OPEN ACCESS Freely available online

ISSN 2737-5315
Volume 2, Issue 1
https://www.iikii.com.sg/journal/EIET
Educational Innovations and Emerging Technologies

Article

Remote Learning with Virtual Reality Technologies: Student Mastery, Community and Agency

Eileen McGivney*, Cameron Tribe and Tianyi Feng

Harvard Graduate School of Education, USA; camerontribe@gse.harvard.edu, dianafeng@g.harvard.edu
* Correspondence: eileen_mcgivney@g.harvard.edu

Received: Feb 5, 2022; **Accepted:** Mar 5, 2022; **Published:** Mar 30, 2022

Abstract: The affordances of virtual reality (VR), including a strong sense of spatial and social presence, could make it a useful tool to improve learning and social connection in remote learning, yet little research has examined its effectiveness in authentic learning environments. This mixed-methods case study of a remote Master's in Education course asked how using VR repeatedly and with varying implementations impacted students' learning, and how synchronized or shared experiences in VR impacted their sense of community. Students completed weekly surveys of their sense of presence in VR applications, sense of class community, and learning experience, and also participated in a post-course interview. Surveys revealed students' sense of presence remained high over time, indicating little evidence of a "novelty effect," but that it varied based on features of the VR applications. Interview results pointed to students' increased mastery of the technology and its affordances for learning, and highlight how connecting with classmates via videoconference while using VR can create a shared experience. Students' sense of agency in VR emerged as an important consideration for learning design. These findings suggest fruitful ways to use VR to increase educators' mastery of immersive technology and provide remote students a sense of shared experience and raise questions about the impact of VR implementation and instructional design in authentic learning environments to promote exploration and community.

Keywords: Virtual Reality, Immersive Learning Environments, Remote Learning, Class Community, Learning Design, Student Agency

1. Introduction

Virtual reality (VR) technologies have been promoted as a transformative tool for education, yet little research has studied their effectiveness in authentic learning environments (Georgiou et al., 2021; Hamilton et al., 2021), such as remote online courses. In the wake of the COVID-19 pandemic, remote learning in higher education is likely to continue increasing (National Council for State Authorization Reciprocity Agreements, 2021). The affordances of VR that include a strong sense of spatial and social presence among users could make it a useful tool to improve learning and social connection in such remote learning contexts (Cortiz & Silva, 2017). However, more research is needed to understand how VR can be effectively designed and delivered in these contexts (Mysakidis et al., 2021).

This study explored the use of VR in a graduate-level course taught fully remotely due to the COVID-19 pandemic. Various VR applications were used throughout a six-week class for Master's in Education students to learn about the affordances, limitations, cultural variation, and issues of identity in immersive educational technologies. Students completed weekly surveys of their sense of presence in response to VR applications, their sense of community in both the class and the university, and their perspective on learning with VR. Students also participated in an interview at the end of the course.

We asked how using VR repeatedly over time and with varying class implementation impacted students' learning, and how synchronized or shared experiences in VR impacted their sense of community in a fully remote class. The focus of this study was on describing the experiences of this class to better understand how VR can be integrated into remote instruction, generate ideas for consideration of the design and implementation of educational VR, and discuss opportunities for future research regarding the impact of VR in education.

1.1 Related Literature

1.1.1 Learning with Virtual Reality

VR is a technology that surrounds a user with a digital image, using stereoscopic imaging and sound to immerse them in a virtual environment and evoke a feeling of "being there" in a place other than their physical location, also known as presence (Slater, 2009). It can have a strong effect on users' emotions (Markowitz & Bailenson, 2021), can provide a sense of agency through interactivity with the virtual environment (Makransky & Petersen, 2021), and can make them feel they are with other people (Oh et al., 2018). While much research has focused on the technical characteristics of VR devices and experiences that evoke users' sense of presence (Cummings & Bailenson, 2016), the design of the experiences themselves is also crucial (Slater, 2009).

When well-designed, VR can immerse learners in meaningful learning experiences that leverage their actions, powerful symbolism, and visualize phenomena and environments difficult or impossible to experience in the real world (Dede, 2009). For example, VR is used in medical education to provide hands-on practice in surgical training (Locketz et al., 2017), in science education to support learning about cells in the human body (Thompson et al., 2021), for virtual educational field trips (Boda & Brown, 2020; Mills, 2020; Markowitz et al., 2018), and to provide a first-person perspective of history (Egea-Vivancos & Arias-Ferrer, 2020). Recent reviews and meta-analyses find that VR has mixed results on learning outcomes when compared with other media, (Wu et al., 2020; Radianti et al, 2020), but it may have a greater impact on procedural skills and affective dimensions of learning than on knowledge retention (Hamilton et al., 2021). Additionally, VR experiences have consistently been shown to increase interest and motivation to learn, including learners' beliefs in their abilities, termed self-efficacy (Chen et al., 2016; Parong & Mayer, 2018; Makransky et al., 2019; Chen et al., 2020).

The way VR is designed and integrated into the curriculum can also explain its varied effect on learning outcomes. For example, Parong & Mayer (2018) found that a PowerPoint slideshow was more effective than a VR experience for teaching scientific information unless students were asked to generate summaries at certain points of the VR experience. Meyer et al. (2019) found that learning outcomes were significantly enhanced by engaging with pre-training materials that introduced learners to the makeup of a cell before using a VR simulation of cells inside the body. These studies have highlighted the importance of instructional methods and design for learning in terms of VR experiences themselves and the activities learners engage in during a lesson. However, most research on learning with VR has occurred in laboratory experiments rather than authentic instructional environments (Southgate, 2020), so there remains scant evidence of the best instructional methods and implementations for supporting learning in classrooms.

Additionally, most research on learning with VR studies its impact in relation to one brief VR experience (Jensen & Konradsen, 2018), raising questions of a novelty effect in which outcomes may be explained by learners' reaction to an unfamiliar technology (Huang et al., 2021). While some have argued the benefits of VR for learning will diminish over time as its novelty wanes, Huang et al. (2020) found that neither motivation to learn nor performance decreased over the course of three VR-enabled science learning sessions. Similarly, Han et al. (under review), found that students' sense of presence and other indicators of their VR experience increased throughout 8 sessions in a collaborative VR environment throughout a fully remote university course. Yet studies of VR usage in learning environments over time remain rare, and more evidence is needed to assess the longitudinal impact of VR-enabled class activities.

1.1.2 Teacher Education and Technology Adoption

Teachers are a key in the adoption of educational technologies, yet they are often not significantly engaged in their design and deployment into classrooms. Cuban (2001) described how digital technologies like computers have been "oversold and underused" in classrooms, pointing to the mismatch between the promise of these tools to transform education and the lack of adequate resources for teacher training and sound pedagogical design. Teachers need knowledge on how specific technologies can best enable instruction for their curricula and content domains to use them effectively (Koehler & Mishra, 2009). Teachers' beliefs are also an important part of this process, both about the value of new technologies for teaching and learning and about their own ability to use them effectively (Tondeur et al, 2017; Admiraal et al. 2017; Ertmer & Ottenbreit-Leftwich, 2010). While access to VR in schools is increasing, there remain barriers to supporting its integration into education, including giving teachers "the time to deeply explore the pedagogical and learning affordance" within the constraints of school schedules (Southgate et al., 2018). A recent study of teachers' intent to use VR in their teaching found that enjoyment of using the technology was the strongest motivator, while few teachers identified having a habit of using VR as a motivator for using it in the classroom (Bower et al., 2020), in contrast to studies of other technologies such as mobile learning. They recommend giving teachers "extensive opportunity to use" VR to support their adoption of the technology (Bower et al., 2020, p. 2227).

1.1.3 Class Community in Remote Learning

In addition to improving students' learning opportunities, VR affords opportunities for novel social interactions that may enhance remote education. The immersive qualities of VR not only evoke a sense of presence in a different place but also can

engender a sense of co-presence, the feeling of being with other people (Oh et al., 2018). Many VR applications are focused on helping people connect who cannot be in the same physical space, such as VR social media, remote work applications, and gaming platforms (Jonas et al., 2019).

