Fall 12-9-2022

An Analysis of the Effectiveness of Virtual Reality in Distance Learning

Rashana Weerasinghe
rashana.weerasinghe@uconn.edu

An Analysis of the Effectiveness of Virtual Reality in Distance Learning

Rashana Weerasinghe
Student Researcher
rashana.weerasinghe@uconn.edu

Bob Day
Honors Advisor
robert.2.day@uconn.edu

Jonathan Moore
Thesis Supervisor
jonathan.a.moore@uconn.edu

Abstract

This study focuses on the applicability of emerging technologies in education. To explore this, our research was conducted through an "Intro To Emerging Technology" course taught by the OPIM Department at the University of Connecticut. The class meets in two modalities: virtual reality environment and video-conferencing platform. Our research explores the learning outcomes produced by the different classroom environments, seeking to better understand the impact of virtual reality in distance learning. The purpose of this is to identify and predict how virtual reality will be integrated into a distance learning environment and understand if it can be used as a mechanism to enhance the student experience. This study is composed of both qualitative and quantitative data. Qualitative data is gathered through a compilation of survey questions, and quantitative inputs are measured during class time. Ultimately, this research can be used to inform decisions related to the future of education in the classroom from a student perspective.

1. Introduction

Extended reality (XR) is the next evolution in human-computer and environment interaction. It serves as an umbrella term for all virtual combined environments and human-machine interaction. Three types of technologies fall under XR: Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). This study focuses on VR, a type of interactive technology that enables a fully immersive experience for users. VR is a three-dimensional computer-simulated environment that creates a sensory experience using sounds, images, and computer graphs to reproduce real-world scenarios.

1.1 Main Subject Definition and Background of Virtual Reality (VR)

Virtual Reality (VR) refers to technology that allows users to perceive and immerse themselves in a virtually constructed space [2]. It creates a virtual environment, through graphics, allowing the user to experience a virtual world through virtual reality. It is defined as "an interface between a human and a computer that makes a particular environment or situation into a computer and makes the user use it as if he or she is interacting with the surrounding environment"[2]. This interface creates a unique environment, and different scenarios, and makes it possible for people who use it to feel and interact with reality. VR can be easily incorporated into a user's current environment through a Head Mounted Device (HMD). It is a monitor worn on the head to provide high immersion to the user [2]. Virtual reality devices include controllers, VR headsets, and haptic equipment. An important aspect of the virtual reality experience is real-time interaction. This shows a user's response in real time through immediate input and processing of various reactions. In turn, minimizing the difference between reality [2].

The new era of the Metaverse has unleashed interest in the integration of virtual reality in both professional and academic environments. Primarily seen in the gaming industry, VR serves as a successful product in bringing video games to life. With virtual reality products becoming more affordable and consumer-oriented, the technology has experimented with different types of classrooms and student demographics.

Virtual reality-based education provides students with a realistic three-dimensional environment to deepen their learning experience. It serves as a platform to allow students to develop more practical learning skills through experiential learning and active participation. The environment promotes cooperation, and collaboration, and provides unique opportunities that would be hard to replicate in a classroom setting.

However, within an academic environment, a gap in knowledge related to if the simulated environments truly "benefit learning outcomes" is unknown. Similarly, how students will interact with the technology and how it will impact student-to-student and student-to-teacher relationships is another unknown which remains. Lastly, how the technology can be seamlessly integrated into a classroom setting

without disrupting the curriculum and learning content has not been fully researched.

1.2 Problem Statement and Objective

With VR considered to be a technology that will restore and transform the educational experience, questions and concerns related to the efficacy of the technology and its impact on learning outcomes remain unanswered. The objective of this study seeks to provide more clarity and a better understanding of the student experience in VR while measuring its implications on student learning and behavior.

Hypothesis: A student's level of classroom involvement in a distance learning environment will be improved through the use of virtual reality technology. This will be measured through the evaluation of participation, engagement, and empathy. Web conferencing will serve as a control to monitor the difference in approaches.

2. Literature Review

Virtual reality-based education is perceived to have a greater effect on academic achievement than classical education. It is determined that classical education primarily focuses on reading and listening knowledge, with limited opportunities for students to apply their learnings [2]. According to one study, virtual reality-based education typically has a 2.7-fold increase in effectiveness and concentration by over 100% compared to conventional education [2]. The improvement of academic achievement through interest and immersion in learning is shown to have a positive effect on students. In addition, wearing an HMD removes blocks from a student's current environment allowing them to better concentrate in their virtual environment. This leads to better learning outcomes for distracted learners as virtual reality-based education showed that stronger attention concentration is maintained [2].

Research performed by the Google Academy indicates people can remember 20% of what they hear, 30% of what they see, and 90% of the scenes they have experienced. This statistic indicates that simulated learning environments can support positive learning outcomes. Achieving these outcomes have been in medicine, gaming, and sports industries. More specific to education, previous VR pilot experiences and research supports VR serving as a tool to teach specific academic topics such as geography, pharmacy, anatomy, and psychology.

According to the BMC Medical Education, research findings confirm that VR is an efficient way to improve a learner's understanding of anatomy. The primary outcomes of the study identify that VR improves test scores in comparison to other teaching modalities. In addition to anatomy, VR is considered to be a more conducive high-dimensional medium for students to absorb, understand, and accept content related to medicine and visual sciences. Increased learning enthusiasm and student motivation in the classroom have also been identified as common outcomes of VR [1].

2.1 Measuring Efficacy of VR In The Classroom

While VR has served as a tool in supporting learning outcomes, the integration of the technology in the classroom is critical " one cannot simply create a VR program and expect transformations in student learning outcomes; any VR tools developed must be fit for purpose and implemented into curricula appropriately" [2]. For instance, research performed by Maresky used a desktop computer program that had been converted into an HMD VR program and led to severely limiting interactivity due to uncoordinated hand controls. In turn, this inhibits the overall student experience in VR. Conversely, Maresky developed a purpose-built model of the human heart in VR and witnessed significant benefits to student learning with pre and post-intervention tests indicating an improvement in visual-spatial understanding.

Similarly, Parkhomenko used purpose-built VR tools and saw increases in self-perceived confidence and understanding of the material. Based on past findings in incorporating VR in the classroom, it is important to forecast "fit" and design curriculum content that can be integrated into a simulated learning environment. As such, educators and software designers are encouraged to work together in creating targeted learning tools in VR [2].

In measuring the efficacy of VR in the classroom, it is important to record both the interaction with and implementation of VR tools in the classroom. With interaction in VR, previous research suggests visual-spatial knowledge improved when there was even limited interactivity with virtual anatomical models as opposed to none [2]. This combined with the negative results seen in Maresky and colleagues' study could be attributed to a lack of intuitive and interactive hand controls with which to manipulate the environment.

Previous findings also indicate the time spent in VR can be an important factor in evaluating the effectiveness. The study by Maresky and colleagues allowed approximately 30 minutes of interaction and saw a positive impact. Meanwhile, the study conducted by Stepan and colleagues allowed students

10 minutes in VR revealing minimal differences between experimental and control groups [4]. Thus, students must have on average at least 30 minutes of interaction in VR, in order to measure its impact on learning outcomes.

