

## Article

# Adding a Web-Based Virtual Reality Classroom Experience to a Hybrid, Blended Course Modality

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**Abstract:** The blended classroom is a unique space for face-to-face (F2F) interaction and online learning. The blended classroom has three distinct interaction types: in-person synchronous, virtual synchronous, and virtual asynchronous; each of these modalities lends itself to different forms of extended reality. This case study looks at using a virtual reality (VR) classroom for an online synchronous weekly meetings for three upper-division or advanced (junior and senior level) higher education design classes at a university. The use of social web VR for a classroom can offer a collaborative, real-time environment that bridges the gap between virtual video conferences and gaming platforms. This paper examines how to use social web VR in a virtual classroom. Mixed methods were used to collect usability data at the end of the semester survey. The system usability scale (SUS) and several qualitative questions gathered student feedback. Overall, the students enjoyed using the VR classroom, but audio issues seemed to be the most significant pain point. While the overall response was positive, this study will address several areas for improvement from both the student and instructor perspectives. Social, web-based VR offers promising potential. Designing a human-centered virtual environment and considering all participants' total user experience is critical to a successful learning tool.

**Keywords:** virtual reality; blended learning classroom; social virtual reality; web-based virtual reality; virtual reality classroom; extended reality



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## 1. Introduction

Virtual reality (VR) is an advanced technology used across different sectors including medicine, aviation, art, and design [1,2]. Virtual reality can be used for training, therapy, exhibits, and gaming, yet it is not widely used in daily life. Virtual reality is not a new concept; the accessibility of VR technology has dramatically increased in the last few years. Social virtual worlds are increasingly embedded into e-commerce and e-learning [3]. In education, virtual reality technology is a way for teachers and students to create a simulated three-dimensional world [4].

Hardware like head-mounted displays (HMD) has become more cost-effective, yet it is not commonly owned by the masses like a smartphone. According to Pew Research, 85% of Americans own a smartphone. Web-based VR consists of 360-degree content that can be viewed and navigated using a web browser. In theory, any device capable of connecting to the internet could run a web-based VR experience. Web-based VR offers unique access across multiple devices, including phones, tablets, laptops, and head-mounted displays (HMDs). Leveraging existing devices increases digital equity and allows access to be scaled up quickly [5]. Web-based social VR is a subset of desktop-based VR and virtual worlds [6].

Unfortunately, there is often a digital divide issue in practice. While various devices like phones and tablets can, in theory, run web-based VR, many device variables can contribute to a negative user experience, such as older hardware and slow or inconsistent internet connection speeds. Ideally, access to head-mounted displays could give students additional immersion. However, the HMD should be an option used primarily for shorter

meetings where movement and interaction in the space or with others is the primary objective; as noted in earlier studies, discomfort or VR sickness from long-term wear and difficulty with note taking while wearing an HMD are known issues [7–9]. In addition to the digital divide, digital skill gaps are increasingly an issue. There is a great need to establish projects addressing the digital skills needed for using social virtual environments or web-based VR higher education [10].

Social VR allows people to communicate in real time through avatars that can interact in a virtual world. Web-based social VR facilitates communication, collaboration, and interaction between people in a virtual world when meeting in real-life is too tricky, or inconvenient [11]. During the pandemic, many instructors sought alternatives to video conferencing to increase immersion and presence. Some turned to web-based virtual reality as a viable option. While research was already being conducted on distance learning using social virtual reality environments in education, the pandemic forced everyone to adopt distance learning, and some chose to explore the use of social virtual worlds. There was a significant rise in usage of this technology in multiple regions of the globe [12]. Current social VR platforms can provide an easy and affordable way for educators to utilize VR [13].

Several studies on Mozilla Hub web-based VR studies have been conducted since the pandemic [5,7,8,11,14]. Being unable to meet in person, especially for large events, made the virtual environment an exciting alternative. Conferences, expos, and festivals turned to VR to interact, collaborate, and meet up with people worldwide. One could even attend the annual Burning Man festival—where artists and makers gather to build Black Rock City, a participative temporary metropolis in the Nevada desert—in virtual reality in 2020.

Using avatars can create an enhanced sense of self for the learner since they can often customize and control the avatar that digitally represents them [10,15]. Some studies have even shown that the increased connection to the learner's avatar positively affected their engagement and ability to follow online discussions in the virtual world [16]. Social VR can be a successful tool in social learning spaces. [17] Some studies have shown that the VR learning environment can effectively ensure students' motivation and sociability in distance learning [18].

While there was an increase in the use and experimentation with virtual reality as a replacement for not being able to meet in person during a time of mandatory physical separation, previous studies on the use of virtual reality in education pre-COVID have shown how social virtual reality can be used as an educational tool to foster deep, meaningful learning [10]. Delivering course material via a virtual environment is beneficial to students [19]. Additionally, a literature review by Mystakidis et al., of studies before 2020 suggests, that social virtual reality Environments or SVREs “can provide authentic, simulated, cognitively challenging experiences in engaging, motivating environments for open-ended social and collaborative interactions and intentional, personalized Learning”. This pre-pandemic literature review of social virtual reality environments or SVREs shows the promise of using virtual reality to facilitate deep, meaningful learning and foster engagement in a virtual setting across different disciplines through distance learning.