Students' sense of community refers to their feelings of cohesion, trust, safety, belonging, interdependence, and shared educational goals and values with members of their school and classes (Rovai et al., 2004). In remote learning contexts, social dimensions including the sense of community are important predictors of student success (Wegerif, 1998). Yet research shows students in online learning feel less community than face-to-face (Rovai et al., 2005; Kirtman, 2009) and suffer from limited social connections with their peers and instructors (Rodriquez-Triana et al., 2017; Joshi et al., 2020). During COVID-19 remote learning, students reported lacking social interaction and connection to their peers (e.g. Ewing & Cooper, 2021), and schools struggled to provide adequate social interaction (Reich et al., 2020).

Evidence on learning with VR has primarily focused on its impact on learning outcomes and engagement rather than students' sense of community (Radianti et al., 2020; Nesenbergs et al., 2021; Bailenson et al., 2008). However, studies are beginning to show that using VR over time in remote instruction can support students' social interaction and group cohesion (Han et al., Under Review).

2. Materials and Methods

2.1 Description of the Course

This case study explored the use of VR technologies in a six-week remote course taught at a graduate school of education in the fall of 2020, during the COVID-19 pandemic. The course was a masters-level class on learning in virtual worlds. Students received Oculus Quest VR headsets through the mail at the start of the course, donated through a headset recycling program from Facebook (currently named Meta).

The course aimed to support current and future teachers and educational technology designers in understanding the affordances, limitations, cultural variation, and issues of identity in immersive educational technologies. The aim of using VR - in addition to other technologies like games, simulations, and mobile-based augmented reality - was to apply the course concepts through their own experiences using VR and to help build a sense of class community through shared and synchronized experiences.

Each week, students explored 1-3 educational or entertainment VR applications, either independently as homework, during synchronous class meetings, or in small group meetings (termed small learning communities or SLCs), as described in Table 1. When using VR applications at the same time, students were connected synchronously via videoconference. Sometimes, they engaged in shared experiences, with social interaction as avatars inside a VR application. Others were synchronized: guided through 360-degree videos or photos at the same time during course meetings. Some of the in-class experiences were led by their creators and included discussing the application's genesis. Students wrote critical response papers each week in which they discussed applications used (both with VR and other devices) and related them to the course readings and discussion topics. When used during synchronous class and small group meetings, students also engaged in structured discussions of the experience with their classmates.

Table 1. Description of virtual reality applications used for the course. [SLC = Small Learning Community; Sync = Synchronized]

Name of Experience	Week	Type	When Used	Independent or shared	Sync	Description of the Experience
Anne Frank House	2	Interactive graphical	On own	Independent	No	Guided tour or free exploration of virtual recreation of the Anne Frank House museum with interactive elements and you hear her diary read aloud in relevant rooms
National Geographic Explore	2	Interactive graphical	On Own	independent	No	Antarctica and Machu Picchu: Role play as a National Geographic explorer, taking photos and completing hands-on activities (e.g. rebuilding a structure, kayaking).
Rec Room	2	Interactive graphical, social	With SLC	Shared	No	VR game room where you can play games like ping pong or laser tag with other people, often strangers.

Table 1. *cont.*

AltspaceVR	3	Interactive graphical, social	With SLC	Shared	No	Social network in VR. The user creates an avatar and attends events or network with people.
Keep Talking and no one explodes	3	Interactive graphical	With SLC	Collaborative	No	A game where one person is inside the VR environment and the other person outside gives instructions from a manual to diffuse a virtual bomb.
Immerse: The Hydrous	3	360º video	In class	Independent	No	A virtual dive led by a marine scientist and showing coral bleaching.
NASA Mission: ISS	4	Interactive graphical	On own	Independent	No	Complete missions or free exploration in zero gravity on the international space station in the shoes of an astronaut.
Black Dot Films: Climbing Giants (Sequoias), Eagle, Polar Obsession	4	360º videos	In class	Independent	Yes	360 videos made for National Geographic: climbing giant sequoias with scientists who study them, observing and then flying a European Eagle, and following a Nat Geo photographer who works in the Antarctic and swimming with a polar seal.
Travelling While Black	4	360º video	On own	Independent	No	Documentary about dangers Black Americans faced historically when traveling (the Green Book) and dangers they continue to face from police.
Roam VR	5	Photogram metry temple	In class	Shared	No	A Burmese temple recreation from photogrammetry scans. Students met as a class in the temple, each represented as a generic avatar to walk around the space and handle artifacts.
Spatial	5	Social interactive graphical	In class	Shared	No	A VR meeting space. Students created avatars with their own photos for a face. The app allows users to use virtual whiteboards, and sticky notes, and to sit around a table.
Home After War	5	Photogram metry video experience	On own	Independent	No	A documentary about an Iraqi family who returns to their home. The user can walk around the house and the father shows appears as a hologram in different rooms to describe their experiences throughout the house
Clouds over Sidra	5	360º video	On own	Independent	No	Documentary where you follow Sidra, a Syrian living in a refugee camp in Jordan
Waves of Grace	5	360º video	On own	Independent	No	Documentary about an Ebola survivor in Liberia
My Beautiful Home	5	360º video	On own	Independent	No	Documentary that follows a woman who lives in the Kibera settlement in Nairobi
Son Doong Cave	6	Interactive 360º photos	In class	Independent	Both	A photo tour of the largest cave in the world. Students did the tour twice: through a browser on students' computer monitor synchronized & guided by the photographer, and through free exploration in a VR headset.

Table 1. *cont.*

Wander	7	360º Photos	On own	Independent	No	Explore Google Street View in VR
La Republique	7	360º video	On own	Independent	No	Videos created by Harvard French professor Nicole Mills that follow the lives of 5 Parisians. Users choose from different moments or parts of their day to be immersed in their conversations (e.g. sitting at a cafe table with friends or going to a birthday party).

2.2 Research Methods

This exploratory study reports the findings of a concurrent mixed-methods case study of this course (Creswell & Plano-Clark, 2018). Students were surveyed weekly about their experiences in the course and with the technology and interviewed at the end of the course. This study was approved by the Harvard University Institutional Review Board.

Of the 14 Master's in Education students in the class, 12 opted into the study, and 10 (7 females, and 3 living outside of the U.S.) completed surveys and post-interviews. They are referred to here by pseudonyms.

Students completed weekly surveys throughout the course that asked for their sense of presence in some of the VR experiences they used that week, the device they used, their sense of community in the class and in the university, their class satisfaction, and their perceptions of learning with VR. Survey items and instruments are detailed in Appendix A. Surveys were sent each week following class activities that used VR experiences.

The first author conducted semi-structured interviews after course completion, on average 40 minutes (29-46 minutes). Students were asked about their sense of community in the class and the master's program, memorable VR experiences, and their experience of its different types and implementations. Students were asked specifically if they preferred having experiences synchronized. See Appendix B for the interview protocol.

2.3 Analysis

2.3.1 Surveys

Students' responses were analyzed by estimating a mean score for the sense of presence in response to each VR experience (6 items, mean α=.90,range=.76–.97), and weekly scores for the mean sense of community in the class (9 items, mean α=.77,range=.59–.90), the sense of community at the university (16 items, mean α=.87,range=.77-.92), and class satisfaction (9 items, mean α=.96,range=.92–.98). The responses for perceptions of learning with VR did not cohere into a single measure, so individual items were analyzed.

Means for each score were analyzed for change over time, and differences between groups based on the hardware used. Due to the small sample size, quantitative data is only used to suggest trends and patterns among this group of students and are not necessarily generalizable to broader populations and contexts. Further, the design of the study does not allow for causal inference about the VR and learning or community outcomes.

2.3.2 Interviews

Interviews were transcribed and coded using a flexible, thematic coding procedure (Deterding & Waters, 2021). The first and second authors recorded listening notes, indexed broad themes related to students' learning and community, and wrote memos for each participant. From this, a codebook was developed that included emic codes, or those that emerged from the data (e.g. agency in VR), and etic codes, or those that were determined from the research questions and prior literature (e.g. synchronization preferences). The first author coded all transcripts, and the second and third authors each coded half. All authors reviewed discrepancies and discussed each quotation to reach a consensus, revising or removing inconsistent codes. As for validity checks (Maxwell, 2010), we conducted member checks by sharing a synthesis of main findings with the participants and searched the data for discrepant evidence for each finding. We also use full-text quotations in tables to allow readers to judge the findings' trustworthiness.