2.2 Problems and Limitations of Virtual Reality-Based Education

As with any type of technology deployed in a classroom, there are limitations. Based on previous research, virtual reality technology has raised concerns related to student health, course content development, and technical limitations. The primary concern related to implementing VR in the classroom stems from the material costs and student/faculty training required to meet the needs of the industry. additional drawbacks include virtual reality include motion sickness, lack of content availability, low vision, and space limitation. Specifically, with nausea or motion sickness, students can start feeling the effects of dizziness within 10 minutes. [2]. In addition, exposure to the screen for a long time at a narrow distance may affect children who are still developing their optic nerves. Hence, cyber and motion sickness developed through interacting with technology can lead to negative learning outcomes.

It is important to factor in the student's age when considering incorporating VR into the classroom. Specifically, younger students can be more sensitive to technology and could experience negative effects from long-term wear. A protocol and stipulations need to be in place to better determine the right age to introduce VR to students. This is because long-term wear can lead to photosensitive seizures which are when users experience overexposure to the necessary amount of light. As virtual reality continues to become more developed and the scope of use widens, it is important to conduct studies of stability to identify and minimize any potential risks.

The curriculum and types of content taught in virtual reality are limited. Particularly, fields of study such as humanities, liberal arts, and law may not be as fitting in a VR environment. Put more simply, VR may not be able to offer much in enhancing the environment of humanities-related classrooms. This leads to another downside of the technology which is the lack of available content. In order to effectively administer a classroom in VR, relevant content that fits a VR classroom needs to be generated. Currently, there is a limited assortment of existing material, implying that faculty that want to incorporate VR in their classroom will need to develop their types of VR content. This is an important need that can impact virtual reality-based education. Thus, the market will need to develop content that is synergistic with existing systems. Virtual reality learners are interested in gamified learning content. Creating a variety of such content would be important to successfully scale the technology.

User adoption is important. Training and developing VR skills can be a burden in education environments that may not have the resources, guidance, and availability to do so. While the products can be relatively easy to use, understanding how to troubleshoot in VR and transitioning into the virtual environment will require training. Such training includes eliminating potential threats to the hardware and software from improper implementation.

The final, and most important, limitation includes its cost Historically, VR has been pricey. Currently, the Meta Quest 2 sells for $500. This is considered the mid-range for VR headsets, with most falling between the $300 to $600 price range. While the technology is evolving to cater more to consumer buyers, there are occasional price hikes. In July 2022, due to supply chain and production costs, Meta raised the price of the headsets by $100. It can be assumed that as the technology becomes more available and accessible, the overall cost will decrease. However, its price will continue to remain a cost factor in popularizing and making the technology more accessible.

With previous studies supporting VR-based learning for particular content areas, additional factors such as degree of satisfaction, cost-effectiveness, and adverse reactions should be evaluated to assess the entire student learning experience in VR.

3. Methodology

Based on the criteria given in Section 1.2, the choice of methodology for this research study includes both qualitative and quantitative methods. The three areas of measurement include engagement, empathy, and participation. We incorporated a qualitative approach to measuring engagement and empathy and pursued a quantitative approach to measuring participation.

The materials used in our research included the WebEx conferencing video platform and Oculus Quest 2 Headsets. Due to university licensing, WebEx was the selected platform to conduct the distance learning portion of the class. Many different types of VR hardware exist, Oculus Quest 2, which provides both an HMD and hand controllers, was selected to allow students to have a full immersion experience with haptic feedback, hand tracking, and 3D positional audio.

In order to launch the course, UConn partnered with the Glimpse Group, an AR and VR Enterprise Solutions company. The immersive technology platform provided enterprise focused VR software for the class to use. The Operations Information Management (OPIM) department received funding from the UConn Werth Institute for Entrepreneurship and Innovation to partner with Glimpse Group. The Werth Institute has worked with the Glimpse Group in the past to teach an Entrepreneurial Journey course several times in VR. With our partnership with the VR enterprise solutions company, Glimpse Group creates a "UConn App' specific for UConn students and faculty to use. The customized app is composed of VR breakout rooms with whiteboards and a main classroom. Several functionalities in the app include the ability to share a presentation, upload documents, and take notes in the app.

The "Introduction to Emerging Technology" course was composed of 14 students with varying backgrounds. The course provides students with a foundation and high-level introduction to the fast-paced world of emerging technology, innovation, research and development and business applications. The course objectives for students include developing a moderate understanding of emerging technologies through hands-on modules, exploring the current and future business and societal implications of these technologies, and applying the skills to develop an original idea, research the technology and business needs and pitch it to key stakeholders.

The class consisted of several components and activities that would contribute towards the student's grade. For instance, students had to complete "technology kits" which were hands-on modules designed to introduce students to technology pathways. Additionally, students spent the semester working towards delivering a final project which included a minimum viable product for their business idea, a developed business plan, and a presentation covering final and execution-based information. During the semester, students completed "food for thought" discussions to promote critical thinking on emerging technologies and innovation based on current news articles. The final several components included attending networking events with technology professionals and entrepreneurs, and regularly participating in class activities.

Student participation was measured using a participation tracker that measures how many times each student spoke during class, engaged via chat, or demonstrated inattentiveness during class. Participation was measured in both the virtual reality environment and video conferencing platform. The class operated in split events including both a video conferencing platform and VR. Students would experience on average 90 minutes in WebEx and 60 minutes in VR in each class.

3.1 Experimental Design

Qualitative data was collected through survey feedback and student interviews. The course included a total of six surveys. Students completed a pre-class survey to assess their familiarity and previous experiences with VR prior to joining the class. During the semesters, students completed bi-weekly surveys assessing the meaningfulness of classroom activities in both WebEx and VR. Students were also asked to measure the effectiveness of different types of platforms, and learning methods used in class. The final survey gathered feedback from students and assessed their student's overall experience in VR. The use of survey responses provided data for measuring student engagement and empathy. The type of survey questions included Likert scale questions, short answer questions, and multiple choice. All survey responses were collected anonymously.

Data gathered through surveys measured the effectiveness of classroom activities from the students' perspectives. Such activities included case presentations, user interviews, "Food For Thought" class discussions, and the Miro collaboration tool. In addition to the classroom activities, the modes of instruction/collaboration were also measured. This includes WebEx class discussions, WebEx breakout rooms, VR class discussions and VR breakout rooms.

4. Results

The primary factors measured in our study include the impact of VR on student engagement, empathy, and participation. Participation was measured using a tracker. The tracker recorded how many times students participated in VR and WebEx, measured the number of messages sent in the WebEx chat, and any signs of distraction during class. Six surveys were conducted over the course of the semester to measure engagement and empathy. Each survey focused on a different topic and produced a different set of results. All quantitative survey results are captured in Figure 1-1. Below we analyze key findings from each survey.

