al., 2016; J. Lee, 2020).

Technology use can have adverse effects on instructors, which one study referred to as technostress. Technostress is lessened by self-efficacy in the use of technology (Trujillo-Torres et al., 2020). Online learning and especially blended learning added an element of technological complexity to teaching. Task switching between video screens, LMS systems, and document cameras, plus simultaneously addressing the needs of both in-person and remote students, challenged even tech savvy instructors. Technical issues with hardware, networks, and devices, or the complete lack of access to the resources for online learning by students and faculty, worsened access disparities (Jones et al., 2021; Nworie, 2021; Stewart & Lowenthal, 2021; Vogels et al., 2020).

Increasing access to faculty development and training, not only around hardware and software usage but more importantly related to the sound pedagogy of teaching online, is the first step toward reducing the technological stress of instructors (Schwartzman, 2020). Looking at ways that technologies such as telepresence robots could reduce the amount of task switching and increase the engagement and social presence of students may be another important way of supporting instructors.

Limitations and Discussion

The studies included in the literature review had various limitations such as small sample sizes, homogenous groups, problems with the technology, and limited quantitative data collection. The current study attempted to address some of those limitations. The current sample included 71 participants in four courses, with 27 students who participated primarily as robots or through video conferencing. In two of the previous studies, the robot participants were in the majority, and in one study there were only two in-person participants to 10 telepresence robots. Increased robot participation may impact overall classroom bandwidth, so the current study attempted to limit the number of robots per section to four. However, in one course there were regularly seven robots. Also, the current capabilities of the robot technology-imposed audio and video challenges that made it difficult for robot participants to see and hear one another plainly without help from in-person participants. Previous studies focused primarily on the perspective of the telepresence robot student. However, it is important to listen to both perspectives in courses where robots and people share the same learning space. The present study allowed for the perceptions of in-person participants and telepresence robot students to be analyzed.

Telepresence studies have focused on graduate students taking technology-related courses. The current study included undergraduate students taking humanities and education courses. Studying the use of telepresence robots with undergraduate students in a non-technology-related course may provide better insight into challenges that need to be addressed for a more generalized use of telepresence robots in higher education. What it means to be present in a classroom may differ for an undergraduate and a graduate student. The potential impact of technological challenges on social presence and engagement, such as students' frustration level when unable to hear other participants, may differ depending on students' previous experience with online learning.

Little can be done by instructors to address the audio and video limitations of the robots themselves. The room chosen for the current study had cement floors and bare walls, which made sound echo. Robot students were shown how to adjust the sensitivity of their microphones in the hopes of mitigating some of the echo. In-person students were shown how to adjust the volume on a robot's speaker to match the purpose of the activity. In-person and robot students needed time and practice to learn how to ensure the robot volume levels were appropriate because the robot students could not detect their relative loudness to the in-person students. Robots were put into position before the beginning of class to maximize battery life, save transition time, and ensure that the robots were placed at a comfortable distance away from the in-person students. However, positioning the robots before the start of class limited the autonomy of the student robots to maneuver to where they wanted to be in the room.

Gaps in Literature and Limitations

In the research reviewed for the current study, further suggestions included a need for a broader mix of students from diverse backgrounds, a larger sample size, and a more comprehensive selection of courses. Studies published in the last five years on social presence using telepresence robots included small sample sizes (7 to 18 participants) and used only graduate-level programs. The current study included four undergraduate courses with 71 participants, 45 of whom were in-person and 27 were remote. The ratio of participants was much more balanced than in previous studies. This ratio provided a larger sample size and allowed for comparison between the responses of in-person and robot students. Although the classes used were undergraduate courses, the students ranged from first year to fourth-year students and provided a more diverse perspective.

Previously, most student studies were either in a highly technical class (engineering) or a doctoral-level educational technology class. These students likely had a higher level of experience with technology, allowing them to be both more knowledgeable about possible technology issues that might arise and more tolerant of technological difficulties. The current study used general undergraduate courses that included students who were still deciding on majors as well as students completing final requirements before graduation.

The courses in previous studies were either lecture or discussion-based and did not include mention of group work. Although exploring how the type of class (hands-on vs. lecture) might impact students using telepresence robots, the current study was not designed to explore differences between the courses or the instructional pedagogy used in the course. Although the content of the four courses was different, the teaching styles of the instructors were similar. Three of the courses were taught by the same instructor. Therefore, neither the course content nor instructors were used as variables in the data analysis.

It was also suggested that participants and instructors needed more time practicing with the robots before using them. The instructors, additionally, may need time to adjust their teaching strategies. In the current study, instructors and students had an opportunity for training and practice before the start of the term. Additionally, instructors received weekly emails from the researcher to address troubleshooting issues and to offer support.

Finally, the research in higher education around the use of telepresence robots in hybrid classes is in its infancy. There have been several instruments built to attempt to measure social presence (Biocca et al., 2001; Cui, 2013; R. Garrison et al., 2000; Tu 2002) and engagement (Appleton et al., 2006; Handelsman et al., 2005; Hart et al., 2011; Henrie et al., 2015; Mazer, 2012). However, none were built that specifically applied to the use of telepresence robots or that measured both in-person and remote students' perspectives when the robots were used simultaneously in the classroom. The TEMS instrument (Bell et al., 2017) was built to address those gaps but had only been used in one previous small-scale study. The current study helped further determine the reliability and validity of this instrument and its potential benefit for future researchers in the field of telepresence robot research.

Chapter 3: Methodology

Participants

Participant Characteristics

The participants in the current Institutional Review Board approved study (IRB#202106003) participated in one of four undergraduate humanities courses at a private university in the Pacific Northwest during the spring term of 2021. Of the 87 total students enrolled across the four courses, 10 declined to participate in the study, dropped the course early in the term or did not complete both surveys. Of the 77 students remaining, six students, even after several reminders, chose not to complete both the informed consent and the final survey. As part of the informed consent process, participants were notified that they had the right to drop out of the study at any time without penalty. Seventy-one students completed both surveys (see Table 1).

The courses were general education humanities classes taught by two instructors who agreed to teach blended courses in which the online students participated using telepresence robots. The content of the three larger art courses was similar and they were taught by the same instructor. The second instructor taught a single course. Both instructors were full-time experienced faculty who had previously taught these courses with all students physically present, and one had taught their course in hybrid with Zoom. The sample sizes of the sets of courses taught by each instructor were uneven. No specific questions were asked in this study regarding the influence of instruction on the use of telepresence robots. The course type and instructor were examined to rule out as confounding variables but were not the focus of this study.

The initial breakdown of demographic data collected shows that the gender makeup of the 71 study participants was female (n = 58), male (n = 11), and non-binary (*n* = 2). The courses are highly skewed toward females, which is representative of the university (67% females and 33% males), with no reporting of other gender designations on the university's website. The corresponding percentages of gender balance for the study courses were slightly different from the university, with 81% females, 15% males, and 4% other designation, but gender differences with telepresence robots were not explored in previous studies and were also not the focus of this study.

Most students were in their first year of college (*n* = 40), with second year (*n* = 10), third year (*n* = 12), and fourth year students (*n* = 9) making up the rest. Students' previous number of online classes varied widely. First-year students reported an average of 10.4 online classes, second-year students averaged 12.3, third-year students averaged 10.0, and fourth-year students averaged 16.7. The data were collected to help determine the homogeneity of the sample group. No data were collected on race or ethnicity for this study partly because no previous studies reported this demographic data, and partly out of respect for student privacy given the small sample size. Race and socioeconomic status have been tied to inequities in access to technology—for example, the device and internet access to log on to the robot from a student's home (McDonald, 2020). Digital equity is worthy of future research, but it was not the focus of the current study.

Table 1

Participant Distribution Across Courses

	Reading		Art 1		Art 2		Art 3		Totals
	In-Person	*Remote*	*In-Person*	*Remote*	*In-Person*	*Remote*	*In-Person*	*Remote*	
Total Registered Students	6	4	16	8	24	7	16	6	87
Dropped or Incomplete Survey	1	1	3	2	4	1	4	0	16
Final Study Participants Based Attendance Choice	5	3	10	9	21	5	8	10	71
Outliers Removed	0	0	0	0	0	0	1	1	69
Total Participants								43 In-Person 26 Remote	

The smallest class, Reading, met twice weekly, one day with a combination of in-person and telepresence robots and the second day by video conference only. Nine students registered for this course, but one in-person student did not complete both surveys and was not included in the study. The final study participants included five in-person students and three remote students (see Table 1). The instructor was an experienced faculty member who had taught this course for several years fully in-person and had taught the same class earlier in the year as a hybrid course using Zoom.

The second instructor taught three blended courses using the telepresence robots. Art 1 was comprised of a total of 24 registered students who met weekly. Overall, five students from this course did not participate in the study because they either declined to participate, dropped the course, or did not complete both surveys. The total study participants included 13 in-person students and six remote students (see Table 1).

Because the Art 2 class enrollment was larger than the social distancing capacity of the classroom, the students were split into two groups that met in person on different days. Of the 31 registered students, 26 participated in the study. Twenty-one attended in person and five were remote students. Three in-person students and one robot student did not participate in both surveys and were not included in the study (see Table 1).

The Art 3 course met once a week in person. Of the 21 students registered for the class, 17 participated in the study. One dropped the course and three either declined to participate or did not complete both surveys. Of the total study participants, eight were in-person participants, and nine were telepresence robot participants. This class had the largest number of in-person students not completing both surveys and choosing not to participate. The actual registration of the class showed 11 in-person and six online students, but at least three students chose to use robots instead of coming in person some days. These three answered the survey based on their robot experience rather than their in-person experience, which made the numbers look like there were more robot students than in-person students (see Table 1). On a daily basis, however, there were six to seven robots being used.

Sampling Procedures

COVID-19 created challenges and opportunities for running a study with blended courses and telepresence robots. Choosing courses to include in the study was primarily determined by the willingness of the instructor to teach using the telepresence robots. To find willing instructors, the university registrar provided a list of classes being offered online and in-person by the same instructor during the spring term. The list was narrowed down to courses where instructors indicated an interest in teaching their online and in-person sessions concurrently. The potential instructors were emailed details about telepresence robots and how they might be used as an alternative to video conferencing. The email included links to telepresence research studies and a list of possible benefits, such as the greater sense of social presence, increased student agency, and the ability to interact more realistically (Bell et al., 2016; Fitter et al., 2020; Gleason & Greenhow, 2017; Lei et al., 2019). Four instructors were initially interested but two had courses with five or fewer students. The two study instructors selected had planned to teach both in-person and remote students simultaneously, had larger class sizes to yield larger sample sizes, and were willing to use the telepresence robots in place of video conferencing. Although this was a convenience sample (Lavrakas, 2008) of courses which was based on the willingness of the instructors to participate, students had the option to sign up for this course as one of many options to fulfill a general academic requirement, which addresses some of the bias that convenience samples are sometimes prone to.

There was some confusion prior to the start of the term regarding the vocabulary used to designate the sections students were able to register for, whether online or blended. The online section was intended for students who wished to attend remotely during the term and the blended section indicated students who chose to participate in person. The professors informed students prior to the term that the online section would be using telepresence robots. In practice, there were students registered for the online section who participated in person, and some registered for the blended (in-person) section who attended by robot. In the end, determining whether a participant was in-person or remote was based on the student's actual choice of attendance method, rather than on which section they registered for (see Table 1).

Statistical Power

Of the 77 initial students who agreed to participate in the study, 25 of the 27 registered telepresence robot students participated in the final survey for a completion rate of 92%, and 46 of 52 in-person students participated for a completion rate of 88%.

The software program G*Power (https://www.psychologie.hhu.de//gpower) was used to calculate the statistical power of the TEMS instrument. Statistical power is a measure of the probability that the null hypothesis will be rejected if it is truly false (Faul et al., 2007; Field, 2013). The higher the statistical power, the higher the probability that it will find the effect that is being tested, assuming that an effect exists (Field, 2013). The Cronbach's alpha scores can be used to calculate the statistical power of the instrument. A post hoc power analysis was used to determine the power of the instrument using the effect size from the Cronbach's analysis and the sample size of the two groups in the study. For two tailed *t*-tests using means between two independent groups (in-person and remote) and using the sample sizes 44 in-person and 26 remote, with an α error probability of 0.5 and effect size of 0.971, the power was calculated at 0.987. This means that there was a 98.7% probability that the statistical tests run for this study will find effects if they exist.

Materials

The telepresence robots used in this study were Ohmni Robots developed by OhmniLabs Inc. The Ohmni Robots consisted of a moveable base with two larger front wheels and one central back wheel (see Figure 1). A charging connection between the two front wheels magnetically connected to the charging base. The body of the robot consisted of a stand about three feet high. A hinge, located in the middle, allowed the robots to be folded in half for storage and included the power button, microphone, and far-field speaker (see Figure 2).

Figure 1

Robot Base and Matching Space in Classroom

Figure 2

Full View of Robot and Social Distancing Space with Telepresence Robots

The robot included a 10x8-inch touch screen which the user tilted up or down using keyboard controls. If a telepresence robot student wanted to change their view, the keyboard arrow keys were used to rotate the base until the robot and screen faced the speaker. Two cameras were located on the robot. The front-facing camera was a Wide Angle 4k Supercam that could zoom up to 3x. Below the screen was a downward-facing camera that allowed users to see and avoid obstacles around the base when moving.

The battery lasted approximately six hours depending on how often the users were moving the robot. During the study, the robots accommodated three classes on the same day without returning to the base to charge, as long as they were turned off or in sleep mode between classes.

The Ohmni software allowed participants to turn their camera and microphone on and off. Participants could also zoom in and out with the camera, change settings for brightness to adjust for low light, and modify microphone sensitivity for different types of conversations.

Measures for Quantitative Data Collection

Demographics and Technology Comfort Level Survey

The students were asked to complete a Technology Comfort Level survey during the first two weeks of the term. The survey asked for information such as how a student intended to attend class (in-person, telepresence robot, or zoom), gender, and year of study. Additionally, it included questions regarding how many online courses they had taken in the past. Participants were also asked to rate, on a 5-point Likert scale, their comfort level with learning new technology, how often they seek help or need troubleshooting when learning a new technology, and how likely they are to give up when learning new technology. Scores were rated 1 (*Strongly Disagree)* to 5 (*Strongly Agree)*. An open-ended question was included at the end for general questions or concerns about the robot. This information was used to generate useful answers to common questions which were communicated to the participants during week four. This communication addressed troubleshooting issues related to microphone sensitivity and robot controls and connection that were brought up in the open-ended questions. Unfortunately, due to a human error, the first version of the form did not collect names for the consent form that was part of the survey, and students had to fill out the form and survey a second time. It took three weeks of reminders to collect all the informed consent forms. Demographic data were used as part of the analysis but data on technology comfort levels were not used for this study and no direct tests were planned.

Exit Tickets

To allow robot students to communicate with the researcher about problems and experiences mid-study, students had an opportunity to complete an exit ticket during weeks three through six. Participants rated their robot experience during the week and shared open-ended feedback. The purpose was to collect ongoing feedback and gauge if the students' experiences changed over time. Other studies that used multiple surveys (Fitter et al., 2020) reported concerns of survey fatigue. That concern, on top of the general concerns around the pandemic and students' energy levels, led to the exit ticket surveys being deliberately short and non-mandatory. Since participation was optional, frequency data were generated by consolidating results from all four classes to look for trends.

TEMS Instrument

The TEMS survey (Bell et al., 2017) was made available to students during week seven to avoid conflicting with end-of-term projects and papers. The survey was open until the end of the term. Students were reminded to participate via emails sent from the researcher and the instructors. Both instructors gave two extra credit points to students for completing the survey.

The survey measured students' sense of social presence, embodiment, and engagement in blended courses from both the in-person and telepresence robot student perspectives. The TEMS instrument captured multiple dimensions of the telepresence robot experience such as co-presence, the awareness or sense of being with other people, psychological involvement, the sense of being with conscious beings, and behavioral engagement, the sense that one is interacting with others (Bell et al., 2017). The TEMS was used as a measurement tool in the *Student in the Shell* study (Lei et al., 2019) referenced in the literature review. The survey included five items for Embodiment, 13 items for Social Presence, 12 items for Psychological Involvement, and 17 for Engagement (composed of seven Behavioral Engagement, four Affective Engagement, and six Cognitive Engagement). All questions were measured on a 5-point Likert scale (1 = *low agreement* and 5 = *high agreement)*. Items in the original TEMS instrument were worded to match the vocabulary used in the course that was being studied. For example, the original instrument used the term "live sessions" to refer to in-person class attendance. In the current study, the terms "in-person" and "robot" were used to be consistent with vocabulary in the course. When items in the TEMS instrument were explicitly directed toward a particular group—either robot or in-person—they were reworded to reflect the perspective of the attendance type (robot or in-person). Any item that was directed at both groups was left alone. For example, an item measuring psychological involvement and directed at remote students would be worded as, "I felt that the in-person students acknowledged my point of view." The same item directed at in-person students would be stated, "I felt that the robot students acknowledged my point of view." The survey was set up to branch to in-person or remote student items depending on which mode they reported as the method of attendance they used most often.

The TEMS instrument was developed specifically for blended learning environments where some students are present using a technology-mediated tool such as video conferencing or telepresence robots. It is intended to measure embodiment, social presence, and engagement (Bell et al., 2017). The items on the instrument were developed from the work of Haans & Ijsselsteijn (2012) on the three components of embodiment (morphology, body schema, and body image) and the work of Biocca (1997) and Short et al. (1976) on social presence. Bell and his colleagues had not validated the instrument at the time of publishing their paper, but it was used in a study in 2018 (Lei et al., 2019). The researchers in Lei's study reported that the social presence, affective engagement, and cognitive engagement scales appeared internally reliable $\alpha > 0.80$. The embodiment ($\alpha = 0.660$) and behavioral engagement ($\alpha = 0.694$) scores were below the threshold for reliability (Rodriguez & Maeda, 2006). They did not report the alpha scores for psychological involvement. The instrument, however, was used on a small sample size ($n = 7$), making the alpha scores unreliable. Cronbach's alpha scores, which are widely used to determine an instrument's ability to consistently measure what it is intended to measure (Rodriguez & Maeda, 2006), were calculated to determine if more reliable scores would occur with the larger sample size ($n = 71$) in the current study.