2.3.3 Researcher Positionality

The first author of this study was the instructor for this course and acknowledges biases that may affect students' reporting and her interpretation. To separate research and course activities, students were not required to participate in research to participate in the VR activities, and no questions were asked about the instructor or her teaching. Further, the instructor did not view survey data or conduct post-class interviews until all grades were completed and submitted. She may hold assumptions about students based on their performance in the course. Students were encouraged to be honest in their critique of the VR experiences, and the authors did not create or were otherwise invested in them. The second and third authors were not involved in the course implementation or data collection.

3. Results

3.1. Quantitative Results: Trends in Sense of Presence, Community, and Learning Experience

First, we present the results of students' weekly surveys, which help to describe broad trends in their experiences with the technology and in the class. As previously stated, given the small sample size, this exploratory study did not aim to establish causal or generalizable associations between the VR applications used and students' resulting sense of presence, community in the class, and experiences learning with VR. The quantitative analysis only serves to provide an overview of the experiences of students in the class in a numeric manner. This helped to guide, support, or supplement qualitative analysis as we explored students' experiences in more depth through the interviews.

3.1.1 Sense of Presence

Results from students' reported sense of presence indicate the device used and characteristics of applications themselves were both important sources of variation. They also suggest a sense of presence was not only due to the first-use novelty of the technology, as it did not significantly or substantively wane over time.

Variation by Type of Device: Students' reported sense of presence varied significantly by the type of device they used, with higher levels of presence when accessing the experiences on a VR headset than with other devices (e.g. laptop or mobile phone). The mean sense of presence across all applications used with a VR headset was 4.97 (1.2 SD) out of 7, and 2.77 (1.4 SD) with a different type of device. This confirms findings from prior studies that the characteristics of a device that make it more immersive can determine users' sense of presence in a virtual environment (e.g. Cummings & Bailenson, 2016). Because of this effect, and the relatively small number of students using non-VR headset devices for these applications, the following results report students' sense of presence only when using VR headsets.

Change over time: We do not observe a substantive or significant change in students' sense of presence from the early to later weeks of the course. As depicted in Figure 1, the mean sense of presence was approximately the same in the second week (4.71 (1.0 SD)) and sixth week (5.10 (1.1 SD)) of the course, with little variation week-to-week.

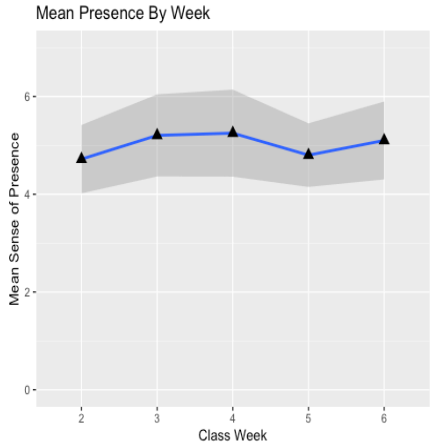

Fig. 1. Students' Reported Mean Sense of Presence by Week for applications accessed with a VR headset.

Variation by Application. We observe that students' sense of presence varied based on the application they used. Figure 2 illustrates the median and range of students' sense of presence for each app when accessed with a VR headset, depicted chronologically by those used in early to later weeks of the course. For example, the applications Anne Frank House and National

Geographic Explore have relatively high medians and small ranges. These were both interactive graphical environments students explored independently which may share features that heightened their sense of presence. Alternatively, these apps may have best captured the novelty of the technology at the start of the course. Similarly, the Hydrous virtual dive and Black Dot Films indicate a high sense of presence. These were 360-video experiences that students engaged in at the same time during a whole-class activity, potentially indicating the heightened sense of presence from completing them "with" their classmates. The synchronization of Black Dot Films may have heightened this even further, as the median presence is slightly higher, and the range tighter than for the hydrous.

On the other hand, Rec Room, Roam VR Temple, and Spatial have more varied ranges of presence scores. These were all social experiences in which students interacted with classmates and other people as avatars, both during class time and in their small group meetings, indicating these experiences may be less immersive for some users than others.

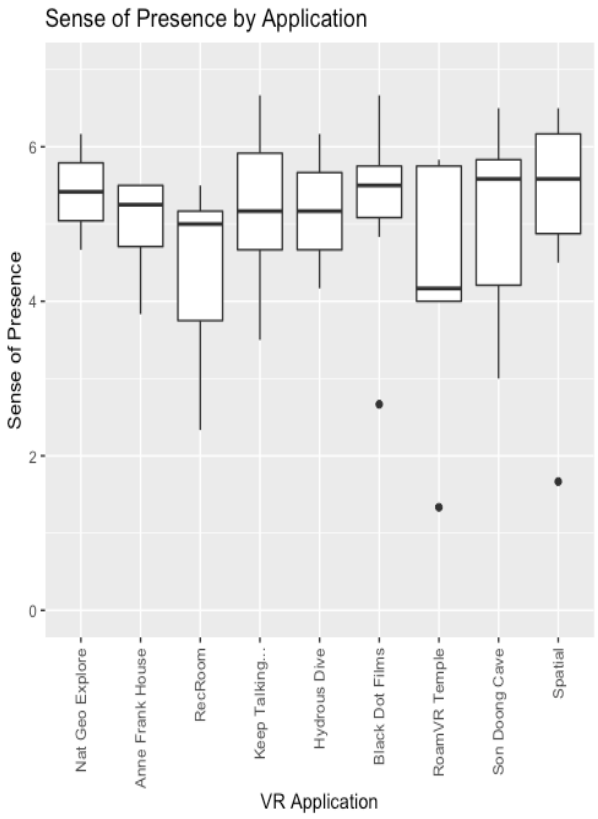

Fig. 2. Median and range of students' sense of presence in each application. Only those accessed using a VR headset are included. Applications are ordered chronologically by the sequence of application use, starting with the earlier weeks of the course on the left.

3.1.2 Sense of Class Community

Students' feelings of the class community increased slightly throughout the course as depicted in Fig. 3. On a five-point Likert scale, the initial mean sense of class community was 3.29 (0.7 SD), and in the final week was 3.86 (0.8 SD). The average peaked in week 5, which is when students worked in teams to have a debate and met in shared VR environments. The overall positive trend in this measure is to be expected, as students feel more connected to each other as the class progresses and they get to know one another. We did not find a correlation between students' reported sense of community each week and the type of VR application or implementation used.

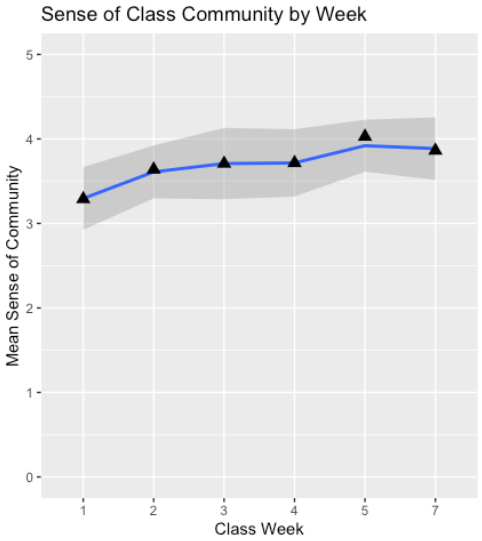

Fig. 3. Students' mean sense of community in the class by week.