4.1 Student Experience Survey Results

The Pre-Class survey served as a pulse check to identify if students had interacted with VR prior to joining the class and what their previous experiences

were like. Captured in survey response summary table, Figure 1-2, of the 14 students present, 64% had been in a VR environment before. Students had engaged with the technology in a game setting, mostly either watching videos or playing games through headsets provided at Arcades. Specific games included TopGolfVR, Plex, Pavlov, and Skyrim. It is worth noting that gaming was the only use case students shared. In addition, of the students who had been in a VR environment before, 50% had used an Oculus Quest / Quest 2 VR headset. When asked to rate to forecast the value VR would provide on a scale of 1 to 5 (1 being not valuable, 5 being very valuable), 50% of students rated it a 5, considering it would be very valuable in the classroom. Similarly, when asked to predict how they feel VR would compare to online web conferencing tools, 64% felt VR would be better.

Qualitative gatherings from the initial survey included many students sharing an interest in seeing how breakout rooms in VR would work "If breakout rooms can be done in VR, I am curious to see how that will work". This came as students reflected on their experiences in online breakout sessions with 85% of participants recording that the breakout rooms in WebEx were not effective, "Breakout rooms across all my online classes rarely worked and it always ends up being silent unless someone steps up and says something but even then, people are very reluctant to turn on their mics or even chat".

Survey 1 asked students behavioral questions on how they predict their experiences in VR will compare to WebEx. To do so, we first asked students to share all the video conferencing platforms they have used. WebEx, Zoom and Blackboard (offered through HuskyCT) had been used by all students. Google Meet and Microsoft Teams were used by approximately half of the students. Based on their past experiences on the video conferencing platforms, students seemed to feel indifferent about the tools. Most mentioned that their overall experience has been "pretty good with the exception of technical difficulties". A handful of students mentioned that all the platforms feel the same and " it gets stuck looking at a screen for all your classes". On the other hand, one student expressed a preference towards Microsoft Teams "I have not used Teams for any of my classes, mainly for work, I think if UConn moved to other platforms like teams it would be a nicer experience".

When specifically asked to share a positive experience in video conferencing the main theme highlighted was the accessibility, ease of use, and convenience provided by all of the platforms. Some students called out specific features that they liked which included the raise hand feature, and the share screen feature. An interesting response mentioned how video conferencing platforms are a positive experience as they "decrease the chances of being late". Thus, video conferencing is most prominently liked by students for its convenience.

On the other hand, student responses to a negative experience in video conferencing all related to a theme of lack of engagement. Some responses included "lecture with no interaction", "when cameras are off it is dead", "awkward pauses when people are talking defeats the conversation dynamic", and "people have webcams off during breakout rooms and won't turn the mic on so nothing gets done". In addition, students mentioned low video quality and connectivity issues can create a poor video conferencing experience. The strengths of conferencing platforms are their ease of use and accessibility, and the lack of engagement and promotion of student interaction is a weakness felt by students. As displayed in summary table Figure 1-2, when asked to measure the value of WebEx on a Likert scale (1 being not valuable, 5 being very valuable) 43% of students answered 3. Based on this result, it can be assumed most students feel indifferent towards the platforms.

Survey 1 was administered during the third week of classes in which most students still do not have a full experience in VR yet. To gauge pre-VR sentiments, the survey included how students feel video conferencing will compare to VR. Below we summarize some of the key responses received for this question: "VR allows one to engage and connect in the classroom", "I believe VR allows for more accountability than WebEx", and "VR would be better for visual learners". Overall positive sentiments were expressed before entering the VR classroom with 100% of students feeling that it would be valuable in a classroom setting. Similarly, all students felt more comfortable leading VR breakout sessions compared to a WebEx breakout session. There also was a positive correlation between having conversations with peers in VR and asking questions in class in a VR environment. Overall, this survey reflected a positive and open attitude students had towards integrating VR into the classroom.

Survey 2 measured the efficacy of idea-generation activities, design-thinning activities, and class discussions. The results displayed that class discussion in WebEx and VR are both effective, 60% of students rated discussion in WebEx a 5, and 90% of students rated discussions in VR a 5 (1 being not effective, 5 being very effective). This is important as it indicates that while 30% more felt VR was effective, a majority of the class felt that WebEx was just as effective.

During class, students completed an idea generation activity using Miro in WebEx. When asked to evaluate this experience 50% of students felt

indifferent to the activity. When asked a hypothetical question of whether students felt this activity would be more effective in VR (despite not completing the activity in VR), 60% of students said it would. This is interesting as without experiencing the activity in VR, the student confidence remained strong with it being a better experience than in WebEx. A similar pattern was witnessed for design thinking activities. Sixty percent of students felt indifferent towards completing the activity in WebEx.

Lastly, how students feel about giving a design thinking presentation was evaluated. There was a varied set of responses for giving a design presentation in WebEx, with answers across the entire spectrum. The class was split with 50% considering themselves to be comfortable giving a presentation in WebEx, while another 50% either felt indifferent or uncomfortable. Contrastingly, there was less hesitancy and variations in the responses for a virtual reality environment. Again, while at this point in the semester students had yet to give a presentation in VR, 80% still felt comfortable if they had to do so. Hence, it is interesting to measure student confidence in VR compared to WebEx. While some of the questions were assessing hypothetical situations that could occur in VR and compared them to actual situations that occurred in Webex, students overall felt more confident and comfortable in trying an activity or giving a presentation in a VR environment.

4.2 Mid-Semester Student Survey Results

Survey 3 measured the efficacy of conducting user interviews, giving case presentations, and working in smaller groups in VR. There was a consensus among students preferring to conduct user interviews in VR. They noted that user interviews in WebEx would not be as effective. With measuring the efficacy of breakout rooms in WebEx there were varied results, with answers ranging across the spectrum of very effective to not effective at all, with 50% of respondents feeling indifferent about its effectiveness in WebEx. Contrastingly, for VR, all students felt breakout rooms are effective, with 75% of respondents giving its effectiveness a 4 out of 5. A similar pattern of results was seen when students were asked to share their sentiments on giving a presentation in both environments. While students

Survey 4 was measuring students' health and comfortability in VR in comparison to WebEx. The majority of students, approximately 57%, feel comfortable in both a VR and WebEx environment. Specifically in VR, approximately 38% of students experienced multiple health-related drawbacks such as nausea, dizziness, sensitivity to brightness, and blurred vision. Dizziness and blurred vision are the most common symptoms of discomfort in VR. In contrast, the one discomfort students reported in WebEx was related to sensitivity to the brightness of staring at the screen for too long. Thus, students endured more discomfort in VR in comparison to WebEx. However, the results were reversed as it relates to the impact of time spent in each modality.

According to Survey 4 results, depicted in Figure 1-2, 56% of students did not feel that spending long periods of time negatively impacted their learning experience. While, in WebEx, the majority of students felt that spending too much time on the platform does hinder their learning experience. Additional perspectives on their experience in VR included the need for "2-minute breaks" to avoid discomfort stemming from being in the headset for too long such as nausea and dizziness. Similarly, a student expressed discomfort due to the hardware of the headset. The student mentioned that the headset does not properly sit on their head, causing consistent readjustments and disturbance. The last perspective shared on health and comfortability alluded to vision deteriorating in both environments, however, WebEx overall is the harder platform to spend more time in.