Validity occurs when there is evidence that an instrument actually measures what it sets out to measure (Field, 2013). The TEMS instrument was developed by researchers in the Design Studio at Michigan State University who had been engaged in designing and researching telepresence robot experiences. They had previously used primarily qualitative data, but wished to design an instrument to measure embodiment, social presence, and engagement quantitatively, especially in blended or hybrid learning environments. The engagement items for the TEMS were based on the review of seven different instruments of student engagement which are widely used in higher education research (Bell et al., 2017; Lei et al., 2019). Some questions were adapted to capture behavioral and affective engagement. Items measuring social presence were taken from Haans and Ijsselsteijn's (2012) work on embodiment which includes concepts of projection, perception, and projection of perception to address the affective dimensions of social presence measures of psychological involvement, which includes immediacy and intimacy measures (Biocca, 1997; Short et al., 1976). The developers of the TEMS instrument had qualitative data from survey participants that they felt supported the item validity. The researchers stated that their next steps would be to run cluster analysis of the items to ensure they loaded properly on the variables.

Qualitative Data Collection

Recordings of the in-person course meetings were created using the 360-degree Owl video tool in order to collect qualitative data to support the findings in the quantitative data, especially around behavioral engagement. The camera was set at the front of the room slightly to the left of center to allow the instructor to move back and forth to the presentation computer unimpeded by cords. The camera primarily tracked the speaker. Randomly selected recordings, one from each course, were intended to be used to look for behaviors by the robots and in-person students to indicate behavioral engagement. This included indicators of both in-person and robotic students turning toward the speaker, or robot students asking questions of the instructor, or a response to another speaker (Redmond et al., 2018). In addition, indications of whether a student had their camera on or off while participating as a robot were to be noted. Behaviors were intended to be counted and categorized by the number of behaviors for robot students and in-person students to compare them. The analysis of the qualitative data would be used to support the findings from the analysis of students' self-reported measures of behavioral engagement. Data and observations were documented. To double check whether a participant had shut off a camera instead of just losing connection, the researcher requested log-in data from the Ohmni corporation for the study duration. If the data can be obtained, it will be used to match with observational data of the robot cameras to determine if a student chose to turn off their camera or was disconnected.

The qualitative data gathered from open ended questions on the surveys was analyzed using a realist thematic method that reported on the experiences, meanings, and realities of the participants' experiences (Braun & Clarke, 2006). Theoretical coding was based on the known areas of interests for the survey: embodiment, social presence, psychological involvement, and engagement. These included mention of interaction with others or feelings of belonging in the learning environment and of being recognized by other students. These codes were matched with comments students made in the open-ended questions to help support the quantitative data or to help identify areas of contradiction.

A second coder was used to provide a second set of eyes and to check for consistency. The second coder was an elementary digital learning teacher and a student in the first year of her doctoral program at the same university as the study. Although she teaches technology, she had no prior experiences with telepresence robots and little prior knowledge of embodiment, social presence, or engagement related to the study. Responses from participants were entered into the Dedoose (www.dedoose.com) analysis software to facilitate coding and comparison with the second coder. All data were matched with the TEMS data and then de-identified prior to sharing.

Qualitative data were also collected from the instructors twice during the term. They were interviewed at the midpoint of the term and asked to share their experiences with the robots. After the end of the term, an open-ended questionnaire was sent to instructors to give written feedback and answer more targeted questions about their experience teaching with the robots. The first interview allowed the instructors a chance to share initial reactions to the robots while it was fresh in their minds. A follow-up survey was sent to instructors after the term ended. The timing of the survey allowed instructors to teach with robots after some technical issues were resolved. Instructor comments were analyzed with the same open coding system.

Procedures

Two months prior to the start of the term, a meeting took place to introduce the instructors to the study design, answer questions, and talk about potential issues they might encounter. An email was generated to share the general purpose of the study with the students, describing the robots, the potential experience, and offering students an opportunity to attend one of five available training times to learn how to navigate the robot prior to the first day of class.

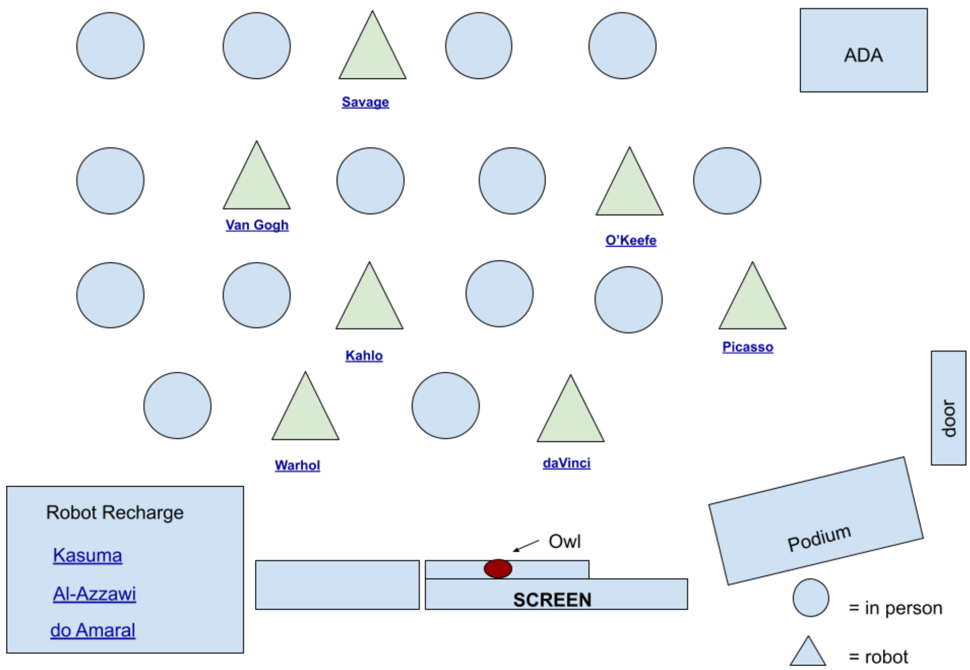
The classroom used for the study was chosen because the Art instructor was planning to teach in the room and there were no other courses or activities scheduled for the building during the term. This minimized the number of people in the building for social distancing purposes and assured less competition for internet bandwidth as well as provided some security for the robots. The room was limited to 14 in-person seats. Desks for the in-person students were spaced approximately six feet apart. In between desks, space was designated for the telepresence robots by taping paper to the floor with a robot's name (see Figure 1). Because of COVID procedures, the room had to be set up in a traditional layout of rows with desks facing the front of the room.

The Owl video camera, which records a 360-degree view of the room, was set up on the front podium to record the classes. Video recordings of classes were made in case of a robot error that forced students to miss a part of the class. These recordings were also used for qualitative analysis.

Each instructor allowed the researcher to place a Research Study button on the home page of their LMS course to help students quickly find the Telepresence Study module and the page with the login links to the robots. The module included written instructions and video demonstrations for navigating the robots and turning them on and off. This module also had the Log in Map (see Figure 3) that allowed students convenient access to choose the robot in the part of the room that they preferred and provided an easy link for logging in to the robot.

Figure 3

Robot Map Posted in LMS



Note: Robots were named as artists because three of the courses were Art related. Students clicked on the live link to connect to the robot they chose.

Students who signed up for the online section of the class were sent an email the week prior to the class inviting them to participate in an optional 30-minute robot training course three days prior to the start of the term. This date, unfortunately, was during the students' spring break, but 11 of the 23 students took advantage of the training. In addition, the two professors attended a session on their own, before the student sessions, to experience the robots as their students would. This allowed for the opportunity to work out any problems before training the students. One additional student training session was offered the morning of the first class and three students logged in early and were given a quick overview. Students from the other classes were provided a brief training session by the researcher before their first class that week, and the rest were able to learn what they needed by trial and error or from the LMS module.

After the first training session for the robot participants, a decision was made to roll the robots to their designated space prior to class. This cut down on time for robot participants to move into position before class started and on the potential disruption of robots navigating around obstacles such as chairs and people. Areas were marked on the floor with the robots' names (see Figure 1) to ensure they always went to the same location in the room, to match the mapping system. To log in, students navigated to the classroom map (see Figure 3) in the LMS and clicked on the robot they wanted to use. This allowed students autonomy about where they wanted to "sit" in the classroom (see Figure 4).

Figure 4

Student View of the Front of the Classroom

The researcher attended each class session for the first two weeks to orient new students to the robots and troubleshoot technical issues. It was discovered that some robots were dropping connections and one instance occurred where two students somehow simultaneously logged on to the same robot. A request was made to the university's technology department who then moved a Wi-Fi access point closer to the room to strengthen the signal. The Ohmni company support was also contacted and was able to troubleshoot the issue of two participants connecting to the same robot. However, connection issues persisted throughout the quarter. Further communication with Ohmni revealed that a typical Zoom call uses 600 kbps for one-to-one calling and 1mbps for group calling. Each Ohmni robot uses up to 3mbps, i.e., up to five times more than a one-to-one Zoom call and three times more than a group Zoom call (A. Chau, personal communication, March 29, 2021). This may account for some of the call-dropping issues as not all students had home internet capacity to sustain this level of bandwidth for an entire class period.

During the first two weeks, the instructors and several students were trained to move and turn on the robots, turn them off at the end of class, and then get them back to their charging stations to make sure they were ready for the next class. Instructions with pictures were put on the wall near the robots and in the LMS course for reference. The materials in the LMS also included explanations for all the controls on the user end and step-by-step directions for everything they would need to control the robot.

Online students were initially asked to participate as robots. They had the option of using video conferencing if they felt uncomfortable using the robots, had connection trouble in the middle of class, or had trouble with their home network. Some students chose to switch to video conferencing after participating as a robot, but all online students except two used the telepresence robots at least once. For this study, participants were counted as remote if they used the robot one or more times and identified that they were taking the TEMS from the perspective of a remote learner.

Proposed Data Analysis

This quasi-experimental research study is a between-group design in which students are self-selected into either an in-person or fully online section of the same course. The two groups participated simultaneously in class meetings, with the online students primarily using telepresence robots and receiving the same instruction as the in-person students for the entire term.

The two instructors had similar levels of experience and expertise with the courses they were teaching. Their teaching styles were similar with a combination of lectures and discussions in a large and small group format. Although the instructor may have had an impact on students’ experiences with the robots, it would be difficult to directly compare them since the class sizes and the number of robots active in their classes were different. The course content was also not considered a variable for analysis because the study focused on students' feelings of presence in the classroom and with their peers, which is related more to social and behavioral measures. Content can be related to engagement, however, and may be analyzed separately if the measures of engagement seem skewed toward one group or the other. Courses could be used as a controlling variable to see if there are significant differences between individual courses that might account for the higher engagement scores for one group.

Students had the option to use video conferencing if they did not feel comfortable using the robots. Only three students used video conferencing more than half the time. However, five participants identified themselves as primarily video conference users. This may be because they ended the term using video conferencing. All participants were asked to take the survey thinking about their experience with the attendance mode they used the most. In all but three cases for remote learners, that was by telepresence robot. Only two other users used the video conferencing option more than the telepresence robot. It is not known if this was from troublesome connection problems or personal choice.

Seven in-person students used the robots at least once because there was some initial confusion at the beginning of the term. During registration, two sections for each course were labeled “blended” and “online.” The word “blended” was used to indicate a course section included a combination of in-person asynchronous work, while online was intended to be fully remote. Some students misunderstood “blended” to mean that they would attend remotely, so they mistakenly attended at least the first class by robot or zoom.

Because only one participant attended solely by video conference and did not use the robots, it is not possible to have an independent variable with three levels. Instead, the Zoom only student’s data were removed, and the other Zoom participants’ data were consolidated with the other telepresence robot participants and it became considered as a remote learners group. The data were analyzed using only two levels, in-person and remote learners. Any student who used a robot at least once would be able to form an opinion about their experience and be counted as a telepresence robot participant, or more generally, a remote learner.

Of the 71 participants, 27 identified themselves as remote participants, using either the telepresence robots or video conferencing, when they took the final survey. The sample sizes of in-person and remote students were not equal. Because homogeneity across sample populations can be an issue that effects parametric assumptions, descriptive statistics were examined to identify outliers and check for normal distribution and linearity across the sample groups. A Levene's test was run when applicable, and the sample size was considered large enough that is could predict violations of assumptions (Field, 2013).

On the TEMS survey, there were multiple items in each of the subcategories (Embodiment, Social Presence, Psychological Involvement, and Engagement). TEMs is a new instrument and two of the subscale scores in a previous study had not met the $\alpha >$ 0.80 reliability threshold. It was suggested that using a larger sample size may yield different reliability scores, so a Cronbach's test was run on each of the subscale scores to see if all the subsections were consistently measuring the same variables across participants. It would be acceptable to use a lower reliability threshold, such as $\alpha > 0.70$; however, a lower threshold risks reducing confidence in the instrument reliably measures the variables. Any subscale scores that were not statistically reliable were reported.

Other variables such as instructors, course content, gender, or level of schooling could also impact the results. Research questions were used for this study and there are no specific hypotheses. Demographic data were explored to look for potential influence on the data. Two-way ANOVAs were used to look for interaction effects with other demographic information. For each post hoc test run, tests that control for inequality of sample size were also run. Because the sample sizes are similar but not equal, Bonferroni was used to control for Type 1 errors as it is a fairly conservative test.

The independent variable in this study was the mode of attendance (in-person or remote). The dependent variables were the measures of embodiment, social presence, psychological involvement, and affective, behavioral, and cognitive engagement. Although previous studies (Oh et al., 2018) have found that as the mode of communication engages more of the senses and becomes a more immersive experience (embodiment) the higher one's sense of social presence. In this study, embodiment can only be reported for the remote participants as they were the only participants asked to answer the questions related to embodiment on the survey. The social presence subscale included the combination of the scales of social presence and psychological involvement which combine the sense of being with others (Biocca, 1997) and the sense of being with other thinking beings (Biocca et al., 2003), and which make up both the physical and affective sides to social presence. Engagement, as a subsection, includes the three characteristics of engagement: behavioral, affective, and cognitive. Each item is measured on a 5-point Likert scale as continuous interval variables. To calculate the subscale scores, the sum of each student's scores for that particular subscale were calculated and then the mean was determined. This was done separately for each larger scale—embodiment, social/psychological presence, and overall engagement—as well as for the individual subscales.

Tests for normality and parametric assumptions were run on all dependent variables (measures on the scales and subscales) and independent groups (mode of attendance: remote or in-person) included in this study, to determine if the samples were normally distributed. If they were, parametric tests such as *t*-tests and correlations were used to analyze the data. If certain groups' data were not distributed normally, non-parametric and post-hoc tests were used.

Research question one asked whether there was a relationship between embodiment and the telepresence robot students' perceptions of social presence. A Pearson's correlation test was used to look for a relationship. The score indicates the strength and direction of the relationship but does not indicate causality.

Research question two explored the relationship between the telepresence robot students' senses of embodiment and engagement. As in question one, a Pearson's correlation was used to look for the strength and direction of a relationship.

Research question three asked whether there was a difference in social presence measures between remote and in-person students. Independent samples *t*-tests were run between the attendance type (remote or in-person) and each subscale score (embodiment, social presence, and engagement). The remote student group (n = 27) is slightly smaller than the in-person group (n = 44). Levene's scores and effect sizes were calculated to ensure the two groups were not significantly different and to determine the strength of the differences.

Research question four asked whether there was a difference in engagement between remote students and in-person students. The same independent samples *t*-tests run on the same groups as in question 3 were used to analyze engagement.

Research question five is a qualitative question that was answered by examining the feedback from instructors through the notes from the mid-term interview and the written feedback at the end of the term. Open coding was conducted by the researcher and one additional coder (Creswell & Poth, 2018). Codes were based on indications of embodiment, social presence, and engagement as well as technical issues surrounding connection, video, and audio. Other codes were employed as the data were reviewed. Codes were also consolidated to look for frequency and patterns. The results were reported both as part of the research questions where appropriate, and separately for issues not related to the main research questions.

Chapter 4: Results

This telepresence robot research study was conducted during the spring term of 2021 at a private four-year university in the Pacific Northwest. Four undergraduate humanities courses with a total of 87 students were used for the study. There was a mixture of first to fourth year students. The total number of participants who completed both required study instruments was 71. Forty-four identified themselves as in-person students and 27 as remote students. Thirteen students participated both by video conferencing and robot. All but one video conference student used a robot at least once, and these students were combined into a category called remote learners. The data for the student who only participated by video conferencing was removed from the study because they could not speak to an experience with a robot. This reduced the number of active participants in the study to 70 with 26 participating as remote students (see Table 1). The students took two surveys, the Technology Comfort survey at the beginning that collected demographic data as well as information on their comfort with new technology, and the TEMS survey at the end of the term. During weeks one through six, exit tickets were optionally available to collect ongoing data and open-ended feedback. This exploratory study sought to find answers to the following questions:

1. Is there a relationship between the telepresence robot student's sense of embodiment and their perception of social presence?
2. Is there a relationship between the telepresence robot student's sense of embodiment and their perception of engagement?
3. Is there a difference in the sense of social presence reported by the in-person students and the students attending by telepresence robot?

4. Is there a difference in the sense of engagement reported by the in-person students and the students attending by telepresence robot?
5. What are the instructors’ experiences with telepresence robots?

TEMS Instrument Reliability

Telepresence robot research is still in relatively early stages of use in higher education, and the TEMS instrument has only been used in one published study. The TEMS was built to collect data from both in-person and remote students in blended courses. It includes embodiment, social presence, and engagement scales that addressed the research questions of this study. Although the current study is not directly a replication study of the *Student in the Shell* study (Lei et al., 2019), it provided a chance to further test the TEMS instrument on a larger and broader sample size. The current study can further determine TEMS usefulness for future research related to telepresence robot use in higher education.

TEMS items used a 5-point Likert scale where 1 = *low agreement* and 5 = *high agreement.* One social presence item was reverse coded. After the survey data were collected, a Cronbach’s alpha score was generated based on 47 items directly related to the scale scores on the TEMS instrument. This showed a high level of internal consistency with $\alpha = 0.971$.

Since reliability scores for this instrument had originally reported subscale scores separately (Lei et al., 2019), subscale scores were generated for each individual subscale for comparison and use in the data analysis. The two subscales of concern in the previous small-scale study using this instrument were embodiment ($\alpha = 0.660$) and behavioral engagement ($\alpha = 0.694$) which did not meet the threshold of $\alpha > 0.800$ to show high reliability (Lei et al., 2019). In the current study, subscale scores were calculated for the individual sub scales (embodiment, social presence, psychological involvement, as well as behavioral, affective, and cognitive engagement). Table 2 shows the Cronbach's alpha scores for the individual subscales and combined scales. The internal reliability of the instrument in whole and in part showed high levels of reliability of $\alpha > 0.800$, with the exception of the social presence alpha which was 0.793. This score still represents a reasonably high level of internal reliability.