3.1.3 Learning Experience with VR

Students' reported engagement in the course, with the VR, and the value they ascribed to it for their learning were consistently high throughout the course, as depicted by individual survey items in Fig. 4. The means from week 4 may indicate the value of less interactive media like well-produced 360-videos as particularly engaging and explicitly educational tools. In that week, the majority of the VR used was 360-degree videos: a whole-class activity with Black Dot Films in which students were synchronized and guided through videos, and an independent activity to watch the film Traveling While Black (Table 1). In this week, students had lower ratings of whether the VR felt "hands-on," reflecting the use of videos, but gave high ratings in that they felt the VR was more engaging than other media and it contributed to their learning. This raises questions about the association between types of media and learners' engagement, and in which cases interactivity is more or less valuable.

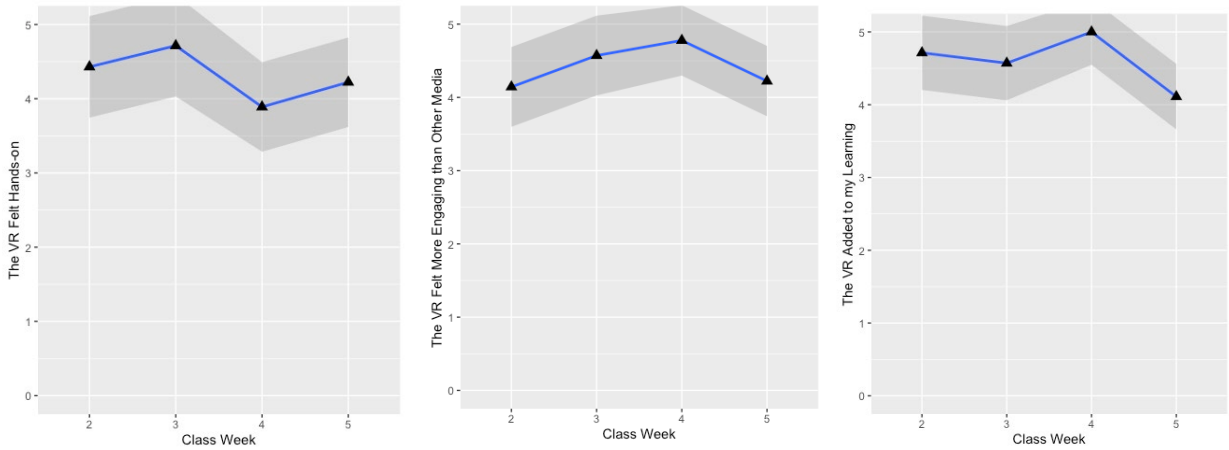

Fig. 4. Student ratings of their experiences with the VR each week as feeling hands-on, engaging, and its addition to their learning (1= *Strongly disagree* - 5= *Strongly agree*)

3.2 Qualitative Results: Students' Learning and Sense of Community

Our qualitative results provide more depth and detail on the trends depicted by the survey results. Here we present our findings that students described a move from novelty to mastery in using VR, highlighting an important learning outcome from using VR repeatedly throughout the course. We also find how students described the importance of connecting around the VR experiences, rather than in them, as a way to connect. Finally, we describe the importance of how VR is integrated into other course activities for its impact on both learning and community building.

3.2.1 Learning with VR Over Time: From Novelty to Mastery

When asked what they were taking away from the course, most students described how they gained mastery over VR technology by using it repeatedly throughout the course. This is particularly true for how they described their increase in self-efficacy for working with VR in educational contexts, whether as teachers or educational technology designers. They described arriving at a balanced view of VR, compared to either the enthusiasm or skepticism they started the course with. Further, they described specific affordances and limitations related to how VR can be used in education.

Students described what they learned in terms that indicated they felt a level of mastery of the technology that indicated an increase in their self-efficacy for teaching and working with VR. For example, as shown in Table 3, Hira discussed how becoming comfortable with the technology made her feel "well-versed" and Zoey described coming to an understanding that someone with her skills can "play an important role" in creating educational VR. Philip described his confidence in being able to work for a VR company.

Table 2. Learning with VR impacted students' self-efficacy and mastery of the technology

Self-Efficacy in creating or teaching with VR	"And I think I just got more comfortable with the technology itself, to just know how to operate it and works and all that. So I feel more well versed in what's going on." -Hira
	"I feel like this class, in particular, has really helped me understand the role that someone without technical skills can play in developing immersive technologies… you don't need to be a computer scientist or a programmer to contribute to how you can make these experiences better for students of all races, ethnicities, mental disorders, like everything like that. I think we play an important role that I didn't realize was an option before." -Zoey
	"I feel like I know enough about VR, at least conceptually and theoretically speaking, to go into a VR company and be able to use it or work with it in a practical way." -Philip

Students described how being able to use the technology themselves repeatedly was a key factor in their increased sense of mastery, and how it brought a hands-on element to the course. As shown in Table 2, Jane described the difference between reading about VR and trying it many times herself, and Jin pointed out that without trying it himself, he wouldn't "know what you can do with it." Lucas pointed to using VR as a way to bring a more "experiential" element to the course.

Table 3. Hands-on VR exposure promoted students' learning about the technology

Hands-on VR Exposure	"Obviously, of course, that we can put on the VR headset and see these experiences and see, "oh, this really works" or like "this is lacking"… Having the VR headset obviously is a huge factor because, without it, I would have been like, 'Okay. What are you guys talking about?'" -Sofia
	"Because [I'd] never used it before… unless you have experience in it, you don't really know what the potentials are… you don't know what you can do with it. And it really kind of opened my eyes to some things in terms of what is possible." -Jin
	"Going through the experiences on my own and in the groups was really beneficial, and like firsthand. I thought I'd read a lot about virtual reality and [thought], 'this is the future,' but I'd never gotten a headset and been like, 'okay, let's experience it myself.' So that was, I thought, really helpful." -Jane
	"[This] course was the only course that was less about creating your own [product]… but it was experiential because we go through the VR experience. So that was kind of, I think that was the tangible part." -Lucas

As educators and educational technology designers, the students specifically described how using the VR throughout the course helped them better understand the affordances and limitations of education. For one, students described tempering their initial enthusiasm or skepticism of the technology and arriving at a kind of balanced view.

Students also described how the opportunity to use the VR over time helped them better understand its powerful affordances and its limitations in education. When asked what they were taking away from the course, most students pointed to their arrival at a balanced view of VR, tempering their initial skepticism or expectations. Table 4 shows Chloe discussing how she still does not see VR as an "end-all-be-all" tool, but she feels more excited about its potential in schools. On the other hand, Lucas had "super-high enthusiasm" which was brought down to a more realistic understanding of where VR has an appropriate place for learning.

More specifically, students gained a deeper understanding of some of the more powerful affordances of VR to contextualize learning. Students described being able to put learners in a context that feels more real can help them understand history (Philip and Chloe), improve learning design for different contexts (Jane), or connect what they are learning in the classroom to what scientists do in real environments (Lucas). They also discussed the current limitations of VR, such as the lack of educational content (Ellie), the "primitive" graphics (Jin), and the strain of additional screen time (Philip).

Table 4. Learning with VR helped students gain a balanced view of its potential and limitations

Arriving at a balanced view of VR	"I know when I came in, I said, I was like, pretty skeptical and I'm still like not convinced it's like, the end-all be-all kind of thing. But in terms of it being a tool that can benefit education and that could benefit students, I'm like really jazzed about it's like potential on that." -Chloe
	"Initially I had this super-high enthusiasm that VR could be like the ultimate answer and then I would read all this research and the low transfers about learning and I'd feel like, 'Oh like VR is maybe not the best.' And then as I started seeing the real work that's being done by different practitioners that you brought in, I realized, 'Oh VR does have a place, it's just not for everything.'" -Lucas
Powerful affordances for contextualizing learning	"I like virtual field trips, particularly in the social studies context because… VR has an opportunity to bring kids [into a historical] environment, have them get a sense of what it was like." -Philip
	"And I think that's where VR [can help] …Not everyone can fly to Egypt to learn about what schools are like in Egypt. But if I can sit in a classroom in Egypt and understand what's being, and how it's being taught, that would give me so much more context." - Jane
	And the museum that I work at, that's how they tell stuff, is they enact things or they have rooms that are set up and like you feel like you could have been there. And I think that's it's very impactful in person. So to make it accessible for everyone on VR that's pretty cool that you can have these kind of experiences." -Chloe
	"If I had this as a teacher, and I could show my students in low-income districts like Oakland about what it feels like to be a National Geographic scientist... that was why it was so powerful, is because I could have them actually perceive what it's like to be a scientist in the field." -Lucas
Limitations of VR for Education	"I don't think there's currently, there's not many resources that I can directly use within for that-for the curriculum, for the classrooms" -Ellie
	"I still think it's kind of primitive, in some ways, like the graphics and the kind of things you can do in it, is still like, 'oh, we still have a long way to go.'" - Jin
	"a big part of me was turned off to VR, because I've realized a lot of the current limitations of it, and also because I don't like being plugged in right now because I'm so plugged in already… [and] my eyes hurt." -Philip