Based on the Survey 4 results it is interesting to note that VR caused more symptoms of discomfort, yet students were willing to spend more time in VR than WebEx. Students experienced less discomfort in a video conferencing environment, however, believe that spending too much time on the platform can negatively impact their learning experience.

4.3 End-of-Semester Student Survey Results

Our final survey, administered at the end of the semester, captured students' reflections on their overall experiences. Firstly, in asking students how their perspective on VR has changed since the start of the semester, many declared there to be no significant difference. Participants mentioned the use of the technology throughout the semester made them feel "far less intimidated and much more interested in the technology". One student shared how their perspective of the technology has changed, specifically as it relates to the maturity of the device "I now believe VR in the workplace/job setting is very far away from being a reality… apps are not developed enough and the mainstream headsets are not good enough yet". The student shared that prior to joining the class, they felt that the technology could be integrated into a workplace environment in the near future. However, their experiences in the classroom have proven otherwise.

Secondly, participants were asked if VR fits in an educational setting. All ten students shared that they believe VR is impactful in the classroom. Respondents mentioned that they prefer learning in VR in comparison to a web conferencing modality, “VR fits in an education environment because it elevates the experience when compared to a normal zoom class. It would be a good replacement for zoom”. Class participants continued to mention that there are specific benefits to learning in a VR environment, specifically in public speaking and giving presentations. Some students even noted that they feel more at ease when giving a presentation in VR “Environments I think it would be beneficial for are ones that require a lot of presenting, it seems to make you less nervous.”

Students also shared that it is easier to concentrate in VR as fewer distractions are making it easier to pay attention to the instructor and their peers. The immersive learning style presented through VR makes “learning fun” as the students feel more engaged. In contrasting their experiences in VR at the collegiate level to a professional setting, many do not believe VR would be fitting or applicable in a work environment. Rather, students feel that VR is better used in education to “close the gap between in-person learning and online”.

Giving presentations in VR was a positive common sentiment shared by students. To better understand the student experience, we asked them to share what pain points they face as students. Responses included time management, stress, paying attention, and giving presentations. Giving a presentation is the primary pain point students mentioned. This stems from students feeling uncomfortable presenting to a large audience. Interestingly, a handful of students shared that despite VR mimicking a more realistic presentation environment compared to online presentations, students felt calmer than when presenting on a web platform. One student mentioned, “I definitely think VR helps with presenting. Since it's in another form of reality, it sort of feels more calm and less stressful”. The student feels that VR helps reduce the pains of giving presentations, however, calls out another pain point that VR does satisfy which is intaking lecture content “If we are looking at a slideshow in VR, it sort of feels odd because Webex would be better. If there were more interactive class pieces in VR like building things right in front of us or interactive things like that, it might make it better than the current pain point of sitting in a lecture for 40+ minutes”. The student does not believe that VR is suitable for listening to a lecture but rather better for hands-on activities

Students were asked to share aspects of VR they liked and disliked. For favorable aspects of the technology, students mentioned the connectivity and “in-person feel” the technology mimics. Others describe it as “a cool way to [interactively] learn online”. Proximity was another theme mentioned in the comments “ the ability to connect with multiple students in a setting where we are all from different places was great. I'm in Stamford and I'm talking to people in Storrs right in front of me”.

For weaknesses, most students pointed to software difficulties and health-related drawbacks such as eye strain and nausea. The lack of comfort in the headset was the main theme majority of students alluded to. A handful of additional students mentioned their dislike of the software app used to conduct class “I didn't like that we only stuck to UConn's VR app, though we could've explored a few as a class”. Student feedback also reflected a need for more interactive sessions in VR that were outside the VR classroom, “If we can find other apps, we can take a "field trip" to explore VR as a group, it would help a lot seeing how vast the space can be.” Students felt that primarily staying in the VR classroom limited their ability to explore all of the functionalities, apps, experiences, and environments that are offered in VR.

Another student in a similar vein mentioned some of the difficulties they had with the app used “A dislike I had was probably the app itself. I felt limited in what I could do, always having to mute/unmute, and things just felt off compared to other apps I have tried. Having a push-to-talk button would be great.”. Seemingly, students felt limited by the functionalities offered through the app, with many hoping to have explored other options and types of activities possible in VR. While the app was designed for UConn to create a personal experience for students, limitations within the simulated environment impacted the student’s overall experience.

Quantitative data gathered from the final survey pointed to an overall positive student experience in VR. When asked if students would take more courses in VR if offered, 100% of students answered “yes”. Similarly, 90% of students felt that VR improved their engagement in class and 100% of students felt it improved their participation during class. Thus, students believed that learning in VR helps them participate in class and be more engaged. As it relates to empathy in VR, 60% of students felt more empathetic in a VR environment. Empathy, in the context of emerging technology class, can be harder to measure due to the lack of social-emotional learning content measured. Thus, such results are aligned with our predicted outcomes for empathy.

The final part of the last survey resurfaced questions presented to students during their intro-class and beginning-of-semester surveys. At the beginning of the semester, when students were asked to forecast

how valuable they believe VR will be in the classroom, varied results were received, 50% of students ranked the anticipated value of VR at a 5 out of 5. The rest of the students had scattered answers across the scale. Now, at the end of the semester, that has increased by 20%. The results show less variation in the student responses with 70% of students ranking it as 4 out of 5, with 20% ranking it as a 5 out of 5. It is important to note that the survey responses for the introduction survey were higher compared to the final class survey, with 14 participants completing the pre-class survey and 10 students completing the final class survey.

Students were asked how they think VR compares to learning on a video conferencing tool. At the beginning of the semester students, 92% of students scored VR as the most valuable classroom tool. By the end of the semester, 100% of students felt that VR was more valuable, ranking it at 3 or above on a scale out of 5. Thus, while students had a positive outlook on the impact of VR coming into the class, their belief in the technology increased as the semester progressed.

While all students agree that VR is more valuable in a classroom setting than a web conferencing tool, in-person teaching cannot seem to compare. In the final survey, 80% of students felt that learning in person is a better experience than learning in VR. This is an interesting finding as before the start of the class 57% of students felt that VR would be more valuable than in-person learning. Hence, it can be concluded that while VR provides significant value in the classroom in comparison to a video learning platform, it is not as valuable as in-person learning.

At the beginning of the semester, 85% of students felt they would feel comfortable asking questions during a VR lecture. That percentage, by the end of the semester, increased to 90% of students feeling comfortable asking a question in VR. Additionally, at the beginning of the semester, 85% of students believed that they would feel comfortable giving a presentation in VR. Now, having had the opportunity to present in VR, 90% of students feel comfortable giving a presentation in VR. This is a much higher rate of comfortability than giving presentations online, with only 50% of students feeling comfortable giving a presentation on WebEx. This is a noteworthy finding as students have had more experience presenting on a video platform. Despite having more opportunities to present online, they feel more confident and comfortable presenting in VR. This ties directly to the final factor measured which was student confidence. Students felt VR has a positive impact on their overall confidence, with 90% of students feeling confident in a VR environment. This can be reflected in the results covering students' preference for having discussions and giving presentations in VR.