Table 1

Internal Reliability of the TEMS Items

Subscales and Scales	Cronbach's alpha
Embodiment	0.802
Social Presence	0.793
Psychological Involvement	0.951
Social/Psychological Presence Scale	0.925
Behavioral Engagement	0.870
Affective Engagement	0.933
Cognitive Engagement	0.909
Combined Engagement Scale	0.935

Some of the subscales were combined into larger scales. Embodiment remained as a scale on its own partly because it was only applicable to the remote students and partly to be consistent with the literature review. It is, in part, a measure of the spatial awareness that is part of telepresence (Biocca, 1997; Haans & Ijsselsteijn, 2012). As Biocca et al. (2001) described, social presence is a combination of awareness of others and the awareness of other intelligences. At higher levels of social presence, psychological involvement deepens as students make connections to the intentional cognitive and affective states of others (Biocca et al., 2001). There are separate categories on the TEMS for social presence and psychological involvement. Social presence measures the feeling of being present in the virtual environment while psychological involvement, which includes indicators of intimacy and immediacy, relates to how close one feels to others (R. Garrison, 2011; Lowenthal & Snelson, 2017; Short et al., 1976) and measures the feeling of being present with others. Since those two scales were both intertwined with the concept of social presence they were treated as a combined scale called social/psychological presence. The three engagement subscales, affective, behavioral, and cognitive, were also combined into the third subscale called overall engagement.

Outliers

Several demographics were used to explore the normality of the sample population. In the first boxplots run of the subscale data on the two groups, in-person and remote, there appeared to be one consistent outlier in the in-person group across four of the five subscales that were applicable to them. Upon further investigation, it appeared that Participant 21 had scored 1's on every item, including one that was reverse coded. *Z*-scores were calculated for all subscales, separately and in combination, to determine if these scores were statistically probable outliers with scores greater than ± 2.58. *Z*-scores higher than ± 2.58 indicate probable outliers as they represent data outside 99% confidence intervals (Field, 2013). Four of the five subscale scores for this participant were $z > 2.58$. Therefore, the participant's data were removed from the dataset prior to running any further tests, and descriptive statistics were recalculated.

Two additional students had *z*-scores greater than ± 2.58 on individual scales. Participant 43 scored high on the overall engagement scale ($z = -2.67$). Within that subscale, two of the three subscales (Cognitive $z = -3.36$ and Affective $z = -2.88$) were greater than ± 2.58. Since those categories reflect the student interest in and enthusiasm for the course content and their engagement with the learning, the scores were included because it is reasonable that a student may not enjoy or be interested in a course and therefore gave lower ratings for those reasons, not because of the mode of attendance. The social presence, psychological involvement, and behavioral engagement scores were within normal range, so the student's data were included in the study. Participant 79 scored high on the embodiment subscale (z = -2.69) and the combined social/psychological presence subscale (z = -2.68). The participant's scores on the overall engagement scale were within normal range. The participant's scores were included even though they may be potential outliers because only two of the six subscale scores on the individual scales were above ± 2.58. It is reasonable to assume that this student may have had difficult experiences with the technology that caused their lower embodiment and social presence scores, while it still allowed them to engage with other students and the content.

After removing the data for participant 21, the statistics for the rest of the test analysis were based on a final sample size of 43 in-person students and 26 remote students for a total N = 69 (see Table 1). The recalculated Cronbach's alpha scores, without the outlier, are shown in Table 3. The alpha score for the social presence scale decreased to 0.769 but is still considered reliable. The total Cronbach's alpha score for the instrument as a whole decreased to 0.960. A post hoc statistical power analysis was recalculated in G*Power based on the new lower effect size, which resulted in a power of 0.967, which is still high.

Table 2

Internal Reliability of the TEMS Without Outlier

Subscales & Scales	Cronbach's alpha
Embodiment	0.802
Social Presence	0.769
Psychological Involvement	0.948
Social/Psychological Presence Scale	0.917
Behavioral Engagement	0.855
Affective Engagement	0.924
Cognitive Engagement	0.891
Overall Engagement Scale	0.919

Note: Recalculated alpha scores with outlier removed

Descriptive Statistics

Descriptive statistics were used to test for assumptions of normality in the data. A sample is a small subset of a larger population. If it can be determined that a small sample is representative of the larger population, one can be more confident in making inferences that might be generalized to the larger population (Field, 2013). Reviewing the assumptions prior to running tests also helps determine whether the model being used can be tested with parametric tests, which assume that the data meets certain basic assumptions of linearity, normality of variance, and independence.

All tests were performed using IBM SPSS Statistics Version 28. Descriptive statistics, correlation analysis, and *t*-tests were used to analyze the data in this study. Descriptive analysis allows for both numerical and graphic views of the data to test for normality and determine if parametric assumptions are met. Identifying if data meets or does not meet parametric assumptions determines the type of test needed for analysis.

An independent samples *t*-test compares the differences in mean scores between two groups, in this case the in-person and remote groups, to determine if there is a statistically significant difference in the means than would be expected in a normally distributed population. Correlation tests identify whether there is a statistically significant relationship between variables. Zero scores indicate no relationship but scores between ±1 indicate positive or negative relationships. A positive relationship indicates that if one variable increases the other increases proportionally. Negative relationships indicate that when one variable grows larger the other grows smaller. Correlations cannot determine whether a variable might be causing a change in another variable (Field, 2013). For all statistical analysis in this study a statistically significant difference of $p < .05$ will be used.

Tests for normality included demographic information on the sample group including year in school, number of online courses taken, and the makeup of in-person and remote students in the four courses. Normality was also tested for the three scales, embodiment, social/psychological presence, and overall engagement, as well as on the individual subscales.

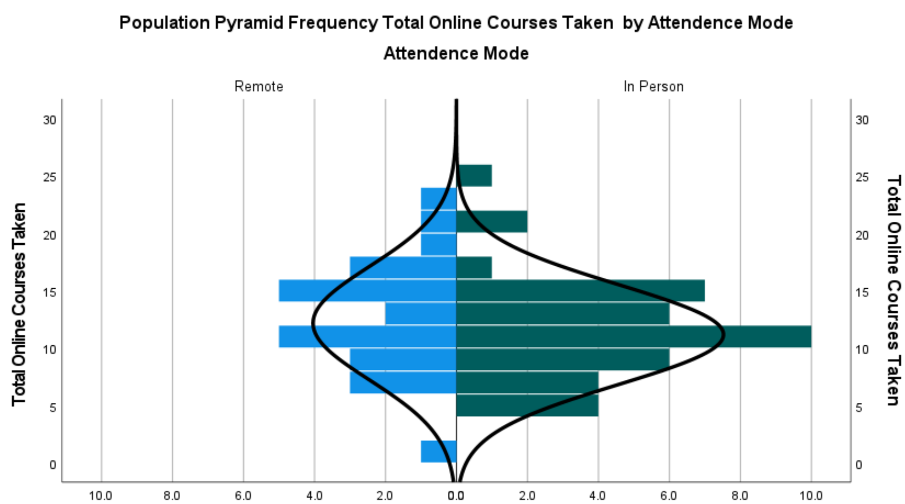
Demographic data were collected about the number of online courses taken, year in school, and gender to help describe the sample group used in the study. The following descriptive statistics helped describe characteristics of this group.

An initial histogram showing the frequency data for the total number of online courses taken by all students in the four courses appears to be a normal distribution with a $M = 11.82$, $SD = 5.06$. When total number of online classes was compared between remote and in-person students, the distribution of both groups appeared to be normally distributed (see Figure 5). The in-person group had a skewness measure of 0.735 (SE = 0.369) and kurtosis of 0.933 (SE = 0.724). The remote group showed skewness of 0.753

(*SE* = 0.456) and kurtosis of 1.60 (*SE* = 0.887). Each group contained a single outlier, at the bottom for remote and at the top for in-person, which contributed to flatter tails. When the in-person and remote groups were tested for normality separately, neither showed significance: in-person $D(41) = 0.118$, $p = 0.159$, and remote $D(26) = 0.106$, $p = 0.200$. Q-Q plots for both groups appeared linear. Box plots for total number of online courses taken by each group showed that the two groups had similar means although the 95% confidence intervals (shown in brackets) were different, with the in-person group at $M = 11.17$, $SD = 4.34$ [9.80, 12.54] and the remote group at $M = 12.85$, $SD = 5.97$ [10.43, 15.26].

Figure 5

Total Frequency Data of Online Courses Taken by Attendance Method

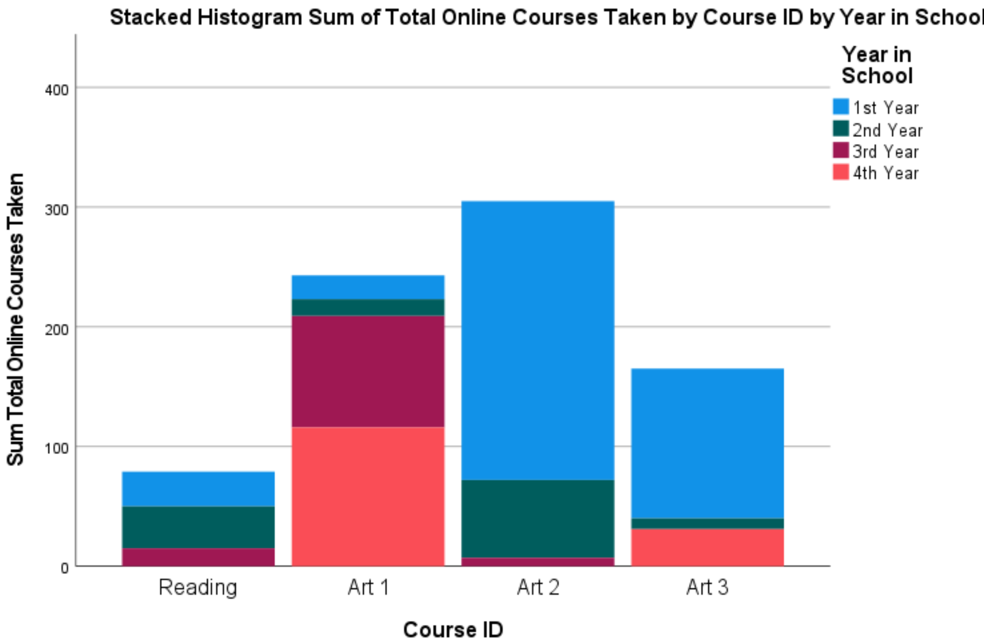


Since *z*-scores had been calculated to look for outliers, P-P plots of the three subscales, embodiment, social/psychological presence, and overall engagement, were created to determine if actual *z*-scores were the same as the expected *z*-scores. All three showed a normal, linear distribution. The scores were all generated from items that had the same 5-point Likert scale and no transformation was needed. The P-P plots of the *z*-scores showed linearity on all subscales.

In other tests of the sample group's normality, it was found that the combined courses were skewed toward having first-year students (55.0%) with a mean of 1.88 (*SD* = 1.12). Second year students made up 14.5% of the classes, third year students 17.5% and fourth year 13.0%. The gender balance was skewed toward females, which made up 81.2% of the participants, while the males constituted 15.9% and non-binary 2.9%. There was no uniformity with the number of online courses taken based on the year in school broken down by course (see Figure 6). All individuals reported that they had taken at least one online course, so all participants had at least some experience with online learning. The previous year of COVID-19 lockdowns and use of online courses may account for the high numbers of students who, in their first year of college, may have only taken online courses.

Figure 6

Total Online Courses Taken Broken Down by Course and Year in School



To check for the potential impact of participants' prior experiences with online learning, a Pearson's correlation was run between number of online courses and all the subscales and scales in the TEMS, which are reported in Table 4. There were no significant correlations between number of online courses and any of the subscales or scales on the TEMS. There were significant correlations between many of the scales and subscales themselves, which will be reported separately.

Table 3

Pearson's Correlations for Online Classes and TEMS Scales and Subscales

	n	*M*	*SD*	1	2	3	4	5	6	7	8
1.Total Online Courses	67	11.82	5.06								
2.Embodiment	26	3.34	0.87	0.31							
3.Social Presence	68	3.18	0.620	-0.17	0.55**						
4.Psychological Involvement	69	3.15	1.00	0.14	0.67**	0.54**					
5.Social/Psychological Presence	69	3.17	0.71	0.03	0.68**	0.82**	0.92**				
6.Behavioral Engagement	69	3.57	0.88	-0.12	0.57**	0.72**	0.36**	0.57**			
7.Affective Engagement	69	3.96	0.96	0.03	0.73	0.47**	0.40**	0.49**	0.51**		
8.Cognitive Engagement	69	4.06	0.82	0.01	0.38	0.54**	0.44**	0.53**	0.56**	0.88**	
9.Overall Engagement	69	3.83	0.77	-0.04	0.52**	0.68**	0.46**	0.46**	0.83**	0.87**	0.90**

Note: **p* < .05, ***p* < .01

Gender and year in school were also possible variables that might have affected the data. To look for possible influences, a 2-way ANOVA was run using gender and year in school with the three main scales (see Table 5). There were no significant interaction effects of gender or year in school on the three scales which means those variables were not likely the cause of variations on the TEMS scores.

Table 4

2-Way ANOVAs of Gender and Year in School with TEMS Scale Scores as Criteria

Variable	ANOVA				
	Effect	F ratio	*p*	*df*	η^2
Embodiment					
	G	0.034	0.856	1,19	0.002
	Y	0.601	0.622	3,19	0.087
	G + Y	0.277	0.761	2,19	0.028
Social/Psychological Presence					
	G	0.183	0.833	2,60	0.006
	Y	1.216	0.312	3,60	0.057
	G + Y	1.916	0.137	3,60	0.087
Overall Engagement					
	G	0.114	0.892	2,60	0.004
	Y	1.063	0.372	3,60	0.050
	G + Y	0.607	0.613	3,60	0.029

Note: N = 69. ANOVA = Analysis of Variance; G = Gender; Y = Year in School.

**p* < .05, ***p* < .01

Descriptive Statistics of the Subscale Scores

Descriptive statistics were run to determine if parametric assumptions were met or if post hoc tests would be needed. Outliers had been previously noted and it was determined that data for two of the participants with outliers would be included in the calculations.

Embodiment

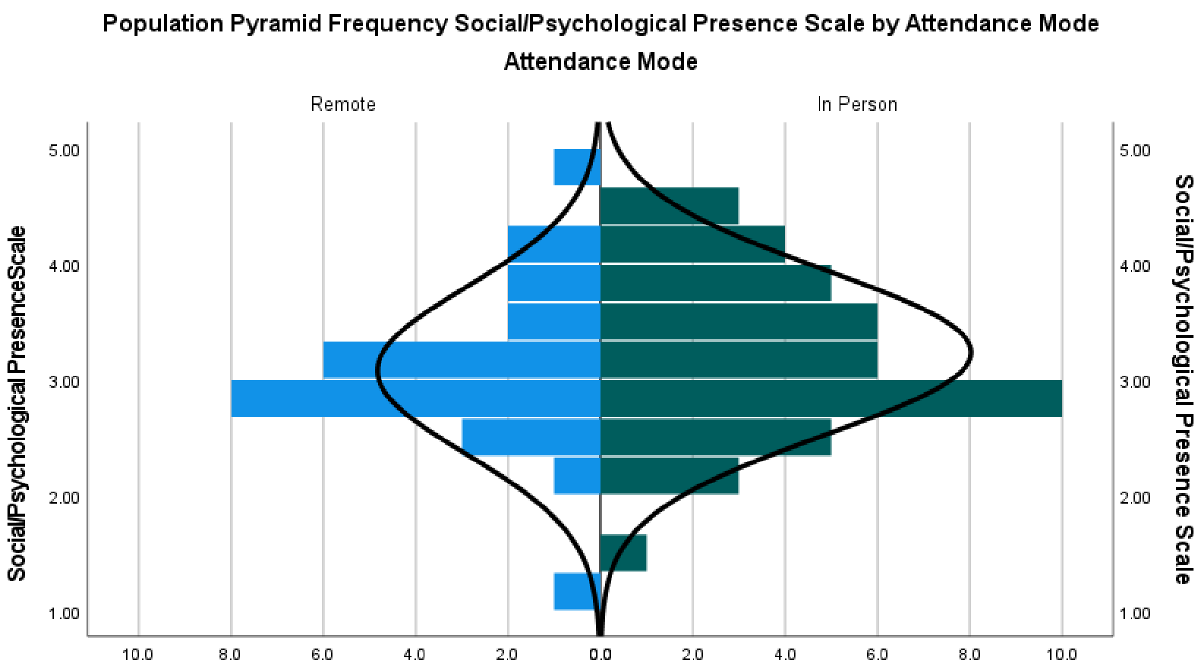
Embodiment was only measured for the 26 students who participated remotely. The mean for embodiment was 3.33, *SD* = 0.868, with skewness at -0.748 (*SE* = 0.456) and a kurtosis of 0.655 (*SE* = 0.887) which indicated the scores were clustered toward the top of the scale and were not symmetrical. Neither *z*-score for skewness nor kurtosis was outside ±2.58. The K-S test showed $D(26) = 0.12$, $p = 0.20$ which was not significant. Neither test indicated that the scores are significantly different than the expected population. One score stuck out as an outlier on the boxplot and was reported earlier as one of the participants whose embodiment measures had significant *z*-scores but were left in the dataset; this lowered the mean, but the Q-Q plots indicated normal linearity for this scale. Levene's statistic was not calculated as only the remote participants answered the questions for embodiment.

Social/Psychological Presence

The combined social/psychological presence scale was measured for both remote and in-person students to ensure normality for each group separately as well as in combination. When considering the in-person and remote students combined, the frequency statistics of the mean showed $M = 3.17$, $SD = 0.71$, with a skewness of 0.086 ($SE = 0.289$) and kurtosis of 0.151 ($SE = 0.570$). There were two scores on the combined histogram that indicated outliers. When the two groups were viewed separately, the mean scores and 95% confidence intervals for each group were as follows: in-person $M = 3.232$, $SD = 0.711$ [3.01, 3.45] and remote $M = 3.075$, $SD = 0.716$ [2.78, 3.36]. The in-person group scores had a skewness of 0.133 ($SE = 0.361$) and a kurtosis of -0.727 ($SE = 0.709$) while the remote group scores had a skewness of 0.016 ($SE = 0.456$) and kurtosis of 1.974 ($SE = 0.887$). The in-person group had a pointier distribution that is slightly shifted to the positive while the remote group had a flatter distribution with heavier tails (see Figure 7). None of the *z*-scores are ± 2.58. The boxplots showed one higher and one lower outlier in the remote group. Removing them resulted in more scores falling outside the smaller confidence intervals and did not change the mean, so the outliers were retained. The K-S test for the in-person group was not significant; $D(43) = 0.116$, $p = 0.165$. However, the remote group, $D(26) = 0.176$, $p = 0.37$, trended towards significance, although the Shapiro-Wilk results were just short of being significant with $W(23) = 0.923$, $p = 0.053$. One final test of normality was run to check for heteroscedasticity or heterogeneity of variance. The Levene's test showed no significant differences in the variances of the means, $F(1, 67) = 0.303$, $p = 0.584$, which indicated that they fell within a normal distribution.