3.2.2 VR as a Shared Experience Facilitated Connection, Engagement and Comfort

When asked about the impact of using VR in different class implementations on their sense of class community, students described the benefit of VR experiences to provide a shared experience between themselves and their classmates. Most often, students described this in terms of connecting with their classmates via videoconference before, during, and after using a VR application. We term this connecting around the VR. This is opposed to connecting in the VR by interacting with each other as avatars or by being guided through synchronized experiences together. They described how this made them feel more comfortable and engaged in the VR as well.

For example, most students did not describe the synchronized or social experiences as important for their sense of community in the class but did describe the benefit of connecting with classmates over videoconferencing while using the VR, whether as part of a whole class activity, or a small group meeting outside class time. In these situations, students were often doing a VR application at the same time and immediately participating in a discussion afterward. Some of the time, they were interacting in a social application like RecRoom while also connected on videoconference.

When asked directly whether it made a difference if an experience was synchronized during class, or just that students did the VR independently but at the same time while connected on videoconference, most were ambivalent, stating that being able to connect with people while participating in a solo experience was no different or better for them than synchronizing it. Hira described this as a feeling of bringing a friend along for an experience rather than focusing on other people themselves, "exploring together" (Table 5).

One student was an exception: Ellie described feeling a sense of community through having joint attention during synchronized experiences (Table 5). Two students described feeling an increased connection with their classmates from participating in social experiences (Sofia and Zoey), namely the class meeting in Spatial (Table 1). These two students were also located outside of the U.S., and therefore may have had a stronger desire for and more difficulty connecting with classmates. Others tended to describe the social experiences as more distracting or uncomfortable for other reasons, and not as facilitation of their sense of community.

Table 5. Sense of connecting in varying implementations of VR

Connecting with classmates "around" the VR	"I think [connecting on videoconference while using VR] was a good blend of having that intimate experience, that kind of exploration, but also like dragging your friends…exploring together like, 'Did you see this?'" - Hira
Connecting in social VR	"I really felt through VR, like putting on this headset, you know, in this virtual reality world of Spatial like I was part of a community, and I was with people." -Sofia
Community from synchronized VR	"…maybe mentally you're thinking, 'Oh, what, what is my classmate looking at right now, and what would this person also say as well?' … knowing that other people are focusing on the same thing as you. I think that's more interactive, more engaging." - Ellie

On the other hand, most students described the benefit of connecting with their classmates around VR as a way to increase their comfort with VR, especially in social experiences. Chloe described this as a "push to explore," knowing her classmates were going through the same thing at the same time. They also described the benefit as increased engagement, in terms of paying attention and being less distracted, as Philip describes in Table 6. Additionally, students described the ability to discuss with others immediately after as a benefit for their learning (Sofia, Table 6).

Table 6. Impact of connecting with classmates while using VR

Increased comfort	"Like Rec Room, *AltspaceVR*, like if I had been in there alone and like not sure what to do. It was kind of nice to have like, "Oh, I can hear my team on zoom and we're all like figuring it out together"… [give you] that like push to explore." -Chloe
Increased engagement	"I definitely remember the ones that were part of class a lot more than the individual experiences. I know that with the individual experiences, I'd be like, half distracted… whereas with the group, I feel like [it's] a lot more engaging." -Philip
Increased learning	"I think it does make a difference in the sense that I can talk to others after the experience, and hear their thoughts about what they've just seen, or what they've just experienced. I can share my own ideas, I can share my own questions. So I feel like that social aspect definitely helps in VR." -Sofia

Together, the way students described doing VR with others points to the importance of viewing VR as a shared experience between classmates. However, it may not be necessary to synchronize or build social experiences where students interact with each other inside the application. A more impactful mode was helping students connect via videoconference while using the VR to facilitate discussions and support each other in exploring the new technology.

3.2.3 VR Technology as a Necessary but Not Sufficient Tool

One result that stood out from students' interviews is how the students found the VR to be necessary for their learning in the course to explore and gain mastery, but that it was equally important how it was integrated with other activities. They discussed how it was used with discussion, reflection, and meeting guest experts was important for their learning, as shown in table 7. When describing what facilitated their learning in the course overall, they discussed other elements of the class more than the VR devices themselves. For example, many students discussed how the VR experiences were related to course readings and discussions as important, that it wasn't just reading research or doing VR, but doing and discussing them "in conjunction" (Chloe, Table 7). They also discussed visits from guest speakers and creators as an important activity, particularly being able to do the VR with them via videoconference, immediately hear about how it was created or being used, and ask questions of them.

Table 7. VR integration with course activities.

Course Readings	"It wasn't just 'Read this research.' It was 'let's read the research and then hey, go watch *Traveling While Black*, probably cry during it, and then see like, okay, it's eliciting this empathetic response and you will use the research also behind like why it works for other people as well.' And I think that those two things in conjunction are really important." -Chloe
Guest Experts	"I think that really helps contextualize and help us understand the impact that this VR experience had in the world as well… that we got to hear from the content creators about the VR. I think that was really important." -Sofia
	"I think it's because just being able to do the hands-on learning together and being able to have discussions about it and being able to ask people that are really experts in it- kind of really shows you, this is what this tool can do." -Jin
Class Discussion	"So I feel like the group kind of learning is important to help scaffold different students around those learning goals. I think having those connections, we stopped in the middle and discuss, stop in the middle and discuss, was actually more helpful for learning" -Lucas

This was also apparent from students' descriptions of what contributed to their sense of community in the class. In general, students talked about class size, working in small groups, and asynchronous communication channels as important for their sense of community in classes. For this class, in particular, students pointed to the small class size and the opportunity for small group interactions via breakout rooms and group meetings outside of class time as the most important influences on their sense of community. None of the students immediately pointed to any of the VR experiences themselves when asked what facilitated their sense of class community. This highlights the way the VR was a helpful tool to give students a sense of shared experience, but that it remained a much smaller amount of time than other class activities, limiting its impact on the sense of class community.

3.2.4 Emergent Finding: Sense of Agency as Key to Students' Experience with VR

While our main research questions regarded how VR experiences could impact students' sense of community and hands-on learning using VR over time, their description of using and learning with VR highlighted the importance of agency and exploration in VR learning environments. Students discussed this related to their experience in VR, such as Hira who described the feeling of personal exploration and "doing my own learning" (Table 8), in the context of why she preferred solo VR experiences over shared or social ones, and Zoey described this as a benefit for using VR with students to allow safe exploration for them. Other students discussed agency in the context of how synchronization impeded their agency in learning, taking away from their focus or sense of control. Other students' comments about guided and synchronized VR experiences, exemplified in Table 8, highlight how it may fit well into a teacher-directed model, where a teacher wanted to specifically highlight certain information (Lucas), and ensure every student sees the same thing (Jane), or to make the experience more passive for students (Ellie).