4.4 Participation Tracker Results

A participation tracker was created to measure student participation in VR and WebEx during the semester. The tracker was used to measure the participation of three classes. In VR, participation was recorded if a student spoke during class. In Webex, participation was recorded if a student spoke during class and sent a message via chat. The classes recorded varied in terms of activities and time spent in VR. Most classes were equally split with VR and WebEx, while some remained only WebEx.

Of the 3 classes recorded, 2 were conducted in both VR and WebEx, and 1 was conducted in WebEx only. The participation total across the 3 classes shown in Figure 2, indicates that students participated a total of 31 times in VR and a total of 23 times in WebEx. With an average of students speaking 2 to 3 times more in a VR setting. An interesting note was if a student was naturally more talkative during class, VR would serve as a participation catalyst. On the other hand, quieter students had higher averages for speaking in WebEx, than in VR.

Based on our results, it is important to bear in mind the types of activities that were conducted in each environment. As will be covered in Professor Insights, Section 4.5, WebEx served as a better environment for lectures, while VR fostered a stronger environment for class discussions. Thus, students may not have felt the need to participate in WebEx due to the type of activities conducted using the web conferencing tool. With the WebEx chat, the majority of students rarely used the feature. It was mainly used during the WebEx-only class, where the highest number of chat messages sent by a student was 2. Based on this finding, it can be assumed that web conferencing tools do not support nor serve as a good reflection of a student's willingness to participate in class.

4.5 Professor Insights: Lessons Learned

Introduction to Emerging Technologies course professor, Tyler Lauretti, shared his thoughts on the technology. Firstly, we assessed how Lauretti felt about teaching in VR prior to the start of the semester. Lauretti shared he was intrigued by teaching in VR, yet had doubts about the current state of the technology. This came with the logistical and technical trickiness of toggling between two virtual environments. He proceeded to share that the technology's current state of maturity could be a

limiting factor in the types of content that would provide value in a VR setting. Similarly, he would have to discover the VR lift points in the classroom " Studies show that VR can provide a significant lift in learning, but typically it is used as a way to enhance a particular topic, not as a general means of communication. Discovering where those lift points could happen proved both interesting and challenging."

Since the start of the semester, Professor Lauretti shares that his opinion on technology has not shifted drastically. He explained the importance of finding the value VR provides to one's particular class as the semester progresses " I do think we found where the lift for this class shines through. The most engaging moments of class seem to be when we do discussions in VR". Lauretti noticed that in WebEx it would be easy for students to hide with no camera on and on mute. While in VR, "they need to give their full attention and overall they seem much more engaged in our conversations." Students have also expressed similar sentiments about class discussions in VR "Even they [the students] have acknowledged this, after one week I asked them if they would rather do the lecture or the discussion in VR and everyone agreed discussion was better." This is an important insight as it highlights that VR provides a unique value proposition to each class, yet cannot be used as a means to seamlessly transfer all class activities and methods of learning.

While VR discussions were successful, VR lectures were deemed to be less impactful. "For VR lectures I find that they tend to get more distracted by all of the VR features and they are less engaged in the content happening. Webex is a bit better for that type of content". For an Emerging Technology course, the nature of the content makes it difficult to use VR to demonstrate class cases due to the lackluster content available. Thus, for the type of content Lauretti was teaching, WebEx was a better forum for students to consume the learning material, while VR served as a better platform for students to participate in discussing the material learned.

Secondly, as the course was split between both VR and WebEx, the class would typically first meet in WebEx prior to transitioning into VR. After attempting the reverse, asking all students to join in VR first, seemed to be a harder transition for the course "seems like Webex into VR is a smoother transition given some of the technical issues we have had over the semester".

Professor Lauretti also shared difficulty with developing VR activities for class topics. Due to the technical nature of the course, there are limited options for how students can enhance their technical aptitude in VR.

Further insights shared by Professor Lauretti during his experience leading the classroom included the lack of maturity in the headsets. Technical limitations can disrupt the overall class flow. As Lauretti anecdotally shares "last week I ran into an issue where my headset power button got pressed and I lost my charge during the day before class, I couldn't log in until it had a certain level of charge and I had no backup way to get into the system". He contrasts this to modern web conferencing tools which do provide alternatives with backup access through a phone or another device. Lauretti shares that such issues can have a significant impact on students if they are unable to attend class or participate in a VR activity. Lauretti points out that this can disadvantage faculty with less technical experience in maintaining the composure of the students and class.

Lastly, Lauretti mentioned the several technical difficulties students faced: "I've had students hit bugs with the platform a few different times this semester and I've had to accommodate by doing a hybrid of Webex and the VR headset to try and make sure everyone stays involved ". Lauretti continues that these disruptions take away important class time by doing tech support with the technology. Based on the insights we can draw that it is important to factor in the technology's maturity when bringing it into a classroom environment. Based on Oculus 2 Headset's maturity, it may be best to wait for the device to reach a more mature state prior to integrating it into a classroom setting. Doing so can improve the overall student and instructor experience.

4.6 Future of Virtual Reality-Based Education

VR is founded upon building and reinventing experiences. The emergence of this technology has and will continue to create the demand to enhance the instruction of content. The goal of VR is to deliver enhanced learning outcomes through low-cost and high-student immersion. Immersion can be measured through active student participation and engagement in the classroom setting. Engagement can include partaking in activities with peers, conversing with peers and instructors, and measurement of understanding of the material. The technology supports positive student-to-student and student-to-instructor communication through its high-resolution and real-time capabilities.

In our final student survey, we gathered insights into the predictions class participants would make on the future of VR in education. Many student responses pointed to a bright future for the technology granted the headsets are more affordable and have

higher fidelity. “The costs associated with having to buy and maintain the headsets are going to provide a massive barrier to entry for most people. [However], I think VR will be a big component of education in the distant future.”

Another student shared they expect to see an overall increase in users of VR and how often it is used. The student made this claim with the acknowledgement that the technology needs to be further developed and offer more functionalities. “I think it definitely will jump in terms of who is using it and how many people are using it. There just has to be more developers pushing for [better] functionality and better feel from within the apps.” This remained a consistent theme in students’ predictions, with one going on to mention how they think VR will replace distance learning “If headsets are made cheaper and higher quality, I can see it replacing online learning.” In sum, based on their experiences this semester, class participants believe VR in education will grow once the technology is refined to be less strenuous and more user-friendly.

Necessary technical improvements for the product include speed, latency, content development, and user adoption. The use of the technology will require skill testing and training to support both students and teachers in adapting to the technology. Herein lies the complexities of integrating and scaling technology in an educational environment.

5. Conclusion and Recommendations

This research validates our hypothesis that a student's level of classroom involvement in a distance learning environment will be improved through the use of virtual reality technology. This conclusion was formed by measuring participation, engagement, and empathy in both VR and WebEx. While empathy remained a difficult factor to measure and quantify in our results, an increase in engagement and participation in VR proved to be a strong indicator of student sentiments toward the technology. VR provided an overall better learning experience for students with a hunch towards improving discussions and student collaboration. Students also felt more confident in a VR environment despite having spent less time in the headsets compared to WebEx.