Figure 7

Comparison of Mean Distributions of Social/Psychological Presence by Group

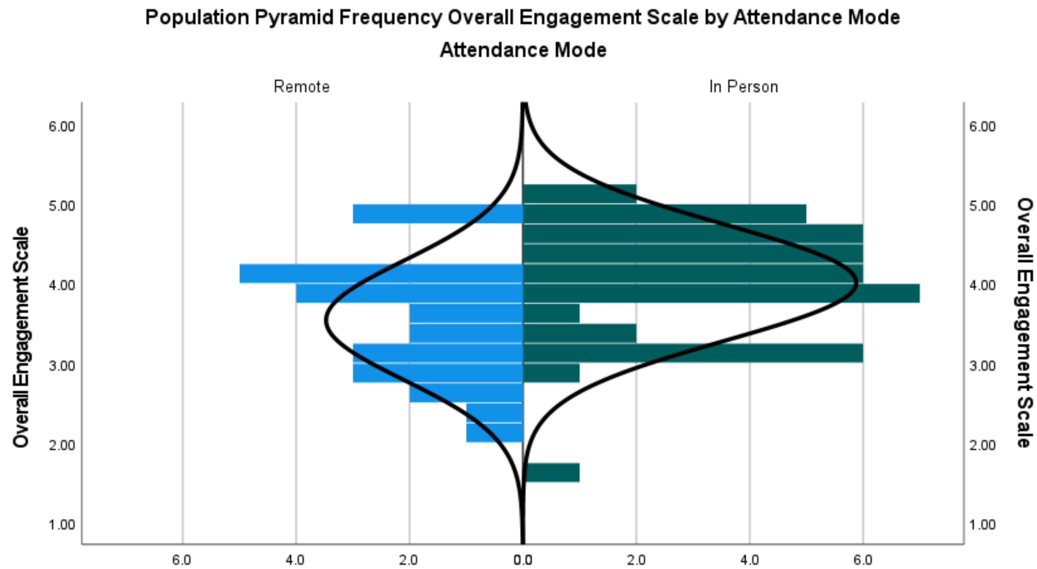


Engagement

The overall engagement scale was also explored for indications of normal distribution for both in-person and remote students. The combined scale frequency statistics resulted in a $M = 3.832$, $SD = 0.766$, with skewness of -0.488 ($SE = 0.289$) and kurtosis of -0.134 ($SE = -0.134$). The histogram showed the cluster of scores to the positive and peaked with short tails. Again, there seemed to be one lower score that stood out in the boxplots, which showed z-scores higher than ±2.58 for the combined engagement scale and was not removed from the data. When taken separately, the mean scores are as follows: in-person $M = 4.01$, $SD = 0.729$ with skewness of -0.965 ($SE = 0.361$) and kurtosis of 1.477 ($SE = 0.709$); remote $M = 3.53$, $SD = 0.74$ with skewness of 0.137 ($SE = 0.456$) and kurtosis of -0.709 ($SE = 0.887$). This was identified in the histogram as a pointed curve with one outlier but heavy tails for the in-person group which was also skewed toward the higher scores. The remote histogram shows a flatter curve but also had thinner tails (see Figure 8). The K-S test for normality showed in-person $D(43) = 0.112$, $p = 0.200$ which was not significant. The remote group was similar with $D(26) = 0.110$, $p = 0.200$. The Levene's test for the combined engagement scales based on the means showed $F(1, 67) = 0.621$, $p = 0.434$, which also showed the homogeneity of the data for the combined engagement scale. The Q-Q plots indicated normal linearity for all three scales.

Figure 8

Mean Distribution of Combined Engagement Scores by Attendance Method



Since the normality scores for the three large scales met the tests for normality for both correlative and independent samples *t*-tests, the following were the results of the tests run to answer the research questions.

Research Question 1

Is there a relationship between a telepresence robot student's sense of embodiment and their perception of social presence?

Questions on the TEMS instrument related to embodiment were only completed by the 26 remote students, as the questions related to their perception of how physically present they felt they were in the classroom, even though they were not actually present. The embodiment subscale included five questions answered on a Likert scale (1 = *low* and 5 = *high*). The embodiment scale resulted in *M* = 3.338, *SD* = 0.868 with 95% confidence intervals of [2.98, 3.68]. There was one outlier whose data was left in the calculations. The overall scale also had a skewness of -7.48 (*SE* = 0.456) and kurtosis of 0.655 (*SE* = 0.887) which meant it was skewed slightly to the top end of the scale. The K-S normality test showed *D*(26) = 0.125, *p* = 0.200 which was not significant.

Understanding the types of questions asked to determine the embodiment scale scores may be useful in later analysis. The results for the individual items on the embodiment subscale are shown in Table 6. The Q-Q plots indicated normal distribution.

Table 5

Student Data: Descriptive Statistics of TEMS Embodiment Items

Survey Items for Embodiment	*M*	*SD*	Var.	Range
I could easily see what I wanted to see.	2.88	1.107	1.226	1-5
I could easily hear what I wanted to hear.	3.31	1.123	1.262	1-5
I felt like people could see me when I wanted to be seen.	3.38	1.169	1.366	1-5
I felt like people could hear me when I wanted to be heard.	3.77	1.107	1.225	1-5
I had a good sense of how I appeared to others.	3.35	1.294	1.675	1-5

Note: *N* = 26; All answer choices based on 5-point Likert scale (1 = *low*, 5 = *high*)

The tests for normality as reported in the earlier section showed that the social/psychological presence scale adhered to the parametric assumptions. This scale also had an acceptable effect size score of *d* = 0.713 which, combined, indicates a stronger chance that results of these tests can be considered a good fit of data to the model.

There was one student who had *z*-scores above the ± 2.58 threshold which indicated a probable outlier in both the embodiment (z = -2.692) and social presence (z = -2.905) scales, and also resulted in the participant's combined social/psychological presence *z*-score being -2.684. Because the same participant's engagement subscales were lower than ±2.58 and within normal range, the researcher determined that there may be other qualitative evidence to explain this, and although the score effected the overall scores for the scales it needed to remain reflected in the results.

Table 6

Correlation of TEMS Scales and Subscales

	n	*M*	*SD*	1	2	3	4	5	6	7
1.Embodiment	26	3.33	0.87							
2.Social Presence	68	3.18	0.61	0.54**						
3.Psychological Involvement	69	3.15	1.00	0.67**	0.54**					
4.Social/Psychological Presence	69	3.17	0.71	0.69**	0.82**	0.93**				
5.Behavioral Engagement	69	3.57	0.88	0.57**	0.72**	0.36**	0.57**			
6.Affective Engagement	69	3.96	0.96	0.36	0.47**	0.40**	0.49**	0.51**		
7.Cognitive Engagement	69	4.05	0.82	0.054	0.51**	0.44**	0.53**	0.56**	0.88**	
8.Overall Engagement	69	3.83	0.77	0.52**	0.68**	0.46**	0.61**	0.84**	0.87**	0.91**

Note: $*p < .05$, $**p < .01$

To examine whether there was a relationship between embodiment and social/psychological presence, a bivariate Pearson's correlation test was run on the two scales with a Fisher's *r*-to-*z* transformation with bias adjustment. The test correlated the 26 remote students' scores on embodiment and social/psychological presence (see Table 7). The results showed a significant relationship on a two tailed test with an effect size of $r = 0.688$, $p = <0.001$. This is considered a large effect size and accounts for over 25% of the variance. Because it is a positive correlation, it also indicates that as one value of one scale score goes up, so does the other value by a proportionate amount (Field, 2013). Given the authentic classroom environment this study was conducted in and the study's design, it is not possible to determine a cause for this relationship.

Research Question 2

Is there a relationship between the telepresence robot student's sense of embodiment and their perception of engagement?

The normality statistics for embodiment and the item statistics were reported in the previous question. The overall engagement scale also met parametric assumptions.

To examine whether there was a relationship between embodiment and overall engagement, a bivariate Pearson's correlation test was run on the two scales with a Fisher's r-to-z transformation with bias adjustment. The test correlated the 26 remote students' scores on embodiment and overall engagement. The results showed a significant relationship on a two tailed test with an effect size of $r = 0.520$, $p = 0.006$ (see Table 7). Because it is a positive correlation, it also indicates that as one value of one scale score goes up, so does the other value by a proportionate amount (Field, 2013). Given the authentic classroom environment this study was conducted in and the study's design, it is not possible to determine a cause for this relationship.

The subscale scores showed that embodiment had a significant positive correlation with behavioral engagement, $r = 0.567$, $p = 0.002$, and non-significant correlations with affective engagement, $r = 0.357$, $p = 0.073$, and cognitive engagement, $r = 0.382$, $p = 0.054$.

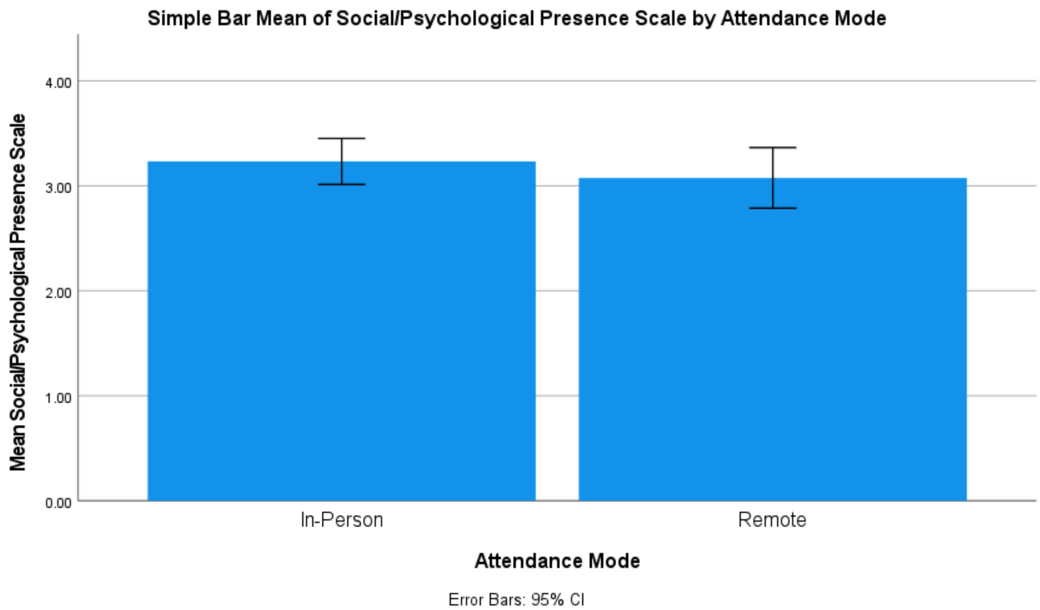
Research Question 3

Is there a difference in the sense of social presence reported by the in-person students and the students attending by telepresence robot?

The social presence scale was made up of 13 items using a 5-point Likert scale (1 = *low* and 5 = *high*). The psychological presence scale also included 13 items using the same 5-point Likert scale. Descriptive statistics for the combined social/psychological presence scale were reported earlier as $M = 3.17$, $SD = 0.71$ with a skewness of 0.086 ($SE = 0.289$) and kurtosis of 0.151 ($SE = 0.570$). The parametric assumptions were met for the in-person group, $D(43) = 0.116$, $p = 0.165$, on the social/ psychological presence scale. There was significance found for the remote students, $D(26) = 0.176$, $p = 0.037$, although the Shapiro-Wilk results were just short of being significant, with $W(23) = 0.923$, $p = 0.053$. See Figure 9 for a visual comparison of means with the confidence intervals. The Levene's test showed no significant differences in the variances of the means with $F(1, 67) = 0.303$, $p = 0.584$. Given that two of the three tests were not significant, a non-parametric test was run.

Figure 9

Means of Social/Psychological Presence by Attendance



Because this research question asked specifically about social presence, both subscales were analyzed separately to examine what might be influencing the slightly non-parametric scores for the remote students on the combined scale.

The combined (all participants) mean scores for each item on the social presence scale were reported in Table 8. There was one student who had *z*-scores above the ± 2.58 threshold; their scores were included in the data but influenced the mean scores and skewness and kurtosis for the induvial items.

Table 7

Student Data: Descriptive Statistics of TEMS Social Presence Subscale Items

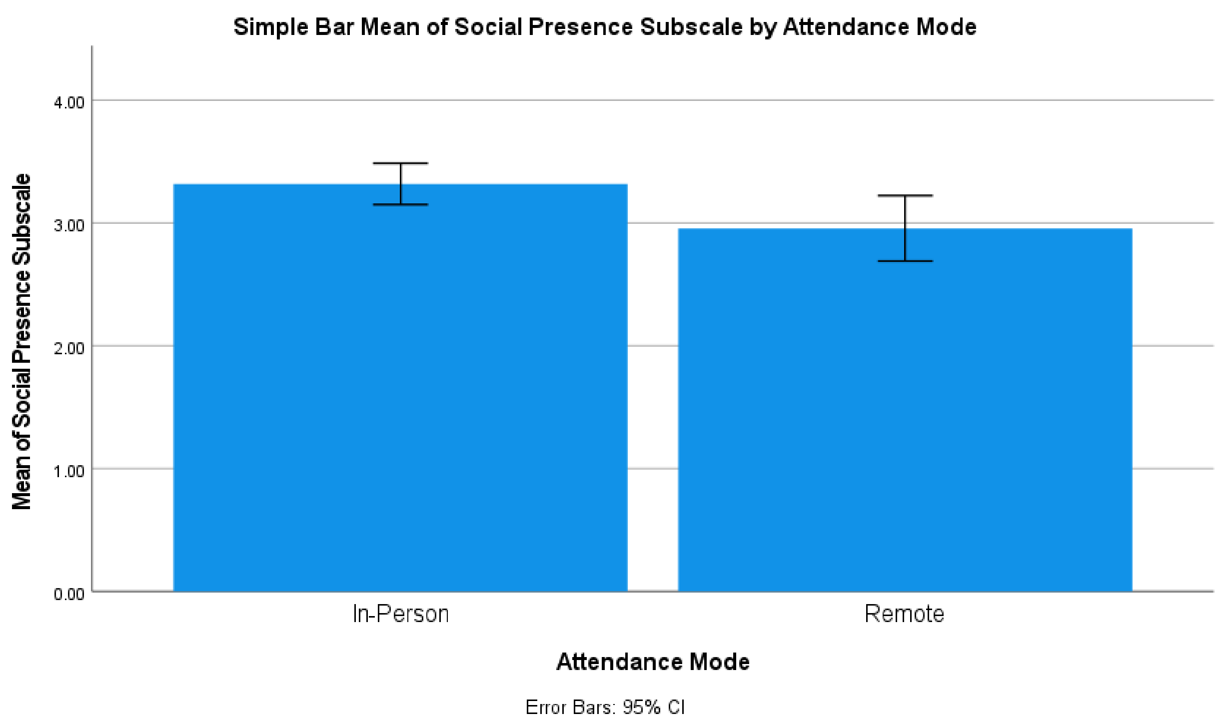
Survey Items for Social Presence	*M*	*SD*	Var.	Range
I felt like I was with those who were physically present in my class.	3.99	1.264	1.597	1-5
I felt like I was with those who were NOT physically present in my class.	2.61	1.166	1.359	1-5
I was aware of those who were physically present in my class.	4.22	.975	.951	1-5
I was aware of those who were NOT physically present in my class.	2.75	1.117	1.247	1-5
I felt close to those who were physically present in my class.	3.38	1.210	1.464	1-5
I felt close to those who were NOT physically present in my class.	2.19	1.123	1.261	1-5
I felt alone during the class (reverse coded).	2.40 4.09	1.384 1.018	1.915 1.037	1-5 1-5
I used VERBAL means (speaking and chat) to communicate with people who were physically present.	3.40	1.317	1.736	1-5
I used NONVERBAL means (gestures, facial expressions, movement, etc.) to communicate with people who were physically present.	2.80	1.399	1.958	1-5
I used VERBAL means (speaking and chat) to communicate with people who were NOT physically present.	2.01	1.144	1.309	1-5
I used NONVERBAL means (gestures, facial expressions, movement, etc.) to communicate with people who were NOT physically present.	3.86	.974	.949	1-5
I could tell when my efforts to communicate reached the intended people.	3.78	1.013	1.026	1-5
I could tell when my efforts to communicate had the intended effect.				

Note: N = 66 (listwise); All answer choices based on 5-point Likert scale (1 = *low*, 5 = *high*). All participants were asked to consider those who were physically present to represent in-person students and those who were NOT physically present to represent remote students.

Looking at only the mean scores on the social presence scale divided into the two groups (see Figure 10) showed the in-person group, *M* = 3.32, *SD* = 0.540 [3.14, 3.48] with a skewness of –0.233 (*SE* = 0.365) and kurtosis of 0.032 (*SE* = 0.717). The histogram also showed a fairly flat, heavy-tailed curve for the in-person group. The K-S test for the in-person group did not show significance, with *D*(42) = 0.111, *p* = 0.200. The mean of the remote group was lower, with *M* = 2.95, *SD* = 0.659 [2.68, 3.22] and a skewness of 0.169 (*SE* = 0.456) and kurtosis of 2.582 (*SE* = 0.887), which was closer to leptokurtic than the combined scale. The K-S test, *D*(26) = 0.146, *p* = 0.162, did not show significance, and the Levene's test for the entire social presence scale also did not show significance, with *F*(1,66) = 0.650, *p* = 0.423.