Table 8. Students' sense of agency when using VR

VR affords Exploration and Agency	"[Doing solo VR experiences] felt like I was doing my own kind of research or exploration, like watching a movie or playing games, my own kind of space where I felt like I was just doing my own learning… I think there is a kind of like intimacy with the technology as well…exploring it in different ways." -Hira
	"I see [VR] as like a chance to explore and like give people more agency. And it affords the opportunity to do that with students… in a way that's safer and just gives us and students more agency in learning." -Zoey
Synchronization Impedes Agency and Engagement	"I found [the synchronized one] to be the least engaging one…because I had no agency. And I was just watching. And I couldn't do anything. It's not like me clicking a button or moving my arm or doing something would make it go." -Jane
	"[*Daughters of Chibok*] was a powerful experience and I wouldn't want somebody to take away from that, by stopping in the middle and being like, 'Hey let's discuss what happened.'" -Lucas
	"I kind of preferred being able to control the video and being able to start it when I… whenever I wanted to. You have a little bit more control over the experience." -Chloe
Synchronized and guided VR aligns with teacher-directed learning	"So teachers would want to probably have control and pause, like have a student go through an experience, pause, have the class come together and discuss what they saw." -Lucas
	"[When I was in the VR headset by myself] I felt like I had to kind of go out of the way to actually click on it and read it. Whereas with a guided tour, I will be looking through things and it will be someone explaining it to me in the background as I'm looking at the view." -Ellie
	"I accidentally missed one of the blurbs in the cave and didn't know how to go back…So that would be an area where I think like someone might miss something that's really necessary if they're doing it on their own." -Jane

4. Discussion

This exploratory study contributes to a growing interest in using VR technologies for teaching and learning, particularly in remote learning contexts. Our study explored a variety of implementations of VR within a remote course and examined students' experience learning with the technology over time and its impact on their sense of community with their classmates. A number of interesting themes emerged that point to fruitful areas for future research.

Using VR over time promotes a sense of mastery as its novelty wanes. Much research on learning with VR has raised questions about a "novelty effect," in which the impact of using VR is due to the new experience of using immersive technology. This course required students to use VR multiple times throughout the course, and while we did not directly measure its impact on

learning outcomes, our findings suggest that as the novelty waned students gained a greater sense of mastery of the technology and a better understanding of its affordances. Further research should continue to investigate how learners' experiences change as they have sustained exposure to immersive technology.

Because our sample consisted of current and future teachers and educational technology designers, this finding is particularly important for understanding ways to increase teachers' knowledge and beliefs of VR. Building a sense of mastery of the technology can be an important part of increasing teachers' adoption of technologies, and our findings lend empirical evidence to others' arguments that teachers need extensive time with VR to increase their comfort (Southgate et al., 2018; Bower et al., 2020). Further, our findings show that for this population, the opportunity to use the VR repeatedly increased their knowledge of its best applications and its limitations, indicating they would more likely be able to implement it effectively. Further research should investigate giving broader populations of teachers extended exposure to VR on their attitudes and teaching practices.

Features of VR applications and how they are implemented affect learners' sense of presence beyond the characteristics of the hardware. Our study confirms prior work on the features of devices that increase a user's sense of presence, as learners' ratings of their sense of presence were significantly higher when using a VR headset than on other devices. However, our survey data also suggests there is important variation based on features of the applications themselves or how they were implemented during lessons. For example, presence in social applications like Rec Room and Spatial was lower on average and more varied than for applications used independently or 360-videos used during synchronous class time. Further research is necessary to investigate the varying features of VR experiences that increase learners' sense of presence and that impact their learning outcomes.

Using VR during synchronous class meetings may be an effective instructional method that also increases students' sense of class community. Students in this class indicated that VR experiences could serve as powerful discussion pieces with their classmates when integrated with class discussion and readings. Using the VR while connected via videoconferencing helped them feel a stronger sense of engagement and comfort, and also increased their learning when well-integrated into class discussions. Using the VR independently while connected via videoconference also helped them feel connected to their classmates through a shared experience, even when it was not synchronized or a social experience. While much of the design of VR activities focus on the user experience within VR, in a class setting, students necessarily interact with the VR product together, even if the VR experience itself is individual. As such, just like Forlizzi and Battarbee (2004) suggested, the co-experience of users as they interact with each other to create "meaning and emotion together" (p. 263) should also be an integral part of the VR product design. Further research should investigate instructional designs of using VR during synchronous class meetings, and compare its impact on student learning and community relative to more technically demanding applications that synchronize or connect students in VR applications.

A sense of agency is an important part of learners' experiences in VR and may be impacted by the design of applications and instructional methods. While not an initial part of our research questions, students discussed how their sense of agency impacted their experience with VR, particularly in reference to different applications and class implementations. For many, synchronized or guided experiences degraded their sense of exploration and agency, which they saw as an important affordance of using VR for teaching and learning. On the other hand, students saw such guiding and synchronizing as a way to integrate VR into more traditional teacher-directed instructional methods. This raises important questions about the ways VR experiences are designed to promote exploration and agency in learning versus attempts to make them more amenable to classroom structures that remove students' agency, aligning with recommendations that VR be used to explore environments not possible in traditional classrooms (Bailenson, 2018; Lee et al., 2021). Others have highlighted agency as an important affordance of VR for learning (Makransky & Petersen, 2021), but less research has investigated specific features of VR hardware and applications that promote the sense of agency relative to affordances like immersion.

While these findings point to important areas for future research and instructional design, they should be interpreted with caution due to the small sample and limited generalizability of this exploratory case study. We aimed to describe this small group of students learning within one context and did not design the study to causally assess the impact of the VR experiences on students' learning and community. Further, it is likely the students who participated in this research and the remote learning model implemented due to the COVID-19 pandemic may not be representative of other students or contexts. We recommend future research conduct experimental studies with larger samples or case studies from other contexts to assess these findings' generalizability.

5. Conclusions

VR is increasingly promoted for its educational benefits, yet little research has explored its use in authentic remote learning contexts. Our study provides an exploration of one remote class that used VR many times in varying implementations. We find that in this class, the sustained use over time helped promote students' mastery of the technology, and when used while connected with others via videoconferencing could serve as a shared experience that promoted learning and a sense of community. On the other

hand, we did not find evidence that synchronizing or participating in shared VR experiences played a role in facilitating students' sense of community. Students described their sense of agency in using VR as an important factor, which raises questions about the design and implementation of educational VR experiences. Together, this study points to fruitful areas of future research in learning with VR over time in authentic education contexts regarding technical and instructional design.

Author Contributions: Conceptualization, Eileen McGivney; methodology, Eileen McGivney; validation, Eileen McGivney, Cameron Tribe, Tianyi Feng; formal analysis, Eileen McGivney, Cameron Tribe, Tianyi Feng; writing—original draft preparation, Eileen McGivney; writing—review and editing, Eileen McGivney, Cameron Tribe, Tianyi Feng; visualization, Eileen McGivney; supervision, Eileen McGivney.

Funding: This research did not receive external funding.

Acknowledgments: We would like to thank the students for generously lending their time and thoughts to this research. We also thank Monica Ares from Meta for contributing the VR headsets and coordinating their distribution. We owe a great deal to Wesley Della Volla from Meridian Treehouse for technical support to pilot the synchronization software, as well as invaluable instructional design and support. Finally, we thank all the creators of the VR experiences used, particularly those who visited our class to interact with students.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A: Survey Items

Surveys were administered via Qualtrics each week following class and VR experiences. Items were randomized within each construct. A pre-survey administered in the first week asked students baseline sense of community and course satisfaction before using VR, and also collected demographic information.

Part 1: Presence. Slater-Usoh-Steed (1994) Presence Questionnaire: Note: All questions are answered on a 7-point scale.

1. Please rate your sense of being in the virtual environment, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place. *I had a sense of "being there" in the virtual environment:* Anchors: 1 Not at all, 7 Very much.
2. To what extent were there times during the experience when the virtual environment was the reality for you? *There were times during the experience when the virtual environment was the reality for me...* Anchors: 1 At no time, 7 Almost all the time
3. When you think back about your experience, do you think of the virtual environment more as images that you saw, or more as somewhere that you visited? *The virtual environment seems to me to be more like...* Anchors: 1 Images that I saw, 7 Somewhere that I visited
4. During the time of the experience, which was strongest on the whole, your sense of being in the virtual environment, or of being elsewhere? *I had a stronger sense of...* Anchors: 1 Being elsewhere, 7 Being in the virtual environment
5. Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in color, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements. *I think of the virtual environment as a place in a way similar to other places that I've been today...* Anchors: 1 Not at all, 7 Very much so.
6. During the time of the experience, did you often think to yourself that you were actually in the virtual environment? *During the experience, I often thought that I was really standing in the virtual environment...* Anchors: 1 Not at all, 7 Very much so.