Furthermore, our findings indicate the need to actively incorporate technical characteristics and new technological tools to enhance the student learning experience. It provides instructors and learners with the ability to engage in “in-depth learning” and explore experiential learning opportunities. Yet, to effectively achieve this, students and faculty need to feel comfortable with the technology and integrate it into their environment. This means offering reskilling and upskilling to faculty and staff to better understand the technology and support its implementation in a classroom setting. Tangentially, VR headsets need to be further developed to pursue this effort. The current state of maturity of the technology is not adequate to cause a system to shift to VR. The cause of a heavy headset, eye strain, nausea, and limited content applications severely hinder both the student and instructor experience.

Thus, our recommendations include continuing research to minimize the effects of HMD hardware on youth. A better understanding of the effects of the hardware will help mitigate any health risks and safety concerns. Secondly, identifying the right types of content and learning curriculum to be taught in VR is important for seeing a positive impact on learning efficacy in the classroom. Offering a more inclusive portfolio of apps that cater to faculty needs and different learning curriculums will promote a more supportive and inclusive learning environment. This too will widen the scope of activities, lessons, and experiential learning opportunities faculty can engage their students with VR.

Future research should focus on measuring the differences between in-person learning vs. VR. Our findings focused on comparing web conferencing tool experiences to VR, however, it would be impactful to conduct a deeper analysis of the student experience in VR vs. in-person learning. Similarly, research on the best types of content to learn in a VR setting could be indicative of which curriculum can lead to higher learning outcomes in a virtually simulated setting. This coupled with conducting further research on faculty sentiments on VR can serve as a good indicator of the future of VR in education. From corporate America to small businesses, and educational settings, VR has paved the way for emerging technologies to enhance an experience. “The use of VR in the process of training for the needs of the high-tech industry, including in the context of Industry 4.0, allows to eliminate physical risk for users (e.g., possible injury, burns, etc.), as well as to eliminate the potential threat to the hardware or software resulting from misconfiguration and improper implementation of the procedure by trainees during the exercises.”[3]

Predominantly known for the impact it can have on retaining a new type of workforce, VR has the potential to change the academic, corporate, and social landscape. While such changes will take time and continued exposure, the possibility of VR entering education at scale remains probable.

References

[1] Peng, L. (2020). *Virtual reality teaching material - virtual reality game with education.* IOPscience. Retrieved November 30, 2022, from https://iopscience.iop.org/article/10.1088/1742-6596/1456/1/012039

[2] An, M. Y. (2020, August). *Problems and directions of development through analysis of virtual reality-based education in Korea* ResearchGate. Retrieved November 30, 2022, from https://www.researchgate.net/publication/346449275_Problems_and_Directions_of_Development_through_Analysis_of_Virtual_Reality-Based_Education_in_Korea

[3] Paszkiewicz, A., Salach, M., Dymora, P., Bolanowski, M., Budzik, G., & Kubiak, P. (2021, April 30). *Methodology of implementing virtual reality in education for Industry 4.0.* Multidisciplinary Digital Publishing Institute. Retrieved November 30, 2022, from https://www.mdpi.com/2071-1050/13/9/5049

[4] Stepan, K. (2017, July 18). *Immersive virtual reality as a teaching tool for neuroanatomy.* U.S. National Library of Medicine. Retrieved November 30, 2022, from https://pubmed.ncbi.nlm.nih.gov/28719062/

[5] Serin, H. (2019, November 12). *View of virtual reality in education from the perspective of teachers.* Amazonia Investiga. Retrieved November 30, 2022, from https://www.amazoniainvestiga.info/index.php/amazonia/article/view/915/1047

[6] Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017, December 27). *A systematic review of virtual reality in Education.* Themes in Science and Technology Education. Retrieved November 30, 2022, from https://www.learntechlib.org/p/182115/

[7] Abich, J., Parker, J., Murphy, J. S., & Eudy, M. (2021, January 8). *A review of the evidence for training effectiveness with virtual reality technology - virtual reality.* SpringerLink. Retrieved November 30, 2022, from https://link.springer.com/article/10.1007/s10055-020-00498-8

[8] Fedorov, N. (2022, November 16). *The history of virtual reality.* AVADirect. Retrieved November 30, 2022, from https://www.avadirect.com/blog/the-history-of-virtual-reality/

[9] Häfner, P., Häfner, V., & Ovtcharova, J. (2013, November 26). *Teaching methodology for virtual reality practical course in engineering education.* Procedia Computer Science. Retrieved November 30, 2022, from https://www.sciencedirect.com/science/article/pii/S1877050913012362

[10] Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2020, July 11). *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. SpringerLink. Retrieved November 30, 2022, from https://link.springer.com/article/10.1007/s40692-020-00169-2

[11] Velosa, J. D., Cobo, L., Castillo, F., & Castillo, C. (1970, January 1). *Methodological proposal for use of virtual reality VR and augmented reality AR in the formation of professional skills in industrial maintenance and Industrial Safety.* SpringerLink. Retrieved November 30, 2022, from https://link.springer.com/chapter/10.1007/978-3-319-64352-6_92

[12] Smutny, P. (2022, February 13). *Learning with virtual reality: A market analysis of educational and training applications.* Taylor & Francis. Retrieved November 30, 2022, from https://www.tandfonline.com/doi/full/10.1080/10494820.2022.2028856

[13] Khodabandeh, F. (2022, June 9). *Exploring the applicability of virtual reality- enhanced education on extrovert and introvert EFL learners' paragraph writing.* International journal of educational technology in higher education. Retrieved November 30, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9177226/

Appendix

Figure 1-1. Student Survey All Responses Table

Student Survey All Responses Table								
Item	**Response:**	**Yes**	**No**	**1**	**2**	**3**	**4**	**5**
Pre-Class Survey								
Have you ever been in a VR environment?	Percent	64.30%	35.70%					
	Frequency	9	5					
Have you ever used the Oculus Quest / Quest 2 VR headset?	Percent	50.00%	50.00%					
	Frequency	7	7					
On a scale of 1-5, how valuable do you think VR will be in the classroom (1 being not valuable, 5 being very valuable)	Percent				7.10%	14.30%	28.60%	50.00%
	Frequency				1	2	4	7
How do you think learning in VR will compare to learning on a video conferencing tool (1 being WebEx is better, 5 being VR is better)	Percent				7.10%		28.60%	64.30%
	Frequency				1		4	9
How do you think learning in VR will compare to learning in the classroom (1 being WebEx is better, 5 being VR is better)	Percent				7.10%	7.10%	28.60%	57.19%
	Frequency				1	1	4	8
You are listening to a 30 minute lecture on WebEx on a given topic, how likely are you to ask a question? (1 being very unlikely, 5 being very likely)	Percent				21.40%	35.70%	35.70%	7.10%
	Frequency				3	5	5	1
You are in a WebEx breakout session, how likely are you to lead the conversation? (1 being very unlikely, 5 being very likely)	Percent			15.40%	7.70%	61.50%	7.70%	7.70%
	Frequency			2	1	8	1	1
You are listening to a lecture on WebEx, how likely are you to ask a question in the chat? (1 being very unlikely, 5 being very likely)	Percent			15.40%	30.80%	23.10%	30.80%	