Figure 10

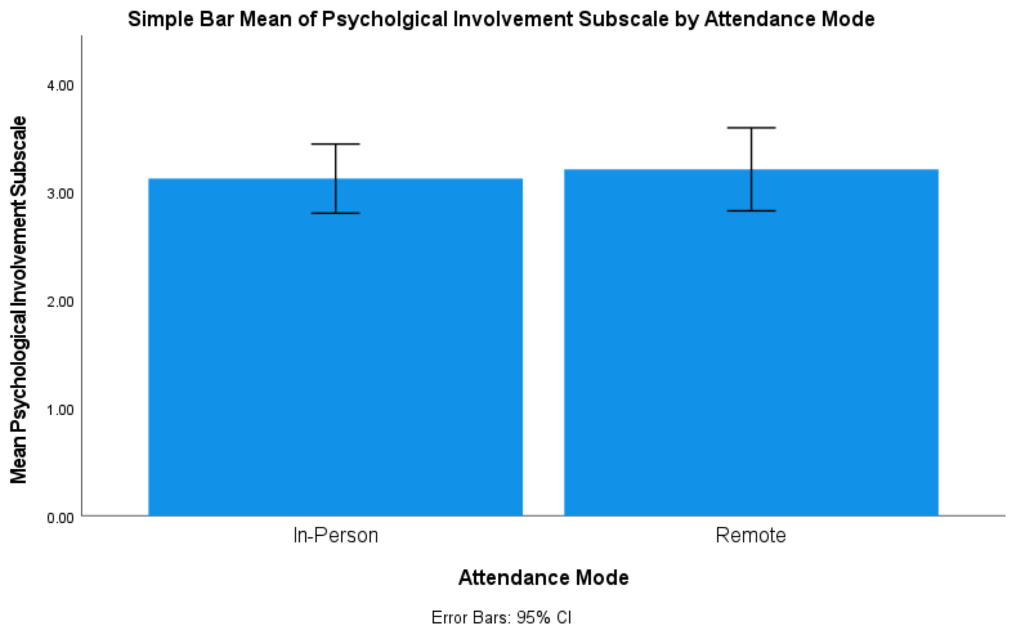
Mean Comparison of Social Presence Subscale by Attendance Mode



If the psychological involvement scale (see Figure 11) is separated from the combined social presence/psychological presence scale, the total mean for the subscale, *M* = 3.15, *SD* = 1.00, is within 0.17 of the mean of the social presence score but the standard deviation is higher. The skewness is 0.269 (*SE* = 0.289) and the kurtosis is -0.574 (*SE* = 0.570). The histogram showed a flat distribution with three spikes at the low, middle, and upper part of the graph. When the scales were separated between the in-person and remote groups, the in-person group, *M* = 3.11, *SD* = 1.04 [2.79, 3.43], had a lower mean score than the remote group, *M* = 3.20, *SD* = 0.951 [2.82, 3.58]. The in-person group had a skewness of 0.290 (*SE* = 0.361) and kurtosis of -0.841 (*SE* = 0.709) and the remote group had a skewness of 0.279 (*SE* = 0.456) and kurtosis of 0.240 (*SE* = 0.887). The K-S tests showed no significance for either the in-person, *D*(43) = 0.118, *p* = 0.145, or the remote group, *D*(26) = -0.153, *p* = 0.119. The Levene's test was also non-significant, with *F*(1,67) = 0.958, *p* = 0.331.

Figure 11

Means of Psychological Involvement Subscale by Attendance Method



As it may also be useful to view the item scores separately, the individual items for the psychological involvement scale are also reported in Table 9. The measurement instrument branched into two different versions of the psychological involvement questions. The remote students were asked to consider their interactions with the live in-person students and the in-person students were asked to consider their interactions with the remote students.

Table 8

Student Data: Descriptive Statistics of TEMS Psychological Involvement Subscale Items

Survey Items for Psychological Involvement	*M*	*SD*	Var.	Range
I felt like I was on the same page as others in the live/remote sessions.	3.20	1.195	1.429	1-5
I felt that others in the live/remote sessions acknowledged my point of view.	3.38	1.214	1.474	1-5
My opinions were clear to others in the live/remote sessions.	3.32	1.118	1.250	1-5
I easily understood how other in the live/remote sessions reacted to my comments.	2.67	1.379	1.902	1-5
I had a warm and comfortable relationship with others in the live/remote sessions.	2.88	1.290	1.663	1-5
	2.88	1.323	1.751	1-5
I felt that others in the live/remote sessions cared about me.	2.41	1.310	1.715	1-5
I felt I was able to be personally close to others in the live/remote sessions.	3.86	1.192	1.420	1-5
I was respected by others in the live/remote sessions.	3.01	1.345	1.809	1-5
I was encouraged by others in the live/remote sessions.	2.70	1.428	2.038	1-5
I was assisted by others in the live/remote sessions.	3.86	1.115	1.243	1-5
I was treated equitably by others in the live/remote sessions.	3.65	1.048	.1.097	1-5
When I compare my experience to students in the other mode…				

Note: N = 68 (listwise); All answer choices based on 5-point Likert (1 = *low*, 5 = *high*).

All participants were asked to consider their interaction with the opposite group when answering, and their version of the questions reflected the change in wording. Final question purposefully left open ended.

Since the parametric assumptions were met for the combined scales and the individual scales, *t*-tests were calculated for all three. The social/psychological presence scale showed that the in-person group ($M = 3.23$, $SD = 0.711$) scored higher than the remote group ($M = 3.07$, $SD = 0.716$). This difference between the means, -0.16, BCa 95% CI [-0.196, 0.510], was not significant, $t(67) = 0.885$, $p = 0.379$. It did, however, show a medium effect size, $d = 0.713$, which indicates that there is a fair amount of certainty that this measured an effect, if there was one present. All *t*-test results for scales and subscales for both remote and in-person participants are listed in Table 10 for reference.

Table 9

Independent Samples T-test Results Between In-person and Remote Participants on TEMS Scales and Subscales

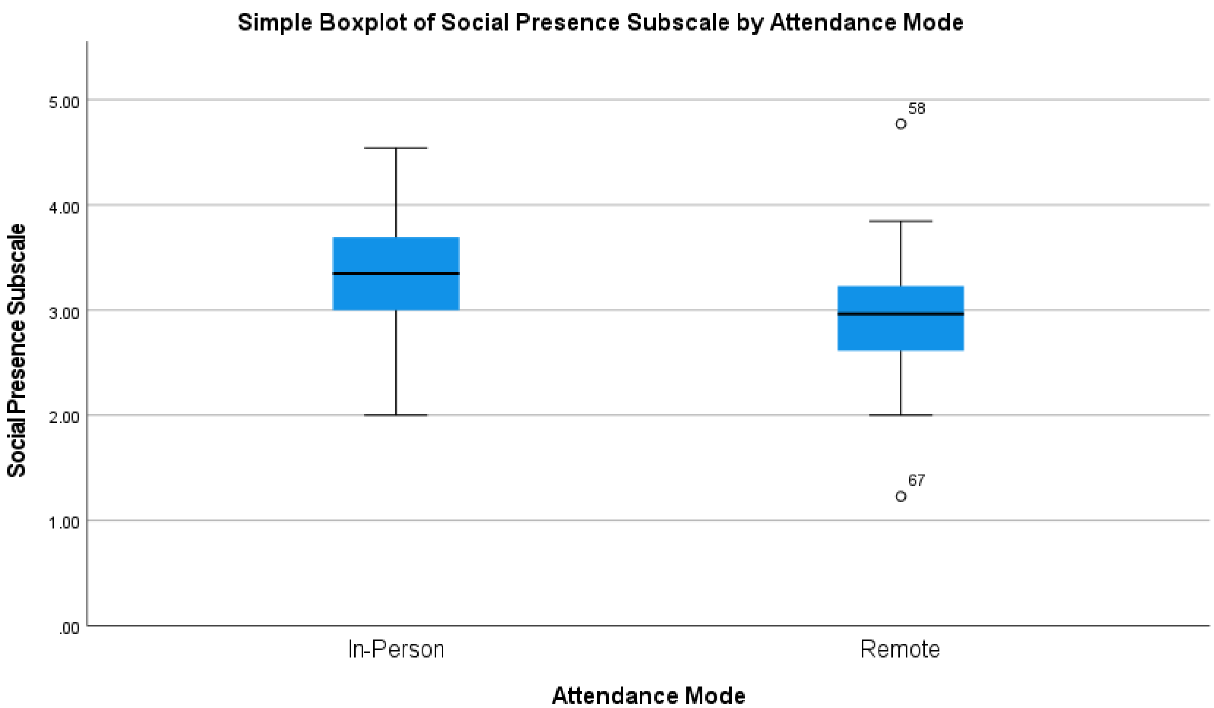
	In-Person			Remote						95% Confidence Interval of the difference	
	n	*M*	*SD*	*n*	*M*	*SD*	*t*	*df*	*p*	Lower	Upper
Embodiment	0	0	0	26	3.338	0.868					
Social Presence	42	3.318	0.540	26	2.955	0.659	2.371	66	0.016*	0.069	0.655
Psychological Involvement	43	3.119	1.040	26	3.205	0.951	-0.34	67	0.732	-0.585	0.413
Social/Psychological Presence	43	3.232	0.711	26	3.074	0.716	0.885	67	0.379	-0.196	0.510
Affective Engagement	43	4.058	0.944	26	3.798	0.969	1.097	67	0.276	-0.213	0.733
Behavioral Engagement	43	3.868	0.773	26	3.074	0.835	4.013	67	0.001**	0.399	1.189
Cognitive Engagement	43	4.147	0.816	26	3.903	0.828	1.193	67	0.237	-0.163	0.654
Overall Engagement	43	4.011	0.729	26	3.537	0.747	2.590	67	0.012*	0.108	0.838

Note: No *t*-score for Embodiment because only remote participants answered embodiment questions. $^{*}p < .05$, $^{**}p < .01$.

Taking the social presence subscale on its own resulted in the in-person group (*M* = 3.31, *SD* = 0.540) scoring higher by a larger margin than the remote group (*M* = 2.95, *SD* = 0.659), that is, by -0.36, BCa 95% CI [0.069, 0.655], which was significant, $t(66) = 2.471$, $p = 0.016$. In this case it showed a lower effect size ($d = 0.588$) than the combined scale. Figure 12 shows the boxplots for the in-person and remote students on the social presence scale by itself. Although the confidence intervals overlap by around 75%, the differences in the samples sizes and the two outliers may have contributed to the significant difference found between the two groups. Although removing the two outliers did not change the mean, it did make the results even more significant, $t(64) = 2.814$, $p = 0.006$, and the effect size smaller, $d = 0.508$, and is therefore not worth removing.

Figure 12

Boxplot of Social Presence by Attendance Mode



Comparing the two groups on the psychological involvement scale resulted in the in-person group (*M* = 3.11, *SD* = 1.040) actually being lower than the remote group (*M* = 3.20, *SD* = 0.951). The difference was 0.90, BCa 95% CI [-0.585, 0.413] and was not significant, *t*(67) = -0.344, *p* = 0.732 (see Table 10). The effect size, however, was, with *d* = 1.008.

Since the parametric assumptions were not met for the social presence scale by itself, the Mann-Whitney non-parametric test was run on the social presence scale to test whether the distribution was the same across both in-person and remote modes of attendance. The data met three of the four assumptions for the Mann-Whitney test (Laerd, 2021). The dependent variable is ordinal (social presence), the independent variable is categorical with two groups (attendance mode), and the observations are independent, but the distributions of the social presence scores for in-person and remote are not the same based on a visual inspection of the histogram. Therefore, the mean ranks were used for comparison. Social presence scores for in-person (mean rank = 39.37) were statistically higher than for the remote group (mean rank = 26.63) U = 341.5, z = -2.584, p = 0.010.

Research Question 4

Is there a difference in the sense of engagement reported by the in-person students and the students attending by telepresence robot?

The engagement scale was made up of 17 items using a 5-point Likert scale with 1 being low and 5 being high. The subscales within that combined scale contained the following number of items: affective (N = 4), behavioral (N = 7), and cognitive (N = 6). Descriptive statistics for the combined engagement scales were reported earlier as M = 3.832, SD = 0.766, with a skewness of -0.488 (SE = 0.289) and kurtosis of -0.134 (SE = 0.570).

The individual subscales were more in line with the combined scale they were part of than the subscales in the social/psychological presence scale. The affective engagement (M = 3.960, SD = 0.955), behavioral engagement (M = 3.569, SD = 0.881), and cognitive engagement (M = 4.055, SD = 0.823) scales showed above average means, and all three skewed toward the positive on the histograms.

When the scores were compared between the in-person group (M = 4.001, SD = 0.729) and the remote group (M = 3.537, SD = 0.747) the mean scores were higher in the in-person group by 0.50. The K-S tests for both the in-person group, D(42) = 0.112, p =

0.200, and the remote group, $D(26) = 0.110$, $p = 0.200$, did not show significance, nor did the Levene's test, with $F(1, 43) = 0.621$, $p = 0.434$. Although the boxplots and histograms showed one outlier, it was decided to include the data for the purposes of the study.

The descriptive statistics for the Engagement scale, including the subscales, can be found in Table 11 for reference.

Table 10

Student Data: Descriptive Statistics of TEMS Engagement Scale Items

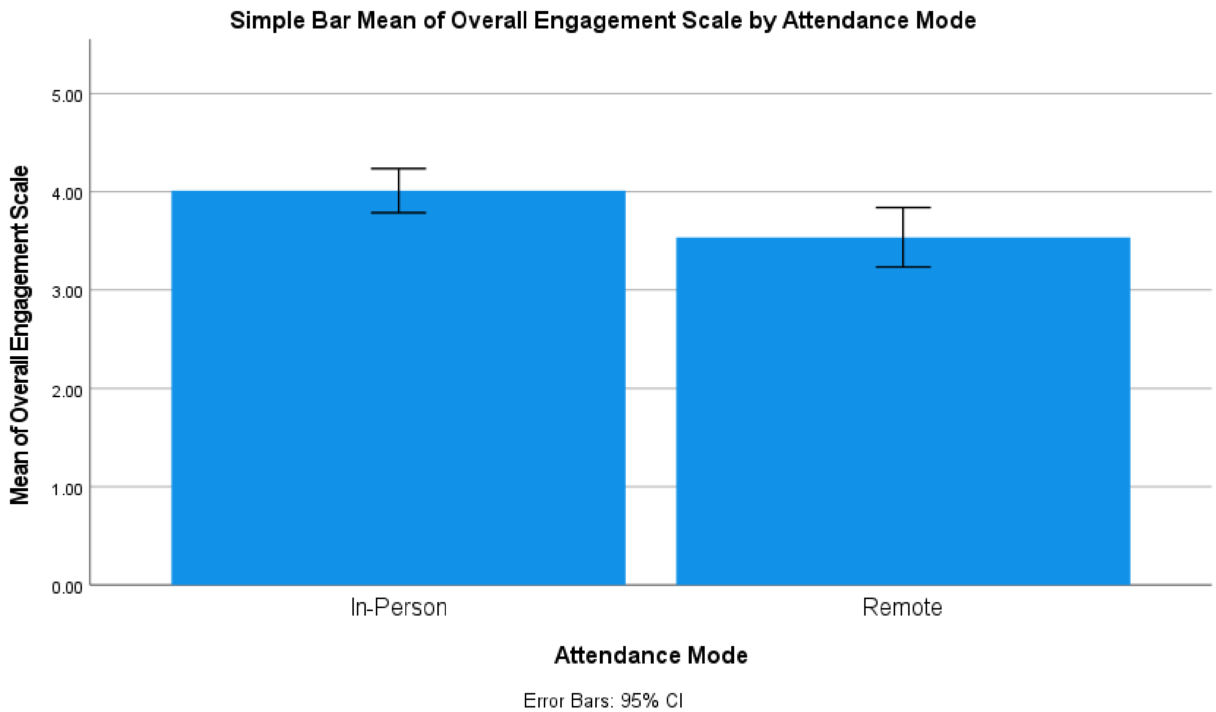
Survey Items for Engagement	*M*	*SD*	Var.	Range
Behavioral Engagement				
I worked with students from this class to complete the course assignments.	2.54	1.530	2.341	1-5
I asked questions in class.	3.12	1.356	1.839	1-5
I participated during class discussions by sharing my thoughts and ideas.	3.71	1.173	1.375	1-5
I discussed course material with the instructor during class.	3.53	1.227	1.507	1-5
I listened attentively to my classmates' contributions during class	4.46	0.884	0.782	1-5
discussions.	3.09	1.292	1.669	1-5
I helped my classmates during class				
(e.g., answer questions).	4.58	0.736	0.541	1-5
I paid attention in class.				
Affective Engagement	3.55	1.157	1.339	1-5
The course material was relevant to my				
life (and/or career/research interest).	4.06	1.042	1.085	1-5
The course was interesting to me.	4.13	1.013	1.027	1-5
I had fun in class.	4.10	1.017	1.034	1-5
I liked the things we covered in class.				
Cognitive Engagement	4.25	0.961	0.924	1-5
I tried to connect new information with				
what I already knew.	3.48	1.313	1.724	1-5
What I learned was important to my future.	4.25	0.864	0.747	1-5
I worked hard in class.	4.32	0.921	0.849	1-5
This course has made me more				
knowledgeable.	3.99	1.000	1.000	1-5
The information in the course was useful.	4.04	1.035	1.072	1-5
I thought about what my classmates said in class even without talking.	3.83	0.766	0.587	1-5
Total Combined Engagement Scale				

Note: N = 69 (listwise); All answer choices based on 5-point Likert scale (1 = *low*, 5 = *high).*

Since the parametric assumptions were met, an independent samples *t*-test was run to compare the combined engagement scale scores between the in-person and remote groups (see Table 10). This test showed that on average, the in-person participants reported feeling more engaged overall ($M = 4.011$, $SE = 0.111$) than the remote group ($M = 3.535$, $SE = 0.146$). This difference, 0.5, BCa 95% CI [0.108, 0.838], was significant, with $t(67) = 2.590$, $p = 0.012$. It also represented a medium effect size of $d = 0.736$. The significance may lie in the fact that the confidence intervals were very small for both groups, and visually they did not overlap by very much, even though their means were within 0.50 of each other (see Figure 13). Since there was one outlier in this data whose *z*-scores were ± 2.58, there was a possibility that the difference in means was due to the outlier, but even with the scores removed the significance remained at $p = 0.012$. Because the sample size of the remote group was relatively small ($N = 26$) a bootstrap calculation was done, which was still significant at $t(67) = 2.590$, $p = 0.012$. The overlap in the confidence intervals was only 0.004, which is a very small window in which the mean population is expected to fall.

Figure 13

Means of Overall Engagement Scale by Attendance Mode



T-tests on the subscale scores also showed significance on the behavioral engagement subscale, $t(67) = 4.013$, $p = 0.001$, but not on the affective, $t(67) = 0.276$, $p = -0.21$, or cognitive, $t(67) = 0.237$, $p = -0.163$, engagement subscales.

Research Question 5

What are the instructors' experiences with telepresence robots?