Part 2: Motivation and interest in the course and sense of community. All statements evaluated on a 5-point Likert scale from *strongly disagree* to *strongly agree*:

Sense of Community at the University

*Items adapted from the university's survey on inclusion and belonging (citation blinded)

Others modified from the The Classroom and School Community Inventory (Rovai et al., 2004).

- I feel like I belong at [University]*
- My relationships at [University] are as satisfying as I would want them to be*
- I feel like I can be my authentic self at [University]*
- I feel like I am part of the [University] community
- I find my [University] courses engaging
- I find my [University] courses challenging
- I feel connected to students in my cohort
- It is difficult to form relationships at [University]
- My studies at [University] feel lonely
- I feel removed from other students in my classes

- I have made friends at [University]
- My classes have been a good way to meet people
- My classes have a strong sense of community
- My classmates are a reason I show up for class
- My classmates are a reason I complete my work
- In remote classes I feel like I am all alone

Sense of Class Community:

Items modified from The Social Presence Scale (Kim, 2011) and The Classroom and School Community Inventory (Rovai et al., 2004).

- I feel more connected to my classmates this week than I did last week
- I feel personally close to other students in the class
- I have enjoyed sharing personal stories with the other students
- I have learned a great deal about the other students in the class
- I have been influenced by the other students' moods
- I think our class has a strong community
- Even though we are not physically together in a traditional classroom, I feel I am part of a group
- I have been able to form a sense of community
- I feel the other students have tried to form a sense of community

Perceived Learning and Class Satisfaction

Items modified based on Eom, Wen and Ashill (2006) and Arbaugh (2000)

- I feel that I am learning much from this course
- I understand the content of this class well
- I feel that this class is satisfying my learning needs
- What I have learned from this class is practically helpful to me
- I am satisfied with my decision to take this course
- I would recommend this course to other students
- My choice to take this course was a wise one
- I feel confident I can do well in this course
- I am excited for the next week of this class

Perceptions of Learning with VR

- The VR content I used this week felt more "hands-on" than other media (books, videos, etc) we are using this week
- I am interested in learning more about the content I saw in the VR experiences
- I am interested in doing more VR experiences like the ones we used this week
- The VR experiences added to my learning
- I don't feel like I learned anything from the VR experience
- I saw something in the VR experience that felt like a different perspective from my own
- I was distracted when using the VR equipment
- I was uncomfortable when using the VR equipment
- I was more focused in the VR experience than other class activities

Appendix B: Post-Course Interview Protocol

Interviews were semi-structured, meaning participants were asked these questions in varying order dependent on how they responded to each question and the flow of the interview. Prior to beginning the interview participants were assured their grades had already been finalized and submitted, so nothing they said would impact their performance in the course. They were also reminded their participation was voluntary and their identifying information would not be shared. All interviews were conducted via videoconference and recorded with participant permission.

Learning in this Class and with VR:

- Tell me about how the semester went for you.
    - Do you feel like you are learning what you wanted to?
- Tell me about how this class was for you.

  - What are you taking away from this class?
  - Did you feel like you learned what you wanted to?
  - Were you motivated to do the coursework?
- Tell me about learning with the VR experiences.
  - Which were most memorable to you? Most useful? Surprising?
  - Did the VR experiences feel more engaging than other media? Why or why not?
  - Would you take a class next semester that used VR if you had the opportunity? If so, what would you want to use it for?
  - Was there anything that made you feel alienated or uncomfortable?
- We used VR experiences in different implementations- in class, outside of class, with small groups, etc. What do you think about the different ways to implement them?
  - Did you prefer to have a VR experience synchronized during class to experiencing it independently while connected via videoconference?

Community:

- Community at the University:
  - Do you feel connected to your classmates across the university?
  - What characteristics or activities make you feel a higher or lower sense of community at the university? In your classes generally?
- Community in this class:
  - Do you feel connected to your classmates in this class?
  - What contributed to your sense of community, or lack of it?
  - Did you feel engaged in this class?

References

1. Admiraal, W., Louws, M., Lockhorst, D., Paas, T., Buynsters, M., Cviko, A., Janssen, C., de Jonge, M., Nouwens, S., Post, L., van der Ven, F., & Kester, L. (2017). Teachers in school-based technology innovations: A typology of their beliefs on teaching and technology. *Computers & Education*, *114*, 57–68. https://doi.org/10.1016/j.compedu.2017.06.013
2. Bailenson, J. N., Yee, N., Blascovich, J., Beall, A. C., Lundblad, N., & Jin, M. (2008). The Use of Immersive Virtual Reality in the Learning Sciences: Digital Transformations of Teachers, Students, and Social Context. *Journal of the Learning Sciences*, *17*(1), 102–141. https://doi.org/10.1080/10508400701793141
3. Boda, P. A., & Brown, B. (2020). Designing for Relationality in Virtual Reality: Context-Specific Learning as a Primer for Content Relevancy. *Journal of Science Education and Technology*. https://doi.org/10.1007/s10956-020-09849-1
4. Bower, M., DeWitt, D., & Lai, J. (2020). Reasons associated with preservice teachers' intention to use immersive virtual reality in education. *British Journal of Educational Technology*, *41*(6), 2214–2232. https://doi.org/10.1111/bjet.13009
5. Chen, J. A., Tutwiler, M. S., Metcalf, S. J., Kamarainen, A., Grotzer, T., & Dede, C. (2016). A multi-user virtual environment to support students' self-efficacy and interest in science: A latent growth model analysis. *Learning and Instruction*, *41*, 11–22. https://doi.org/10.1016/j.learninstruc.2015.09.007
6. Chen, S.-Y., Lai, Y.-H., & Lin, Y.-S. (2020). Research on Head-Mounted Virtual Reality and Computational Thinking Experiments to Improve the Learning Effect of AIoT Maker Course: Case of Earthquake Relief Scenes. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.01164
7. Cortiz, D., & Silva, J. O. (2017). Web and virtual reality as platforms to improve online education experiences. *2017 10th International Conference on Human System Interactions (HSI)*, 83–87. https://doi.org/10.1109/HSI.2017.8005003
8. Creswell, J. W., & Plano Clark, V. (2018). *Designing and Conducting Mixed Methods Research* (Third Edition). SAGE Publications.
9. Cuban, L. (2001). *Oversold and Underused*. Harvard University Press. http://www.hup.harvard.edu/catalog.php?isbn=9780674011090
10. Cummings, J. J., & Bailenson, J. N. (2016). How Immersive Is Enough? A Meta-Analysis of the Effect of Immersive Technology on User Presence. *Media Psychology*, *19*(2), 272–309. https://doi.org/10.1080/15213269.2015.1015740
11. Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science*, *323*, 66–69.
12. Deterding, N. M., & Waters, M. C. (2021). Flexible Coding of In-depth Interviews: A Twenty-first-century Approach. *Sociological Methods & Research*, *50*(2), 708–739. https://doi.org/10.1177/0049124118799377