	Frequency			2	4	3	4	
You are in an online lecture, how likely are you to turn on your camera? (1 being very unlikely, 5 being very likely)	Percent			30.80%	30.80%	15.40%	15.40%	7.70%
	Frequency			4	4	2	2	1
You are in a WebEx lecture, how likely are you to message another student in your class? (1 being very unlikely, 5 being very likely)	Percent			46.20%	15.40%	38.50%		
	Frequency			6	2	5		
On a scale of 1-5, how comfortable are you giving a presentation in WebEx? (1 being not comfortable, 5 being very comfortable)	Percent			21.40%	14.30%	14.30%	28.60%	21.40%
	Frequency			3	2	2	4	3
Survey 1								
On a scale of 1-5 how valuable do you think Webex is in the classroom (1 being not valuable, 5 being very valuable)	Percent			14.30%		42.90%	14.30%	28.60%
	Frequency			1		3	1	2
On a scale of 1-5 how valuable is VR in the classroom (1 being not valuable, 5 being very valuable)	Percent						57.10%	42.90%
	Frequency						4	3
You are in a VR breakout session, how likely do you think you are to lead the conversation? (1 being very unlikely, 5 being very likely)	Percent						42.90%	57.10%
	Frequency						3	4
You are listening to a lecture in VR, how likely do you think are you to ask a question in the chat? (1 being very unlikely, 5 being very likely)	Percent				14.30%	14.30%	42.90%	28.60%
	Frequency				1	1	3	2
You are in a VR lecture, how likely do you think you are to message another student in your class? (1 being very unlikely, 5 being very likely)	Percent				14.30%	28.60%	14.30%	42.90%
	Frequency				1	2	1	3
How comfortable do you think you would be giving a presentation in VR? (1 being very uncomfortable, 5 being very comfortable)	Percent					14.30%	14.30%	71.40%

	Frequency					1	1	5
Survey 2								
Open discussions such as Food For Thought are effective in WebEx (1 being not effective, 5 being very effective)	Percent				10.00%	10.00%	20.00%	60.00%
	Frequency				1	1	2	6
Class discussions in VR are effective? (1 being not effective, 5 being very effective)	Percent						10.00%	90.00%
	Frequency						1	9
Idea generation is effective using Miro in Webex (1 being not effective, 5 being very effective)	Percent				10.00%	50.00%	30.00%	10.00%
	Frequency				1	5	3	1
An idea generation activity in VR would be more effective than WebEx (1 being not effective, 5 being very effective)	Percent				20.00%	20.00%	30.00%	30.00%
	Frequency				2	2	3	3
Design thinking activities are less effective in VR (1 being not effective, 5 being very effective)	Percent				20.00%	40.00%	30.00%	10.00%
	Frequency				2	4	3	1
Design thinking activities are more effective in WebEx (1 being not effective, 5 being very effective)	Percent				10.00%	60.00%	10.00%	20.00%
	Frequency				1	6	1	2
How comfortable do you think you would be giving a design thinking presentation in WebEx? (1 being not comfortable, 5 being very comfortable)	Percent			20.00%	10.00%	20.00%	30.00%	20.00%
	Frequency			2	1	2	3	2
How comfortable do you think you would be giving a design thinking presentation in VR? (1 being not comfortable, 5 being very comfortable)	Percent					20.00%	40.00%	40.00%
	Frequency					2	4	4
Survey 3								
Conducting user interviews is effective WebEx (1 being not effective, 5 being very effective)	Percent			12.50%	25.00%	50.00%	12.50%	
	Frequency			1	2	4	1	

Conducting user interviews in VR is effective (1 being not effective, 5 being very effective)	Percent					12.50%	50.00%	37.50%
	Frequency					1	4	3
Breakout rooms in WebEx are effective (1 being not effective, 5 being very effective)	Percent			12.50%	12.50%	50.00%	12.50%	12.50%
	Frequency			1	1	4	1	1
Breakout rooms in VR are effective (1 being not effective, 5 being very effective)	Percent					12.50%	75.00%	12.50%
	Frequency					1	6	1
I am comfortable giving a case presentation in WebEx? (1 being not comfortable, 5 being very comfortable)	Percent			12.50%	25.00%	12.50%	37.50%	12.50%
	Frequency			1	2	1	3	1
I am comfortable giving a case presentation in VR? (1 being not comfortable, 5 being very comfortable)	Percent						12.50%	87.50%
	Frequency						1	7
Survey 4								
I experience discomfort in a VR environment (1 being not comfortable, 5 being very comfortable)	Percent				28.60%		14.30%	57.10%
	Frequency				2		1	4
I experience discomfort in a WebEx environment (1 being not comfortable, 5 being very comfortable)	Percent				28.60%	14.30%		57.10%
	Frequency				2	1		4
Spending too much time in VR can negatively impact my learning experience (1 being very unlikely, 5 being very likely)	Percent			14.30%	42.90%	14.30%	14.30%	14.30%
	Frequency			1	3	1	1	1
Spending too much time in WebEx can negatively impact my learning experience (1 being very unlikely, 5 being very likely)	Percent				28.60%	14.30%	28.60%	28.60%
	Frequency				2	1	2	2
Final Survey								
Would you take more courses (if offered) in VR?	Percent	100.00%	0.00%					

	Frequency	10	0					
Does learning in VR improve your engagement in class?	Percent	90.00%	10.00%					
	Frequency	9	1					
Does learning in VR improve your participation in class?	Percent	100.00%	0.00%					
	Frequency	10	0					
Do you feel more empathetic in a VR environment?	Percent	60.00%	40.00%					
	Frequency	6	4					
On a scale of 1-5, how valuable is VR is in the classroom (1 being not valuable, 5 being very valuable)	Percent					10.00%	70.00%	20.00%
	Frequency					1	7	2
How do you think learning in VR compared to learning on a video conferencing tool (1 being WebEx is better, 5 being VR is better)	Percent					10.00%	70.00%	20.00%
	Frequency					1	7	2
How do you think learning in VR compared to learning in-person (1 being in-person is better, 5 being VR is better)	Percent			20.00%	30.00%	30.00%		20.00%
	Frequency			2	2	2		2
How do you think VR impacted your student confidence? (1 being negatively impacted my confidence, 5 being positively impacted my confidence)	Percent					10.00%	50.00%	40.00%
	Frequency					1	5	4
You are listening to a 30 minute lecture in VR on a given topic, how likely are you to ask a question? (1 being very unlikely, 5 being very likely)	Percent				10.00%	20.00%	50.00%	20.00%
	Frequency				1	2	5	2
You are in a VR breakout session, how likely are you to lead the conversation?(1 being very unlikely, 5 being very likely)	Percent				10.00%	10.00%	60.00%	20.00%
	Frequency				1	1	6	2
On a scale of 1-5, how comfortable are you giving a presentation in VR? (1 being very uncomfortable, 5 being very comfortable)	Percent			10.00%			60.00%	30.00%

	Frequency			1			6	3

Fig. 1-1. Student Survey All Responses Table: includes all survey responses gathered through the entirety of the semester. Results capture 6 surveys from approximately 14 student responses.