Instructor feedback was captured twice during the term. Mid-term, they were interviewed by the researcher in a Zoom meeting and asked two questions: 1) What has been going well? and 2) What have been the challenges? At the end of the term, the instructors were sent questions by email to ask 1) what went well and what did not, 2) how their own teaching practices changed, 3) what reactions they could recall from students, 4) why students chose to switch from robot to zoom, 5) whether robot students kept the cameras on, and 6) if they would teach with the telepresence robots again.

Instructor 1 taught the three Art courses. In the Art 1 course there were routinely six or more robots in use during class. The Art 2 course used five and the Art 3 course averaged eight or nine on some days early in the term. During the first two weeks the numbers fluctuated because of misunderstandings by the students about which section they were enrolled in. Instructor 1 assigned robots by week three to make it easier for students to log into the same robot, but they still routinely had six to seven robots participating at a time. The Reading instructor, Instructor 2, taught one course that consistently had three robots each day except for a two-week period when a student in quarantine took advantage of being able to continue attending remotely by robot.

Feedback indicated that the instructors' experiences with robots were positive overall. The negative comments were focused on the technical issues related to connection, the disruptive status announcements delivered aloud by the robots, and the audio difficulties students experienced. More detailed comments will be included in the discussion chapter to provide more context.

Qualitative Feedback

The comments from the open-ended questions in the surveys and exit tickets were combined into one spreadsheet and uploaded to a software program called Dedoose (www.dedoose.com), which was used to collate data, allow for coding, and allow for a second coder to independently code comments and calculate inter-rater reliability scores. All participants had an opportunity to give feedback on both surveys and exit tickets, but the exit tickets were not required. Exit tickets were only captured during week one through six of the 10-week term due to course field trips and other disruptions to the class schedule. Fifty-two of the 69 participants contributed open-ended feedback at least once during the term. Sixteen participants provided feedback two or more times.

After uploading the spreadsheet, the researcher created codes based on the main categories used in the TEMS: embodiment, social presence, psychological involvement, and behavioral, affective, and cognitive engagement. After several read throughs, it was determined that five additional categories should be added: technical sound, technical video, and technical connection, as well as general positive experience and negative experience categories. Excerpts such as *n/a*, *none*, and *no feedback* were removed. The 95 remaining comments were coded and excerpted by the researcher and resulted in 144 excerpts. An inter-rater reliability test was created from 33 representative excerpts of the codes for technical sound, video, and connection, as well as social presence, psychological involvement, and positives and negatives for the robots. The second coder took a reliability test in Dedoose which resulted in a 0.47 pooled Cohen's Kappa score. This represents a moderate level of agreement (Cicchetti, 1994). The agreements on identification of individual codes such as technical connection issues and social presence were much higher at 0.86 and 0.79 respectively. The second coder was less apt to identify negative and positive tags. These tags were primarily used to look at frequency scores to determine how many negative and positive comments were made. The second coder had little experience with the concepts of social presence and engagement prior to participating. After coding the rest of the items, agreement was reached on any discrepancies.

Dedoose reported both frequencies and percentages of the total number of codes used. Both were used where appropriate to describe the data. The following percentages are based on breakdowns of the total number of codes applied to the excerpts. When viewed by course, the Art 3 (28.1%), Reading (28.4%), and Art 1 (29.4%) courses had the highest percentages of negative comments while Art 2 (14.1%) had the lowest. The number of positive comments varied widely by course, with 65.3% coming from the Reading course, which had three active robots during most classes and fewer technology issues. Art 1 had 14.4% positive comments, Art 2 had 14%, and Art 3 had 6.3%. When looked at by mode of attendance, the negative comments were higher from remote students (70.8%) than from in-person students (29.2%). However, positive comments were also higher from remote students (67.7%) than from in-person students (32.3%).

When negative comments were further broken down by the attendance mode in each of the courses, the in-person students showed 71 coded negative comments to the remote students' 127, although the break downs by course showed some similarities. For example, the in-person (31.5%) and remote students (27.5%) in the Reading course showed a similar percentage of negative comments. Art 1 had slightly higher percentages of negative comments for in-person students (29.4%) than remote students (23.6%). The percentages in Art 2 were roughly equivalent with 18.2% for in-person and 18.8% for remote students. The Art 4 course had a higher number of negative comments from the remote students (30.1%) than from the in-person students (21%).

Again, positive comments by course varied, but when broken down by attendance mode, the Reading group still showed higher levels of positive comments, although remote students (61%) were lower than in-person students (72.7%). Positive comments in the three Art courses were higher for the remote students than the in-person students.

Coding for indicators such as embodiment, social presence, psychological involvement, and engagement were analyzed in the open-ended feedback. Social presence, when analyzed by course and attendance mode, showed both in-person (53.7%) and remote (50.2%) students in the Reading class with higher social presence scores than the other courses. The Art 1 course was the most discrepant with social presence codes being applied to 19.8% of the in-person comments and 1.9% of the remote comments. Art 2 showed higher in-person percentages at 20.9%, with remote students at 36.8%, and Art 3 percentages were also lower for in-person (5.5%) than remote (11.2%). Psychological involvement was coded less frequently than social presence but was coded more often in the in-person groups in the Reading (72%) and Art 1 (80%) courses whereas in the Art 3 course the remote students were coded more often (60%).

Behavioral engagement was coded less frequently in student comments. Only two comments in Art 3 were coded for an in-person student and six for remote students. The only other code for behavioral engagement was from the Art 4 course. Affective engagement was coded two times and cognitive engagement was coded eleven times.

The final question asked on the TEMS survey was whether the students would use the robots again if the opportunity was offered in the fall. They were given five alternatives and asked to choose one. All students answered the question, but because the groups sizes were different, the frequencies are displayed in Table 12 as percentages.

Table 11

Participants' Responses to "Would you use the Robots Again?"

	In-Person 45 participants	Remote 26 participants
Yes – I like the robot option	13%	15%
Yes – If I was sick/quarantined, worried about coming back in person, or had job or family obligations	33%	23%
Maybe – if connection issues are resolved	24%	15%
No – I'd prefer Zoom	25%	43%
No – I'd probably not take the class that quarter	6%	3%

Summary of findings

Independent samples *t*-tests and Pearson's correlations were used to compare and analyze quantitative data for four of the five research questions, and an open coding process was used to analyze the qualitative data for the final question. The results of the analysis yielded data that enabled answers to the research questions, the interpretations and inferences of which will be included in the discussion.

Chapter 5: Discussion

The purpose of this quasi-experimental study was to examine students' perceptions of their embodiment, social presence, and engagement in a blended course that included in-person students and students attending as telepresence robots. In this study, both in-person and telepresence robot students were surveyed to examine how their perceptions of social presence and engagement differed. Data on embodiment was only gathered for remote students but was used to look for correlative relationships with social presence and engagement. The results of this study may provide some insight into how telepresence robots can be used as an alternative to video conferencing to help students feel more present and engaged in class. This chapter will present the conclusions from the study as well as examine implications for future practice and recommendations for future research.

Research Question 1

Is there a relationship between the telepresence robot student's sense of embodiment and their perception of social presence?

Past research on telepresence found that telepresence is a combination of spatial presence, or "the extent to which one feels present in the mediated environment, rather than in the immediate physical environment" (Steuer, 1992, p.6), and the feeling of self-presence, or embodiment, which involves the feeling of how closely aligned the virtual and physical self are and how connected one feels to their virtual body. That sense of spatial presence and embodiment is important in experiencing the sense of social presence, which is the sense of being with others (Biocca et al., 2003). The embodiment questions measured the remote students' sense of presence in the classroom and social presence questions measured their sense of being in that space with other people. It was anticipated that this study would yield similar positive relationships between the two. The results of the Pearson correlation analysis showed that there was a significant correlation, $r = 0.688$, $p = <0.001$, between embodiment and social/psychological presence. In other words, remote students who perceive a high level of embodiment will likely sense a high level of social presence. This is important in a learning environment because remote students do not have the same environmental cues and cannot naturally use their senses as in-person students can to feel part of the class. A student who has a low sense of social presence may feel a low level of embodiment or actually feel invisible in the classroom, especially if they are not recognized by others as being present in the room. It would be difficult to establish oneself as a part of the learning community if no one has realized you are there. One student, who did not have a positive experience, or felt that the robot did not allow for enough of a feeling of embodiment to make them feel socially present, mentioned the following:

> I was on the robots the first week and couldn't stand it, so I switched to in-person. As an introvert I already feel isolated in social settings when I'm there in person but being on a robot put this feeling on steroids. It was hard to hear, hard to see, and I had a hard time working up the courage to speak (especially because the prof. won't really see if you raise your hand so you just have to blurt out your answer, which feels really rude). I was very distracted the whole time because I felt so awkward and frustrated. When I came in person, I actually found myself enjoying the class and remembered that I actually am a very vocal student who likes to answer questions (zoom

and the robots don't have raise hands features, which makes me feel rude and impolite when I answer questions). (Participant 64)

However, this was not the common experience for the remote students. Embodiment and social presence have been linked since the early development of social presence theory which acknowledged the importance of the contribution of the body to communication and connection with others. The concept of social presence is mediated by how well the technology allows for the transmission of physical feedback like gestures, body language, and facial expressions in order to feel more socially present (Short et al., 1976). The earlier student felt the lack of the ability to raise a "hand" to indicate wanting to participate, but other participants in this study were very cognizant of embodiment and social presence connections even from the first week. Embodiment involved being seen and heard, hearing and seeing others, and having a sense of how they appeared to others, while social presence included the awareness of others and the verbal and nonverbal communication cues they used and looked for in others. When participants were asked what questions they had or what support they needed during the first week of the study, in-person students responded by asking "How do I best speak in order to be heard by the robot?", "How do I better interact with the robots and online students if I am in person?", and "Where do you look at the robot?". These comments show a recognition that the robot represents a person in their physical space and that the students have concerns about how best to include them as social members of the group by being able to speak to them and look them in the "eye." Remote students showed concern for how their "bodies" would interact with others through comments like "I do not want to hurt anyone with my robot body or damage the robot itself", "What is the in-person student's point of view?", "When I turn, do they hear those noises? Does it (the noise) distract them?", and "How do I know if everyone can hear me when I speak?". At one point an in-person student rolled a robot out into the hallway for partner discussions, and the student represented via robot said, "It is really weird to be moved by other students", which suggested that the student felt as if they themself was being moved. Not only does this show awareness of the robot body as a representation of themself in the classroom, but also shows that they are seeking out the social cues they feel they will need, such as not interrupting and knowing if others can hear them, in order to communicate with others socially.

Students perceived a positive relationship between social presence and embodiment, despite the many audio and video issues that could have potentially affected their scores. Audio and visual cues are the primary way remote users have of communicating the nonverbal and verbal cues and facial expressions necessary for communication. Although there was a significant relationship between embodiment and social presence, some of the participants' comments were negative, specifically those related to audio experiences. In-person students reported that it was difficult to hear when multiple groups were talking at once because the sounds overlapped. One remote participant mentioned, "It was challenging to have conversations with other robot students because I could not see their faces very well, and it was hard to discern where the voice was coming from when everyone in class was talking." A major challenge specific to the use of telepresence robots in a hybrid setting during the pandemic was mask-wearing by the in-person students. One remote participant said, "It was difficult to engage with the in-person students because they were wearing a mask. Wearing a mask definitely made it more challenging with trying to communicate or interacting with them more." An in-person student also commented that "since the people in class have masks, it may be difficult for those who are on a screen to tell when their classmates are talking, especially when we are in small groups, and everyone is talking at once."

The masks took away the facial cues and expressions that help with communication, which made it somewhat surprising that results were significant. However, the mask wearing did affect both the in-person and remote groups similarly, which ensured that one group was not experiencing the discussions differently than the other. If the audio issues can be resolved, the experience might be smoother and the comments more positive from the participants, but that should only reinforce the relationship between embodiment and social presence. If the remote participants' experiences are almost like being there in person, it may become an attractive option for remote students who want to feel like they are present with other learners in their class.

Research Question 2

Is there a relationship between the telepresence robot student's sense of embodiment and their perception of engagement?

This question was asked because there is some research that suggests that behavioral engagement specifically was an important characteristic of higher levels of social presence where actions were linked, reactive, and interdependent (Biocca et al., 2001). A person would exhibit higher behavioral engagement as their sense of social presence and psychological involvement increased. Biocca et al. (2001) maintained that the three conditions were hierarchical and that deeper levels of social presence were attained by activating earlier layers. For example, a feeling of co-presence would need to be activated before one could feel psychological involvement and that would precede additional feelings of behavioral engagement. Since results from the previous research question show that there is a significant relationship between embodiment and social presence, and Biocca et al.'s (2001) research shows a connection between social presence and behavioral engagement, then one could speculate that there is also a relationship between embodiment and behavioral engagement.

The Pearson's correlation test showed that the remote students' perceptions of embodiment did have a significant correlation with behavioral engagement, $r = 0.567$, $p = 0.002$, but non-significant correlations with affective engagement, $r = 0.357$, $p = 0.073$ and cognitive engagement, $r = 0.382$, $p = 0.054$. This result supports the idea that as a student feels more embodied as a telepresence robot, they feel a stronger sense of being present in the classroom with others. This sense of embodiment allows them to be more engaged with others by participating in discussions, asking questions, listening, and acting out other behavioral engagement indicators. Affective and cognitive engagement are likely less effected by physical presence as they are more internal mental processes.

The collection of qualitative data to reinforce the relationship between embodiment and behavioral engagement was made difficult by the choice of recording equipment that was used for recording class meetings. The Owl-360 camera did give a full view of the room but did not provide enough resolution to clearly distinguish faces on the robot students' screens. This made it impractical to be able to view and code indicators of behavioral engagement. There was evidence that robot students did participate in discussions and ask questions, although it was couched in comments made by students about the difficulties, such as "it was difficult for the robot students to hear people talking, especially if there were overlapping sounds or multiple group discussions." Behavioral engagement is not something that students would naturally reference in open ended comments. It is unlikely a participant would say they were not paying attention in class or not listening attentively in the comments. They did say that they had trouble hearing others because of the echoing nature of the room and the quality of the audio, but that is different than listening as a part of a learning discussion with their fellow class members.

Higher quality video equipment more strategically placed in multiple points in the room would be necessary to capture the verbal and nonverbal conversational cues, the facial expressions, and the indicators of active listening and asking questions that would indicate behavioral engagement. That will be a consideration for future follow-up studies.

Research Question 3

Is there a difference in the sense of social presence reported by the in-person students and the students attending by telepresence robot?

The in-person and remote students had different experiences in class, and it is important to explore those differences to understand how the robots may have affected the groups. A *t*-test was used to investigate whether there were significant differences between the in-person and remote groups on the social/psychological presence scale. There was not a significant difference, $t(67) = 0.885$, $p = 0.379$, between the two groups when using the combined social/psychological presence scale, although the in-person group's mean scores were higher. However, when the two subscales were separated and compared for the two groups, there was a significant difference between groups on the social presence subscale, $t(66) = 2.471$, $p = 0.016$, with in-person participants perceiving higher social presence. There was a non-significant difference on the psychological involvement subscale, $t(67) = -0.344$, $p = 0.732$, with the remote students' mean scores just 0.13 higher than the in-person students. The negative *t*-test score means that the differences were to the left of the mean. To take a closer look at what this might mean, each subscale will be addressed separately.

For some context, the social presence subscale asked questions about both the in-person and remote students. For example, both in-person and remote students were asked to rate both of these statements: "I felt close to those who were physically present in my class" and "I felt close to those who were NOT physically in my class." The psychological involvement items specifically asked groups to consider their perceptions of the opposite group. For example, the in-person group answered the question "I felt like I was on the same page as others in the remote group" while remote students answered the question "I felt like I was on the same page as others in the in-person group." This makes it more challenging to separate the perceptions in these two subscales.

It is understandable that in-person students might score as more strongly socially present because there are a mix of questions relating to both in-person and remote students. They may have felt more socially present with other live students because that is the norm, and the robots are a new experience. Conversely, it may be that lower social presence scores for remote students were not solely because of the robots but because the technical issues made them feel less "there" with their classmates. The difficulty in being able to hear and be heard in small group conversations and the discontinuity in being repeatedly disconnected from the robot may have contributed to a feeling of being less present with their classmates. Although the pandemic has taught everyone to be more patient with dropped connections or unstable internet, it is likely in-person students and the instructors carried on with class discussions and lectures in these instances, while students who were disconnected might have felt a little lost after having missed parts of class. In-person students may have found it difficult to connect on a personal level with robot students because the technology issues got in the way of more natural conversation and interaction.

Remote participants, who were also answering questions on the social presence scale about both the in-person students and other remote students, may have had lower scores in part because they had little opportunity to interact directly with other robots and therefore no basis to score those questions higher. The deliberate spacing in the room because of social distancing protocols kept the robots six to ten feet apart depending on which robots students signed into. Unless the instructors deliberately paired them up, which did happen occasionally, it would be difficult to interact. Another possible cause might be the design of the robot and the challenges of learning to maneuver the robot. One remote student commented that it was difficult to talk to other robot students because they could not see faces well on the other robots' screens and they could not tell where the voices were coming from when everyone was talking at once. During one visit to class by the researcher, a student said they found it hard to sit and talk to the robot because the robot screen was higher than a sitting student, and lower than a standing student. This lack of flexibility for the robot to adjust its "eye-level" made it difficult for both participants to look at each other directly. Being able to see the board or PowerPoints on the screen was also a frustration, despite the ability to zoom to 3x normal view. It is posited that this was partly due to the angle toward the board or screen to which the robot participant might be orientated. Also, students had become used to seeing presentations in Zoom sessions on their computer screens and being back in a classroom where they might not always have a full view of the screen was not ideal.

The questions on the TEMS survey asked social presence related questions about whether they felt “with” the other students or felt alone and whether they used verbal and nonverbal gestures and facial expressions to communicate with each other. A remote participant reported, “I couldn’t talk to other students or even nonverbally exist in the room alongside them, and I wasn’t able to learn without being distracted, disconnecting, or not being able to see what was being spoken about.” If the participants cannot see and hear each other well it would not be surprising that they marked the social presence questions lower. An in-person student noticed that the robot students were “very disconnected” from class discussions.