13. Egea-Vivancos, A., & Arias-Ferrer, L. (2020). Principles for the design of a history and heritage game based on the evaluation of immersive virtual reality video games. *E-Learning and Digital Media*, 2042753020980103. https://doi.org/10.1177/2042753020980103
14. Ertmer, P., & Ottenbreit-Leftwich, A. (2010). Teacher Technology Change: How Knowledge, Confidence, Beliefs, and Culture Intersect: Vol 42, No 3. *Journal of Research on Technology in Education:*, *42*(3), 255–284.
15. Ewing, L.-A., & Cooper, H. B. (2021). Technology-enabled remote learning during COVID-19: Perspectives of Australian teachers, students and parents. *Technology, Pedagogy and Education*, *30*(1), 41–57. https://doi.org/10.1080/1475939X.2020.1868562
16. Forlizzi, J., & Battarbee, K. (2004). Understanding experience in interactive systems. *Proceedings of the 2004 Conference on Designing Interactive Systems Processes, Practices, Methods, and Techniques*, 261–268. https://doi.org/10.1145/1013115.1013152
17. Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development*. https://doi.org/10.1007/s11423-021-10055-y
18. Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32. https://doi.org/10.1007/s40692-020-00169-2
19. Han, E., Miller, M., Ram, N., Nowak, K., & Bailenson, J. (Under Review). *20,000 Shared Minutes in Virtual Reality: A Large-Scale, Longitudinal Field Study of the Evolution of Groups*.
20. Huang, W., Roscoe, R. D., Johnson-Glenberg, M. C., & Craig, S. D. (2021). Motivation, engagement, and performance across multiple virtual reality sessions and levels of immersion. *Journal of Computer Assisted Learning*, *37*(3), 745–758. https://doi.org/10.1111/jcal.12520
21. Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, *23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0
22. Jonas, M., Said, S., Yu, D., Aiello, C., Furlo, N., & Zytko, D. (2019). Towards a Taxonomy of Social VR Application Design. *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, 437–444. https://doi.org/10.1145/3341215.3356271
23. Joshi, O., Chapagain, B., Kharel, G., Poudyal, N. C., Murray, B. D., & Mehmood, S. R. (2020). Benefits and challenges of online instruction in agriculture and natural resource education. *Interactive Learning Environments*, 1–12. https://doi.org/10.1080/10494820.2020.1725896
24. Kirtman, L. (2009). Online versus In-Class Courses: An Examination of Differences in Learning Outcomes. *Issues in Teacher Education*, *18*(2), 103–116.
25. Koehler, M. J., & Mishra, P. (2009). What Is Technological Pedagogical Content Knowledge? *CITE Journal*, *9*(1), 60–70.
26. Lee, M. J. W., Georgieva, M., Alexander, B., Craig, E., & Richter, J. (2021). *State of XR and Immersive Learning: Outlook Report 2021*. Immersive Learning Research Network.
27. Locketz, G. D., Lui, J. T., Chan, S., Salisbury, K., Dort, J. C., Youngblood, P., & Blevins, N. H. (2017). Anatomy-Specific Virtual Reality Simulation in Temporal Bone Dissection: Perceived Utility and Impact on Surgeon Confidence. *Otolaryngology--Head and Neck Surgery: Official Journal of American Academy of Otolaryngology-Head and Neck Surgery*, *156*(6), 1142–1149. https://doi.org/10.1177/0194599817691474
28. Makransky, G., Borre-Gude, S., & Mayer, R. E. (2019). Motivational and cognitive benefits of training in immersive virtual reality based on multiple assessments. *Journal of Computer Assisted Learning*, *35*(6), 691–707. https://doi.org/10.1111/jcal.12375
29. Makransky, G., & Petersen, G. B. (2021). The Cognitive Affective Model of Immersive Learning (CAMIL): A Theoretical Research-Based Model of Learning in Immersive Virtual Reality. *Educational Psychology Review*. https://doi.org/10.1007/s10648-020-09586-2
30. Markowitz, D. M., & Bailenson, J. (2021). *Virtual Reality and Emotion: A 5-Year Systematic Review of Empirical Research (2015-2019)* [Preprint]. PsyArXiv. https://doi.org/10.31234/osf.io/tpsmr
31. Markowitz, D. M., Laha, R., Perone, B. P., Pea, R. D., & Bailenson, J. N. (2018). Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.02364
32. Maxwell, J. A. (2010). Validity: How might you be wrong? In W. Luttrell (Ed.), *Qualitative educational research: Readings in reflexive methodology and transformative practice* (pp. 279–287). Routledge.
33. Meyer, O. A., Omdahl, M. K., & Makransky, G. (2019). Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment. *Computers & Education*, *140*, 103603. https://doi.org/10.1016/j.compedu.2019.103603
34. Mills, N., Courtney, M., Dede, C., Dressen, A., & Gant, R. (2020). Culture and vision in virtual reality narratives. *Foreign Language Annals*, flan.12494. https://doi.org/10.1111/flan.12494
35. Mystakidis, S., Berki, E., & Valtanen, J.-P. (2021). Deep and Meaningful E-Learning with Social Virtual Reality Environments in Higher Education: A Systematic Literature Review. *Applied Sciences*, *11*(5), 2412. https://doi.org/10.3390/app11052412
36. National Council for State Authorization Reciprocity Agreements. (2021). *NC-SARA Annual Data Report:Technical Report for Fall 2020 Exclusively Distance Education Enrollment & 2020 Out-of-State Learning Placements*. NC-SARA. https://nc-sara.org/sites/default/files/files/2021-10/NC-SARA_2020_Data_Report_PUBLISH_19Oct21.pdf

37. Nesenbergs, K., Abolins, V., Ormanis, J., & Mednis, A. (2021). Use of Augmented and Virtual Reality in Remote Higher Education: A Systematic Umbrella Review. *Education Sciences*, *11*(1), 8. https://doi.org/10.3390/educsci11010008
38. Oh, C. S., Bailenson, J. N., & Welch, G. F. (2018). A Systematic Review of Social Presence: Definition, Antecedents, and Implications. *Frontiers in Robotics and AI*, *5*(114), 1–35. https://doi.org/10.3389/frobt.2018.00114
39. Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology*, *110*(6), 785–797. https://doi.org/10.1037/edu0000241
40. Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, 103778. https://doi.org/10.1016/j.compedu.2019.103778
41. Reich, J., Buttimer, C. J., Fang, A., Hillaire, G., Hirsch, K., Larke, L. R., Littenberg-Tobias, J., Moussapour, R. M., Napier, A., Thompson, M., & Slama, R. (2020). *Remote Learning Guidance From State Education Agencies During the COVID-19 Pandemic: A First Look*. MIT Teaching Systems Lab. https://doi.org/10.35542/osf.io/437e2
42. Rodríguez-Triana, M. J., Prieto, L. P., Vozniuk, A., Boroujeni, M. S., Schwendimann, B. A., Holzer, A., & Gillet, D. (2017). Monitoring, awareness and reflection in blended technology enhanced learning: A systematic review. *International Journal of Technology Enhanced Learning*, *9*(2–3), 126–150. https://doi.org/10.1504/IJTEL.2017.084489
43. Rovai, A. P., Wighting, M. J., & Liu, J. (2005). School Climate: Sense of Classroom and School Communities in Online and On-Campus Higher Education Courses. *Quarterly Review of Distance Education*, *6*(4), 361–374.
44. Rovai, A. P., Wighting, M. J., & Lucking, R. (2004). The Classroom and School Community Inventory: Development, refinement, and validation of a self-report measure for educational research. *The Internet and Higher Education*, *7*(4), 263–280. https://doi.org/10.1016/j.iheduc.2004.09.001
45. Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), 3549–3557. https://doi.org/10.1098/rstb.2009.0138
46. Southgate, E. (2020). *Virtual Reality in Curriculum and Pedagogy: Evidence from Secondary Classrooms*. Routledge. https://doi.org/10.4324/9780429291982
47. Southgate, E., Buchanan, R., Cividino, C., Saxby, S., Eather, G., Smith, S. P., Bergin, C., Kilham, J., Summerville, D., & Scevak, J. (2018). *What teachers should know about highly immersive virtual reality: Insights from the VR School Study*. https://nova.newcastle.edu.au/vital/access/manager/Repository/uon:32249
48. Thompson, M., Uz-Bilgin, C., Tutwiler, M. S., Anteneh, M., Meija, J. C., Wang, A., Tan, P., Eberhardt, R., Roy, D., Perry, J., & Klopfer, E. (2021). Immersion positively affects learning in virtual reality games compared to equally interactive 2d games. *Information and Learning Sciences*, *122*(7/8), 442–463. https://doi.org/10.1108/ILS-12-2020-0252
49. Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, *65*(3), 555–575. https://doi.org/10.1007/s11423-016-9481-2
50. Wu, B., Yu, X., & Gu, X. (2020). Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology*, *51*(6), 1991–2005. https://doi.org/10.1111/bjet.13023