Figure 1-2. Student Survey Responses Summary Table

Student Survey Responses Summary Table								
Item	**Response:**	**Yes**	**No**	**1**	**2**	**3**	**4**	**5**
Pre-Class Survey								
Have you ever been in a VR environment?	Percent	64.30%	35.70%					
	Frequency	9	5					
Have you ever used the Oculus Quest / Quest 2 VR headset?	Percent	50.00%	50.00%					
	Frequency	7	7					
On a scale of 1-5, how valuable do you think VR will be in the classroom (1 being not valuable, 5 being very valuable)	Percent				7.10%	14.30%	28.60%	50.00%
	Frequency				1	2	4	7
How do you think learning in VR will compare to learning on a video conferencing tool (1 being WebEx is better, 5 being VR is better)	Percent				7.10%		28.60%	64.30%
	Frequency				1		4	9
Survey 1								
On a scale of 1-5 how valuable do you think Webex is in the classroom (1 being not valuable, 5 being very valuable)	Percent			14.30%		42.90%	14.30%	28.60%
	Frequency			1		3	1	2
On a scale of 1-5 how valuable is VR in the classroom (1 being not valuable, 5 being very valuable)	Percent						57.10%	42.90%
	Frequency						4	3
Survey 2								

Open discussions such as Food For Thought are effective in WebEx (1 being not effective, 5 being very effective)	Percent				10.00%	10.00%	20.00%	60.00%
	Frequency				1	1	2	6
Class discussions in VR are effective? (1 being not effective, 5 being very effective)	Percent						10.00%	90.00%
	Frequency						1	9
Idea generation is effective using Miro in Webex (1 being not effective, 5 being very effective)	Percent				10.00%	50.00%	30.00%	10.00%
	Frequency				1	5	3	1
An idea generation activity in VR would be more effective than WebEx (1 being not effective, 5 being very effective)	Percent				20.00%	20.00%	30.00%	30.00%
	Frequency				2	2	3	3
How comfortable do you think you would be giving a design thinking presentation in WebEx? (1 being not comfortable, 5 being very comfortable)	Percent			20.00%	10.00%	20.00%	30.00%	20.00%
	Frequency			2	1	2	3	2
How comfortable do you think you would be giving a design thinking presentation in VR? (1 being not comfortable, 5 being very comfortable)	Percent					20.00%	40.00%	40.00%
	Frequency					2	4	4
Survey 3								
Conducting user interviews is effective WebEx (1 being not effective, 5 being very effective)	Percent			12.50%	25.00%	50.00%	12.50%	
	Frequency			1	2	4	1	
Conducting user interviews in VR is effective (1 being not effective, 5 being very effective)	Percent					12.50%	50.00%	37.50%
	Frequency					1	4	3
Breakout rooms in WebEx are effective (1 being not effective, 5 being very effective)	Percent			12.50%	12.50%	50.00%	12.50%	12.50%
	Frequency			1	1	4	1	1
Breakout rooms in VR are effective (1 being not effective, 5 being very effective)	Percent					12.50%	75.00%	12.50%

	Frequency					1	6	1
I am comfortable giving a case presentation in WebEx? (1 being not comfortable, 5 being very comfortable)	Percent			12.50%	25.00%	12.50%	37.50%	12.50%
	Frequency			1	2	1	3	1
I am comfortable giving a case presentation in VR? (1 being not comfortable, 5 being very comfortable)	Percent						12.50%	87.50%
	Frequency						1	7
Survey 4								
I experience discomfort in a VR environment (1 being not comfortable, 5 being very comfortable)	Percent				28.60%		14.30%	57.10%
	Frequency				2		1	4
I experience discomfort in a WebEx environment (1 being not comfortable, 5 being very comfortable)	Percent				28.60%	14.30%		57.10%
	Frequency				2	1		4
Spending too much time in VR can negatively impact my learning experience (1 being very unlikely, 5 being very likely)	Percent			14.30%	42.90%	14.30%	14.30%	14.30%
	Frequency			1	3	1	1	1
Spending too much time in WebEx can negatively impact my learning experience (1 being very unlikely, 5 being very likely)	Percent				28.60%	14.30%	28.60%	28.60%
	Frequency				2	1	2	2
Final Survey								
Would you take more courses (if offered) in VR?	Percent	100.00%	0.00%					
	Frequency	10	0					
Does learning in VR improve your engagement in class?	Percent	90.00%	10.00%					
	Frequency	9	1					
Does learning in VR improve your participation in class?	Percent	100.00%	0.00%					
	Frequency	10	0					
Do you feel more empathetic in a VR environment?	Percent	60.00%	40.00%					
	Frequency	6	4					

On a scale of 1-5, how valuable is VR is in the classroom (1 being not valuable, 5 being very valuable)	Percent					10.00%	70.00%	20.00%
	Frequency					1	7	2
How do you think learning in VR compared to learning on a video conferencing tool (1 being WebEx is better, 5 being VR is better)	Percent					10.00%	70.00%	20.00%
	Frequency					1	7	2
How do you think learning in VR compared to learning in-person (1 being in-person is better, 5 being VR is better)	Percent			20.00%	30.00%	30.00%		20.00%
	Frequency			2	2	2		2
How do you think VR impacted your student confidence? (1 being negatively impacted my confidence, 5 being positively impacted my confidence)	Percent					10.00%	50.00%	40.00%
	Frequency					1	5	4
You are listening to a 30 minute lecture in VR on a given topic, how likely are you to ask a question? (1 being very unlikely, 5 being very likely)	Percent				10.00%	20.00%	50.00%	20.00%
	Frequency				1	2	5	2
On a scale of 1-5, how comfortable are you giving a presentation in VR? (1 being very uncomfortable, 5 being very comfortable)	Percent			10.00%			60.00%	30.00%
	Frequency			1			6	3

Fig. 1-2. Student Survey Summary Responses Table: highlights key insights and responses gathered from all surveys.

Figure 2. Participation Tracker Summary Table

Participation Tracker Summary Table			
Student Name	**Participated in VR (total # of times spoke during class)**	**Participated in WebEx (total # of times spoke during class)**	**Sent Message in Webex Chat (total # of times engaged in chat)**
Student 1	3		
Student 2	3	1	2
Student 3	9	8	
Student 4	3	1	
Student 5	1	3	1
Student 6	4	1	
Student 7	3	5	3
Student 8	1		1
Student 9	4	2	
Student 10	0	2	
Total	31	23	7

Fig. 2. Participation Tracker Summary Table: displays records of participation tracked during 3 classes. Two of the classes were conducted in both VR and WebEx, 1 class was conducted only in WebEx. Participation includes number of times student spoke during classes and number of times engaged via WebEx chat.