At first glance, the higher scores for remote participants on psychological involvement seem anomalous. As discussed in the last question, social presence is the sense of what Biocca et al. (2003) coined “being there with others,” and psychological involvement involves the feelings that one recognizes and has access to another’s intelligence (Biocca, 1997). Others have called it the “realness” of interpersonal relationships (Short et al., 1976). Some participants did get a sense that the robots were people too. One in-person student showed a great deal of thoughtfulness toward their remote classmates by mentioning:

> Referring to students as ‘robot people’ is not a good way to communicate value and respect. I think if we referred to students by their names instead of ‘the students who are using the robots,’ they will feel more included. (Participant 19)

Another participant suggested that the robot participants needed a way to type their name in so that it would appear on their screen. It is interesting that they did not also suggest that the in-person students wear name tags so the remote students could address them by name, but it is possible that this request stemmed partly from their experience with having names on the screens when in synchronous Zoom meetings.

Since the remote students were answering the psychological involvement questions about the in-person students, it is possible that the slightly higher scores were due to the efforts of the in-person students to empathize with and try to include the remote students. The difference in this case was small and non-significant, which suggests that the robot itself is not harming the remote students' sense of connectedness with their in-person peers, and in fact the remote students feel similar levels of understanding, closeness, and respect as the in-person students, and were treated equitably by others. It would be interesting to compare students who used purely video conference methods of attending with telepresence robot participants, to explore whether psychological involvement stays close to equal with in-person students over time, or if the robot enhances that feeling because they have a presence in the room that video conference students do not have to the same extent.

The instructors may have also contributed to helping remote students feel a sense of psychological involvement. One instructor reported calling on robot students more often to keep them engaged, which may have also contributed to a sense of inclusion. The in-person students did make several positive comments about the experiences. One said, "It has been interesting having robots as classmates. It's cool that we still have the opportunity to interact with our classmates even if they aren't here in person." A few students said that “using robots is a good alternative to in-person class” as long as the audio and connection issues were addressed. One robot student, who must have felt a stronger sense of social presence despite the technology issues, reported that they “like that the dynamic feels more like a regular classroom” which was echoed by another remote student that said they were “grateful for an opportunity to feel more ‘in’ class than joining class via Zoom.” This positivity was experienced by in-person students as well; one mentioned that “they had a presence in class almost similar to in-person students,” and another said:

> Being a student in the classroom talking to the robots was a very interesting experience. Having the robots is much better than having students on Zoom. I felt more connected to the robots than students on Zoom in my other blended classes. (Participant 13)

Despite the technology issues, it is interesting to note that there was no significant difference between the two groups on the social/psychological presence scale as a whole. The remote students did score lower but it’s possible that the technology issues had an impact on that. In other studies of social presence, including at least one that compared in-person, video conferencing, and robots (Fitter et al., 2020), the social presence scores have put the robot experience somewhere between the in-person and video conferencing experience on survey results. When participants were asked what mode of participation they preferred after that study, the majority preferred in-person, followed by video conferencing, with the robots only being preferred by one or two students. Based on the evidence, it would be expected that robots would have been the second choice, but there is also the newness factor to consider. Telepresence robots are not yet widely used in higher education. Even five years ago some students would have felt highly uncomfortable with video conferencing, but the pandemic has pulled the band-aid off the newness of video conferencing to the point that some may now prefer it over in-person learning. One remote student commented, “It still feels unnatural communicating and being active in a lecture setting but it is something everyone should get used to over time.” Table 12 shows the final question on the survey taken during this study, which asked students to consider their preferences if they had the chance to use the robots fall term. Seventy percent of in-person students would prefer or would choose the robots over Zoom if the technical issues were taken care of. Only 53% of remote students would prefer robots over Zoom, but they were the ones experiencing those technological issues firsthand.

Research Question 4

Is there a difference in the sense of engagement reported by the in-person students and the students attending by telepresence robot?

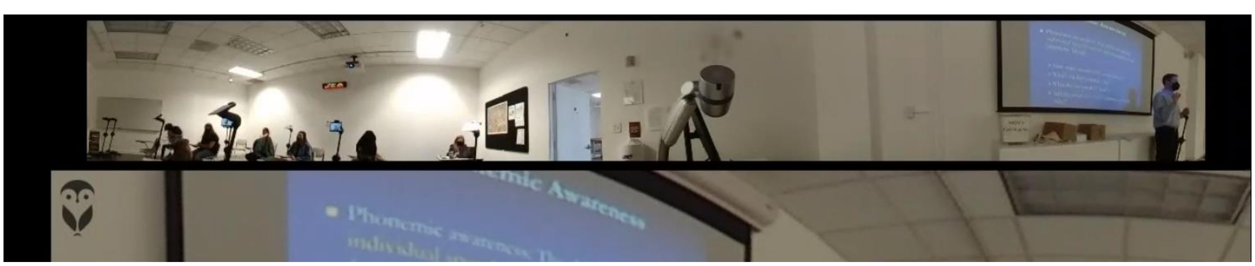
The *t*-tests of the two groups showed significant differences on the overall engagement scale, $t(67) = 2.590$, $p = 0.012$. The in-person group ($M = 4.011$, $SE = 0.111$) scored 0.5 higher than the remote group ($M = 3.535$, $SE = 0.146$). It also represented a medium effect size of $d = 0.736$, which makes it a reliable indicator of the strength of the differences. The confidence intervals were also very narrow for both groups and did not overlap by more than 0.1. Narrow confidence intervals indicate more precise population estimates and when they do not overlap it is possible that they come from different populations (Field, 2013). Sometimes, smaller confidence intervals occur when the sample sizes get larger but in this case the sample size for remote students was smaller.

In order to dig deeper into why the significance exists, it may be useful to look more closely at the items on the subscales. Three of the lowest means on engagement subscale items may have been impacted by the technology: “I worked with students from this class to complete the course assignments” (*M* = 2.54), “I asked questions in class” (*M* = 3.12), and “I helped my classmates during class (e.g., answer questions) (*M* = 3.09). These three items involve communication between classmates that were likely affected by the technical issues experienced by some students.

The original hope was to use the recordings of the class sessions to find evidence of behavioral engagement by coding behaviors such as asking questions, using facial expressions, participating in discussion, and asking for help. Unfortunately, the Owl camera, while it did give 360 views of the room, did not allow for differentiating voices during discussions. If the robot was turned away from the camera or placed at the back of the classroom or in the hallway, it could not pick up behaviors. Also, the 360-video portion could not be enlarged (see Figure 14).

Figure 14

View of 360 Camera Display



In the three class videos that were reviewed, there was evidence that the robots closest to the professor, which were captured on video, would turn toward a speaker who was talking across the room. Once, it was observed that a telepresence robot student raised their hand in the video when the professor asked a general question. Counting the frequency of instances during which the robots used their ability to turn themselves toward the speaker is not an accurate measure of engagement because each class instructor used differing levels of classroom discussions. A better method would be to count instances over time to see if the participants engaged more frequently in behavioral engagement activities as the term went on and they became more comfortable with their robot bodies. There were several instances in all four classes where the instructors asked questions or had small group discussions. Students were actively engaged in discussions in the first two weeks of class when the researcher was observing in person. It was also noted that some telepresence robot students, who had previously met classmates outside of this class, were chatting informally with in-class students before class started.

Beyond the issues previously discussed with the audio quality, there were several comments indicating some measure of affective engagement. Participants thought it was "cool" to work with the robots. A remote student commented that they were "glad that there was a way for me to interact with my in-person classmates in the classroom as a telepresence robot." Another said about their experience as a robot:

> I am enjoying the experience. While I did find it very strange and new at first, I am used to it now and find myself excited for class, not only because of the interesting robot experience, but also [sic] my friends and a great professor of

course. (Participant 10)

A few also commented on cognitive engagement related issues, although these were fewer, possibly because this was a survey about the robot experience and not specifically about what they learned in class. One student expressed enjoyment over learning the course material and learning more about post-impressionist artists. Another student was frustrated with the video quality, not because it did not work consistently, but because it kept them from using the robot that was in the “perfect place for me to see the whiteboard and the professor as well.” An in-person student reported frustration over the time the instructor had to spend troubleshooting issues with the robot and that it was “taking away valuable class time when we could all be learning.” There may need to be some consideration regarding the placement of robots in the classroom so they have a clear view of the screen or allow them the freedom to put themselves in places where they can see. The zoom features on the robot do allow students to adjust the magnification of their view but the camera view is not the same as one would view in person. However, some consideration also needs to be given to the in-person students, as a telepresence robot student could potentially station their robot directly in front of the in-person students because they might not have the same sense of boundaries that they would have in person. It would be important for instructors to set norms in the classroom for spaces for robots and humans, to ensure that everyone has a clear line of sight for presentations but also the flexibility to move into smaller learning groups.

Although the significantly lower overall engagement scores for remote students could be attributed to the technical issues, it is also possible that it is just more difficult to engage as a robot. Instructor 1 may have provided fewer opportunities for interaction and mentioned in the feedback that their students were "probably less and less inclined to do group work over the course of the quarter, because the robot students had a lot of difficulty distinguishing their group members' speech from the speech of others in the classroom." The instructor did more "cold calling" on robot students and felt like they disengaged a bit because of the technology issues. The lack of good video evidence to track and analyze observable behavioral engagement indicators such as facial expressions, body language, raising hands, asking questions, etc., makes it difficult to corroborate the instructor's impression that telepresence robot students were less engaged. Instructors will need to be more cognizant of looking at the screens of the robot students when they ask questions because there is currently no other way for a student to indicate they want to answer a question other than raising their physical hand at home or potentially interrupting someone.

One interesting difference between engagement on Zoom and with the telepresence robots was related to how often students left their cameras on. During the pandemic, having students shut down their cameras during synchronous learning has become widespread (Nicandro et al., 2020). One study surveyed 312 university students about their reasons for turning off their cameras (Castelli & Sarvary, 2021). The study was particularly interested in differences between underrepresented minorities (URM) and non-URMs. Concern for their appearance was the highest rated reason with 45% of URMs and 38% of non-URMs endorsing this reason, and concern about people in their screen background being seen was the next highest, at 38% and 24% respectively. The instructors in the current study, however, noticed that the robotic students, for the most part, were leaving them on. Instructor 2, when specifically asked about camera use said, “The telepresence robot students always kept their cameras on. This is better than what I experienced in prior quarters with Zoom students, who often did not keep their cameras on when attending our in-person (hybrid) sessions.” Instructor 1, who had more technology issues because of the number of robots being used in class, said that students with connection issues generally kept them off but still had them on more often than the Zoom participants. However, a very good point was made that the students on Zoom were projected on the big screen at the front of the class and may have been incentivized by that to keep their cameras off so they would not have their faces staring out from the projection screen. It is also possible that part of the explanation is that Zoom students can see others’ faces and backgrounds up close. Robotic students can be seen by whoever is looking at them but there is not the same sense of being on “camera” as there is with Zoom because no one is sharing the screen with them.

Making eye contact with people plays an important part in developing social connections (Jongerius et al., 2020). Being able to look classmates in the eye as opposed to the often sideway views of people in Zoom, who are looking at the faces of the people on their screens and not at their cameras, makes the interactions feel more natural, which may be part of the reason students leave their cameras on more often. This would make an interesting follow-up study on engagement to see what role eye contact plays in the perception of engagement and how it manifests itself differently between telepresence robots and video conference participants.

Research Question 5

What are the instructors’ experiences with telepresence robots?

The instructors' experiences were fairly positive overall, although one had a much smoother experience than the other. The smaller number of active robots in a room (see Table 13) seemed to have had an impact on students' overall experience in the Reading course (see Figure 1). That course used three robots for all meetings, with the exception of a quarantined in-person student who used a robot for one session. The overall mean scores for all three scales were higher for the Reading course than the other courses. Embodiment was only measured for the remote students, and the social/psychological presence and engagement scores included all students. The Art 2 course was large and was split in half for in-person meeting days in order to maintain social distancing. One class used three robots and the other used four, although there were five remote participants that were part of the study group. Instructor 2 reported that there were fewer problems with the smaller number of robots in Art 2, which is reflected in their higher embodiment scores. However, their engagement scores were lower, and the reason why is not clear.

Figure 15

Stacked Histogram of Means for Three Scales by Course

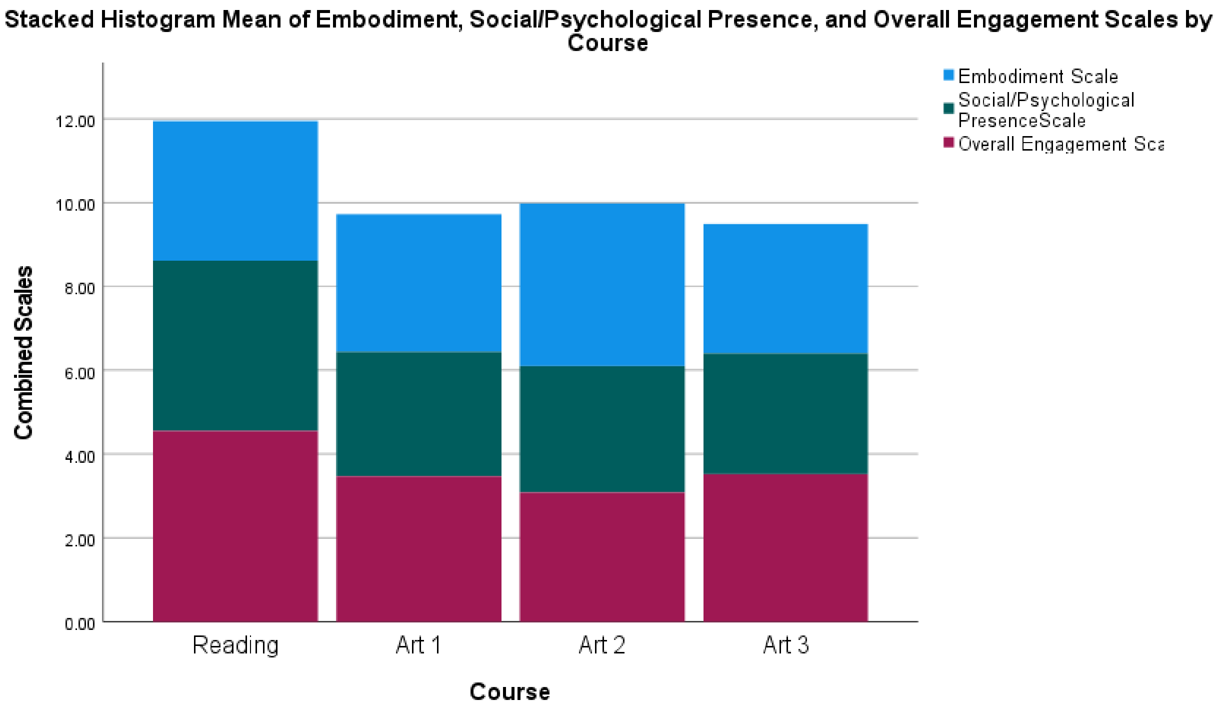


Table 12

Numbers of Remote and In-person Students in Courses

Course	Number of Remote	Number of In-Person
Reading	3	5
Art 1	6	13
Art 2 (split into 2 meeting times)	5	21
Art 3	9	8

The instructors’ comments were coded using the same set of codes as the student data, and their perspectives on embodiment, social/psychological presence, and engagement were similar to their students. In terms of embodiment, both instructors liked "having all students together in class at once" despite the restrictions of social distancing. Participants in a previous study reported that the placement of the camera in the blended classroom often made it difficult to make eye contact with the virtual students or for the students to know who the instructor was looking at (Bell et al., 2016). The robots' physical presence in the current study's classrooms allowed one instructor to "be able to 'see' all my students physically so that I could more easily gauge who was tracking and participating." This presence also allowed for the ability to "build a more cohesive classroom community" in which students felt a part of the whole instead of separate groups.

There were accommodations that needed to be made for the robot students. Longer wait times and "cold calling" on robot students who were hesitant to interrupt with answers or comments were common practices for both instructors. One suggested that it was difficult for the robot participants to monitor all the other students in the room, which may have made them feel that they would interrupt if they jumped in to speak. The other moved to cold calling because, "When you are not physically present, you just don't feel as accountable. I think the robot students felt MORE accountable (and thus more inclined to participate) than the Zoom students, but not by a whole lot." Because of the sound issues, sending groups out into the hallway or allowing time for repositioning robots needed to be built in. The instructor with larger numbers of robots did report cutting back on group work because the students could not hear each other well. In addition, class materials needed to be made available to the remote students on the LMS because it was not always easy to see the screen. Although this was possible to do, the instructor felt that it took away from their ability to improvise during class.

Both instructors echoed the frustrations of the students with the inconsistent connections and audio and video issues. There were also several comments about the announcement the robots made when they went to sleep after being inactive or when a student made a connection. The notifications were turned off during week three which helped cut down on the disruptions but still left a bad feeling, which was noted by several students as well as both instructors.

The move by some students to switch back to Zoom caused at least one student to mention, “It is not effective to have three modes, robot, in-person AND Zoom, all in one class. It is too much for the professor to handle on top of teaching.” Both instructors identified juggling multiple modes of attendance as difficult. Instructor two, who did not have to juggle those three technologies, felt much more comfortable continuing with small group work and discussions throughout the term than did the instructor who dealt with more technology issues that moved students back to Zoom.

Both instructors indicated that they would use the robots again if they could keep the robot numbers to around three to four to mitigate the technology connection issues. It seemed like a sound option for students who were ill or traveling to continue their learning uninterrupted, and the controls were easy for students to master without much prior knowledge so it was fairly easy to use on the students’ part.

Technology Issues

Previous telepresence robot studies include mention of some form of technological issues involving Wi-Fi connection/bandwidth, audio quality, or video quality (Bell et al., 2016; Cain et al., 2016; Fitter et al., 2018; Gleason & Greenhow, 2017; Lei et al., 2019). In the current study, an attempt was made to preplan for the bandwidth issues by using a classroom in a building with no competing classes and by moving the Wi-Fi access point closer to the classroom. Two unforeseen issues arose, with one issue being the number of robots being used simultaneously during class (see Table 13). The robot manufacturer reported that the robots using all video, audio, and movement capacities used three times as much bandwidth as was used in a group video conference. When that amount of bandwidth was multiplied by the number of robots being used during a class session it became problematic. The optimal number of robots for the classroom used in the study seemed to be no more than four at a time. Instructor 1, who taught three of the four classes, reported that the Wi-Fi seemed unable to sustain the full complement of robots, meaning students sometimes lost their signal or had to turn off their video. Instructor 1 did not have that problem in the class when only three or four robots were operative at any given time. This was also supported by Instructor 2, who had only three robots in use during class, who said that connection issues happened infrequently, but did happen. Remote students were not surveyed about their home internet access, so it is possible the connection issues were not all related to the study location. The connection issues may have been a combination of internet access from both sides.

The second issue was the video and audio quality of the robots. Audio and video are the primary modes of communication for telepresence robot participants. The majority of sensory feedback that influences the participants’ sense of embodiment comes from their use of audio and video. The quality and saturation of sensory feedback from robot to user is especially important in developing a sense of spatial presence and embodiment (Steuer, 1992). Higher quality of video and audio feedback, and in the case of the robot, the physical agency of being able to move and control the robot (Bamoallem et al., 2014), contribute to a higher sense of telepresence. Ijsselsteijn and Riva (2003) stated that when a user can dedicate more attentional resources to the stimuli coming from the robot, the more they will identify with the robot and the stronger their sense of telepresence will be (Ijsselsteijn & Riva, 2003). These issues will need to be addressed in future telepresence robots so the stimuli and feedback from the robot are at their highest possible quality.

The numbers of negative open-ended comments related to connection and audio issues were much higher for remote students, who were most effected by the lack of consistent connection. However, almost a third of the negative comments came from in-person students who were also inconvenienced by the robots' connection status announcements and the time needed for the instructor to address students' connection issues. Some of the in-person students' comments showed empathy for the robot users. One student commented that although the robots connecting and disconnecting throughout class time was distracting and time consuming, "It also appeared to be stressful for those that were trying to use the robots." It will be important in blended learning classrooms to consider the impact on both the in-person and remote students when there are technology difficulties.

During testing, the video and audio quality seemed adequate, but the tests involved only two people in the room with no other conversations. A quarter of the open-ended comments reported issues with connection, video, or sound. The video issues were sometimes mitigated by the participants turning off their video. The audio problems were the most frustrating for students because they impinged on their ability to interact with in-person students or other robots easily and informally. The echoing nature of the bare cement-floored room certainly contributed to the overall sound issue, but a larger issue involved the microphones and speakers not having the capacity for switching between distances or filtering sounds like a human ear can. Remote participants were not able to hear themselves or know how they sounded to others, and in-person students reported that the robots were very loud at first. This was eventually addressed when the researcher showed the in-person students how to adjust the speaker on a robot. One instructor had students roll one of the robot students out into a hallway to find a quieter space for small group discussion, but the number of students/robots in a class made that option unmanageable for some classes.

Students were aware of the connection issues with the Wi-Fi and the video and audio quality problems. One student commented, “The connections seem to be unstable most of the time, which can make hearing sometimes difficult.” Students troubleshot by logging off and trying again or trying another robot, but if it got too frustrating, they would connect to the course through the Zoom link. Instructor 1 encouraged students to stick with the robots at first but as more students “asked to decamp for Zoom” they were allowed to switch with no questions asked. This phenomenon was reported as happening regularly in the two courses that had more than four robots in use at any one time, but not in the sections with four or fewer robots.

The social distancing requirements of the pandemic worked in favor of the study because in-person students were required to sit six feet apart, which left room for interspersing robots between them. If robots are used during a non-pandemic year, spacing for the robots would still need to be considered but students might have more agency about where they "sit" in the room, and allowing them to choose might allow for more natural small groups to form.

The technological issues with video and sound will continue to be challenging until future improvements to robot technology are developed. If telepresence robots are to be considered a viable alternative to video conferencing, the bandwidth needs will have to be addressed for any room that will incorporate telepresence robots. Identifying dedicated teaching spaces that could be used each term for teaching with robots might address this issue. The robot manufacturer has made adjustments to their software that will allow users to adjust broadband settings to use less bandwidth, but it will also be important to limit the number of robots to four or fewer in this classroom unless individual robots can be assigned to Wi-Fi access points and multiple access points are present nearby. It is also important to note that none of the in-person students were using laptops in class. If they had been, this may have contributed additional load on the Wi-Fi.

There may be a ratio of robots to in-person students that should be considered when designing learning spaces and courses that incorporate telepresence robots. Although no in-person students commented in the feedback that they did not like being around the robots, there may need to be some additional study around personal space and the presence of robots for the in-person students. One study mentioned earlier had 14 participants in the class and 12 were robot students (Lei et al., 2019). Although the students attending by robot did have a higher sense of social presence than by video conference, the researchers reported several challenges in recreating the social norms that are taken for granted as live participants. Learning when and why to use the robot body's movements, how to communicate within the restrictions that using robots place on nonverbal cues and expressions and showing attentiveness to others were more challenging with robots as the majority of participants in the room (Lei et al., 2019).

Lastly, robot manufacturers need to consider building in physical ways for students to indicate that they have a question or comment. The Ohmni robots do have a light under their base that would allow the user to change the color using the on-screen controls. This has been used in some situations to indicate questions or mood (Lafayette, 2020). However, that only works if the instructor can see the lights or can monitor the lights near the floor as opposed to concentrating on the screen where the participants faces are. A light above the screen or some other way for students to indicate remotely, but unobtrusively, that they would like to speak may help mitigate the feeling of rudeness in interrupting or not knowing when they can speak up.

Implications for Theory, Research and Practice

There will be students who choose to learn online either from preference or a need to work around busy schedules. Students who choose that mode of learning generally understand what they are getting into in an online learning situation. Instructors can play an important role in creating the conditions for communities of learning to be built in the online environment and in fostering the sense of social presence in online learners that helps keep remote students engaged, but the technology medium that remote students choose to attend by may play a role as well. The video conferencing technology being used today offers the participants the audio and visual stimuli to feel a certain sense of social presence in the online environment, but, despite the visual element, it can be difficult to make real eye contact or connect with individuals. There are very few ways that participants can exert some autonomy or control over their learning environment when they are part of a video conference. Students have taken some control in this situation by turning off their cameras and choosing to disengage visually from others for various legitimate reasons, but in some cases, it has left instructors talking to a void of black screens (Castelli & Sarvary, 2021). Many social presence theory researchers moved away from Short et al.'s (1976) idea that the ability of the media to provide visual feedback to the user impacts their sense of social presence. In fact, they believed that removing the visual feedback would produce a "serious disturbance of the affective interaction" (Short et al., 1976). In some respects, this is manifesting itself in the lack of visual participation.

In this study, four robots seemed to be the number that fell just short of putting too much load on the bandwidth. Classes with four or fewer robots reported fewer connection issues although they still had similar issues with the quality of the audio. It is possible that more robots might be accommodated if more Wi-Fi resources are dedicated to them, but it is also important to determine what the right balance between telepresence robots and in-person students might be. It was difficult to pin down a comfortable ratio of robots to humans because it was not considered when first putting together questions nor is it directly accounted for through the TEMS questions. More studies would be necessary to specifically determine how comfortable the in-person students were with the robots and at what point the number of robots caused discomfort, if at all.

The other issue that would need to be addressed is potentially limiting the registration numbers for the online section of the course to ensure that the number of available robots was not exceeded. In the current study, there were more students signed up for the online section in some cases than anticipated, as well as several students who may have taken advantage of the opportunity to not come physically to class during the first few weeks. Assigning robots helped with some of the issues but if the online section was not limited there could again be more students than available robots. Instructors much preferred having all students in front of them, rather than having students in video conference on the screen behind them. Overfilling an online section would potentially force some students to attend by video conference while others were attending by robot, which would add more things to manage for the instructors.

The Ohmni engineers did suggest adding a second access point and directing half the robots to one and the rest to the other to decrease the load on the network, but the resources were not available to make that feasible in such a short amount of time. It would be recommended for the future that there be an access point for every four robots, possibly five if the recent changes made to the software allow students to choose a lower bandwidth mode individually. Also, the choice of a room with carpeted floors or more windows or furniture to lessen the ability of the sound to travel or echo may help control some of the sound issues. Strategically placing robots in groups so that they are facing toward an outside wall may help them pick up less ambient sound from other robots in the room.

Using the map method to offer some choice of which robot to log in to worked fairly seamlessly, although it did not allow students to see which robots were already in use. It also took away a certain amount of choice of where to “sit” in the room if the participant’s preferred robot was already in use. It was possible to give students a view of which robots were in use, but it would have necessitated inviting individual students to create accounts. The difficultly with that lay in the fact that students were coming back from spring break and there was no good way to explain by email the steps they would need to take to create accounts, nor, as it turns out, was there an accurate count of how many robots were needed. If the software was designed in a way that allowed the teacher to provide a code for students to join the robot “classroom” and then pick from a selection of available robots, it might be the best of both worlds.

The training offered prior to class did help students learn to control the robots, but at least one student who used a robot during a quarantine period said that the controls were easy to learn to use and they did not need to watch the available videos to figure it out. There was one comment, however, that suggested that if they had needed to move around the room more it would have been nice to have more time to practice without others around to watch. Providing an opportunity prior to class to orient to the controls and practice moving the robots would allow instructors to teach participants more about troubleshooting known issues and give the students a realistic picture of what to expect. Although the experience is different than Zoom, and students may have felt more present with the robots, there are still limitations to the robots that might have been easier for students to adjust to if they had known ahead of time what to expect.

Telepresence robots do provide some opportunity for feeling more “present” in class and feeling embodied in a robot leads to higher social presence and engagement. Ultimately, all students, remote or in-person, should feel a part of a collaborative learning environment where they can engage with their peers in learning the class content. If it is possible to improve the remote learners’ experience by using telepresence robots to allow them to feel more fully present and engaged with their classmates and their learning, then it is worth continuing to offer it as an option. Although students benefit, there is also a benefit for faculty who can teach blended classes without the same level of task-switching that it takes to move between in-person students, video conference students, and presentation technology such as document cameras, LMS, and PowerPoint. If the technological issues can be worked out to make the experience more seamless for students, it will also become easier for instructors who can focus on teaching, rather than troubleshooting, and allow them to focus on the students in front of them. Even though some of the students' faces might be on screens, they are still in "seats" next to their in-person classmates and can be seen together.

Finally, there are equity and access considerations to using the robots. Telepresence robot participants who are present more fully in class next to their peers are receiving the same instructional experience, but there may need to be accommodations made just like those made for a student with a disability. Robots need unimpeded spaces around them for movement just like a student in a wheelchair might. They may also need presentation slides posted in the LMS because they cannot see the screen well enough, or may need to be placed strategically in the room so they can better hear the instructor, just like an instructor would do for a sight or hearing-impaired student. The student themselves may not need these accommodations in real life but to make the telepresence robot experience equitable, adjustments might need to be made to accommodate for the technology.

Study Strengths

The TEMS instrument had strong effect sizes in all the subscales, which indicates that it is a reliable instrument for measuring embodiment, social presence, psychological involvement, and affective, behavioral, and cognitive engagement in blended learning environments. The qualitative data supported the findings in the quantitative data which adds to its criterion validity because it measures what it claims to measure. The instrument allowed the researcher to see the perspectives of both the in-person and remote students and make various comparisons between the two groups. It may be too early to say that the instrument is predictive since it has only been used as a summative measure in two studies. However, it could be argued that the instrument does assess concurrent validity because there are other studies that have found significance for parts of what the instrument measured, such as relationships between embodiment and social presence (Biocca et al., 2003), and this new instrument is finding similar results.

It was always going to be difficult to get equal groups of participants because of the smaller numbers of robots available. However, a sample size of 26 remote students and 43 in-person students is a larger sample than in previous studies, and normality tests showed the samples were similar. In comparison with other studies using graduate and doctoral students, the undergraduate experience seemed to show similar outcomes, such as higher social presence scores for in-person students than remote students, although different measurements were used so it is difficult to determine definitively. The study that previously used the TEMS instrument reported the seven participants' individual subscale scores but turned them into quartile scores to compare them to qualitative observations, rather than run statistical tests. In this study there were qualitative items that reinforced the quantitative findings and gave support to the validity of the measurement instrument. More studies would need to be done to further support the use of the instrument, such as a factor analysis to ensure items were loading correctly, but for the purposes of this study it seems to be both a valid and reliable instrument that measures what it intended to measure.

Although this was a quasi-experimental study it did include both quantitative and qualitative data from both students and instructors. The qualitative data triangulated well with the quantitative results and reinforced the validity of the measurement instrument.

Limitations and Implications for Future Research

Because of the connection issues, several students switched from robot to Zoom either during the course of a class session, or mid-term, in which case they usually stayed with Zoom the rest of the semester. Although the participants were asked from what perspective they were answering the questions on the TEMS, it is difficult to tell whether a zoom student's previous experiences with the robot affected their answers. They were aware that they were taking a survey called the Telepresence Robot Study and that may have affected their answers as well. Although six students indicated that they were taking the survey from the perspective of a video conference student, all of them had used the robots at least once. Because the sample sizes of the robot and video conference groups would have been smaller, and they all had experience with the robots, they were combined. However, there is no way to know how the robot or Zoom experiences may have influenced their perspectives on either method of attendance.

Another unknown factor is the instructor. Both were experienced, tenured faculty who had previously taught these courses several times, so it is unlikely that experience, content knowledge, or delivery method would have been significantly different between the two. It is possible however, that instructional strategies such as turn and talk, think pair share, and small group work were used differently because of the size of the classes and the limitations created by the technology issues. One study did suggest that social presence and observed behavioral engagement did seem to increase in small group settings (Lei et al., 2019) which is something Instructor 1 cut back on as the term went on because of the technology issues. Minimizing the technology issues would make instructor differences potentially easier to identify.

This study also did not attempt to measure any academic outcomes or measures of satisfaction. Exploring whether increases in social presence and engagement lead to more successful learning outcomes, higher grades, greater retention, or more satisfaction with the learning experience is an important part of determining if telepresence robots are viable attendance modes in blended classes. Engagement in this case was based primarily on meta-cognitive measures, but higher education institutions may be more interested in studying other measures such as student satisfaction, grades, and retention if they were to be used to market alternate attendance modes for students.

There are many questions still to be answered about the use of telepresence robots in higher education and their effect on students' sense of embodiment, social presence, and engagement. Several paths of research would be possible. One option would be to proactively address the technology issues as much as possible to ensure participants have a seamless experience with connecting and staying connected throughout the study. This would make it more likely that participants would continue using the robots for the full term and their scores on the TEMS would be less likely to be clouded by frustration with the robots. A second option would be to create a stronger experimental study in which three courses were used, one in-person group with no technology, one blended course using video conferencing, and one blended course using telepresence robots. This controlled experiment would allow for a cleaner comparison between the three groups without any potential crossover or confusion about which mode of attendance was being evaluated. It may also give some insight into whether the in-person student experience is affected by the remotely present students. This perspective is not something that appeared in the literature. Exploring the effect of gender or comparing undergraduate and graduate students' experiences might also be worthwhile comparisons for future study.

Helping students feel more connected and present in today's hybrid classrooms may address some of the disconnection and lack of engagement being reported in the current online learning environment. Not all students have the skills needed to learn successfully online, and some would simply prefer to learn in the company of their peers. College is more than just learning, and students who attend by robot may have the additional flexibility to independently interact before and after class and at breaks with their in-person peers or other robot students, which is difficult to do when sharing the screen with other remote participants in a video conference. These informal interactions contribute to creating a sense of community in the classroom. Telepresence robots, which work with few technological issues, may encourage students who find themselves disconnecting from the learning in a video conference environment to re-engage when the technology makes them feel just like they are there in person.

Although the technology itself will continue to improve, it will also take time for telepresence robot use to become accepted by students. Video conferencing technology has seen almost instant acceptance over the course of the pandemic because it made participants feel like they were almost together in classes as normal. As a substitute for in-person learning, it did allow for connection and for learning to continue, and it staved off some of the isolation that came with the lockdowns. If more students gravitate toward online learning as their normal way of achieving higher education degrees, they may start looking for a blended experience that provides both the social opportunities that can come with synchronous learning and the flexibility of asynchronous learning. That may involve developing higher quality experiences, but it may also take the form of students wanting a more immersive online educational experience. Now is the time to begin refining technologies like telepresence robots that can provide a more natural and immersive learning experience. Starting to move in that direction now will position higher education to prepare for students who want an online learning experience that is better than "almost like being there."

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Appendix A

Telepresence and Engagement Measurement Scale

1 to 5 Likert Scale used for all questions

Experience and Comfort

1. I am very skilled in participating in academic settings using robotic telepresence technology.
2. I am very comfortable in participating in academic settings using robotic telepresence technology.

Embodiment

3. I could easily see what I wanted to see.
4. I could easily hear what I wanted to hear.
5. I felt like people could see me when I wanted to be seen.
6. I felt like people could hear me when I wanted to be heard.
7. I had a good sense of how I appeared to others.

Social Presence

8. I felt like I was with those who were physically present in my class.
9. I felt like I was with those who were NOT physically present in my class.
10. I was aware of those who were physically present in my class.
11. I was aware of those who were NOT physically present in my class.
12. I felt close to those who were physically present in my class.
13. I felt close to those who were NOT physically present in my class.
14. I felt alone during the class.
15. I used VERBAL means (speaking and chat) to communicate with people who were physically present.
16. I used NONVERBAL means (gestures, facial expressions, movement, etc.) to communicate with people who were physically present.
17. I used VERBAL means (speaking and chat) to communicate with people who were NOTE physically present.
18. I used NONVERBAL means (gestures, facial expressions, movement, etc.) to communicate with people where were NOT physically present.
19. I could tell when my efforts to communicate reached the intended people.
20. I could tell when my efforts to communicate ha the intended effect.

Psychological Involvement

21. I felt like was on the same page as others in the live sessions.
22. I felt that others in the live sessions acknowledged my point of view.
23. My opinions were clear to others in the live sessions.
24. I easily understood how others in the live sessions reacted to my comments.
25. I had a warm and comfortable relationship with the others in the live sessions.
26. I felt that others in the live sessions cared about me.
27. I felt I was able to be personally close to others in the live sessions.
28. I was respected by others in the live sessions.
29. I was encouraged by others in the live sessions.
30. I was assisted by others in the live sessions.

31. I was treated equitably by others in the live sessions.
32. When I compare my experience to students in the other mode… (If you were physically present, this question refers to people who were not physically present and vice versa).

Engagement - Behavioral

33. I worked with students from this class to complete the course assignments.
34. I asked questions in class.
35. I participated during class discussions by sharing my thoughts and ideas.
36. I discussed course material with the instructor during class.
37. I listened attentively to my classmates' contributions during class discussions.
38. I helped my classmates during class (e.g., answer questions).
39. I paid attention in class.

Engagement – Affective

40. The course material was relevant to my life (and/or career/research interest).
41. The course was interesting to me.
42. I had fund in class.
43. I liked the things we covered in class.

Engagement – Cognitive

44. I tried to connect new information with what I already know.
45. What I learned is important to my future.
46. I worked hard in class.
47. This course made me more knowledgeable.
48. The information in the course was useful.
49. I thought about what my classmates said in class even without talking.

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