Social virtual reality environments can enhance distance education efficacy when used in combination with applying instructional methodologies such as situated learning, experiential learning, and game-based learning [20].

This case study looks at using a virtual reality (VR) classroom for an online synchronous weekly meeting for three upper-division advanced junior and senior-level design classes. During the height of the COVID-19 worldwide pandemic, all higher education institutions switched to a virtual teaching model. In many cases, this meant instructors provided class content in a learning management system (LMS) such as Canvas or Blackboard and then held classes over a video chat platform like Zoom or Microsoft Teams.

As institutions have navigated the process of bringing more instructors and students back to a face-to-face (F2F) campus environment, there have been various blended or hybrid learning options. A unique opportunity to research the use of web-based virtual reality for remote learning happened during the pandemic. New literature details the quick pivot to

web-based virtual reality and what we have learned from relying solely on virtual reality as a point of interaction. Moving forward, educators can now look at how web-based virtual reality can fit into a blended learning environment. The blended classroom is a unique space for face-to-face (F2F) interaction and online learning. Blended learning has three distinct interaction types: in-person synchronous, virtual synchronous, and virtual asynchronous; each of these modalities lends itself to different forms of extended reality. Studies have also shown that when virtual environments are used as a supplement and incorporate traditional instruction strategies, they are more effective than autonomous learning experiences [21].

This work aims to look at how extended reality can pair with a blended classroom model. This study specifically looks at using a virtual reality (VR) classroom for an online synchronous weekly meeting for three upper-division design classes. The use of social web VR for a classroom can offer a collaborative real-time environment that bridges the gap between virtual video conferences and gaming platforms. The study is significant and relevant due to advances in extended reality web-based technology and the change in expected classroom modalities. A blended instruction model achieves greater flexibility for both instructors and students. This flexibility allows for quick pivots of classroom modality for any reason. In addition, it creates an equitable environment for students to continue receiving instruction even if they cannot attend F2F in-person classes for any reason.

## 2. Materials and Methods

Three advanced interactive multimedia classes in the Graphics Design Bachelor of Fine Arts (BFA) degree at California State University were used in this study, each class with a description is listed below.

**GD142 User Experience and User Interface Design Course Description:** An intermediate web design class for graphic designers. The class focuses on user experience design methods and practices to improve the usability and aesthetics of a user interface. Students will use user experience methods to engineer the whole experience surrounding a digital environment, emphasizing how data-driven research can improve the layout, hierarchy, typography, and color scheme of a user interface. Summary/outline of the course: Students will design website mock-ups and test functioning prototypes of their interfaces based on user experience methods. Through usability tests, they will refine their prototypes with multiple iterations to create finalized mock-ups ready for development. Similar to a style guide for a brand, they will create style guidelines to document the user interface systems they have created for their website.

**GD157 Motiongraphics Course Description:** Understand and implement animation principles for time-based media. Application of software to create visually integrated, concept-driven motion graphics and interactive web animations. Emphasis on research, including usability research and production of advanced time-based media projects.

**GD159 Immersive Design Course Description:** This course explores 3D digital modeling and its incorporation into augmented and virtual environments. Students will research and explore different ways to implement augmented and virtual reality. Summary/outline of the course: This course will be driven by research and experimental development of immersive technologies. Students will learn the basics of 3D modeling while researching how to implement them in different augmented and virtual environments. Time will also be spent considering the usability, UX (user experience) design, and UI (user interface) design of an augmented or virtual reality interface.

Mixed methods collected usability data at the end of the semester survey. In addition, the system usability scale (SUS) and several qualitative questions gathered feedback from the students. The classes are blended, hybrid class modalities meaning that on Mondays, students can join the instructor in the classroom face-to-face (F2F), join via Zoom or watch a recording asynchronously. On Wednesdays, students meet for check-in via Mozilla Hubs, a social web-based virtual reality platform. This is the text from the syllabus explaining the blended breakdown:

Group meetings will be held on Mondays to allow us to interact together. Most Mondays, there will be live face-to-face (F2F) meetings in person. Some Mondays will be held via a live Zoom meeting locations will be noted on the syllabus and on canvas. Attending the group meeting live is optional but highly recommended. You are responsible for reviewing the content and recordings of the meeting on canvas and asking questions if you cannot make the Monday F2F or Zoom meeting.

Weekly Check-ins will happen on Wednesdays. We will all join our virtual classroom in Mozilla Hubs for 30 min to have a progress check-in. The rest of class time will be work time. You have the option of signing up for an individual meeting with me during class time as well. Check-ins offer you time to ask questions or discuss anything class-related. You will include 1. What have you completed so far this week? 2. What do you plan to finish this week? 3. Any questions you have? 4. Screenshots or videos of any work you would like feedback on.

The same professor taught all three classes with different groups of students. During the check-in using Mozilla Hubs' web-based VR, the professor moderated a group discussion where each student took turns sharing their progress either using their microphone or typing in the chat. Visuals from students of their progress work were uploaded to a collaborative Google slide show and imported as a PDF before the meeting. There were approximately 15 students per class and attendance to the VR check-in fluctuated; 5–13 students would attend the VR check-in at a time. Mozilla Hubs was chosen for its ability to host the entire class, because it was free for the students to use, and because students could join from mobile, desktop, or HMD. At the end of the semester, students were given an option to participate in a post-activity survey asking a few qualitative questions on the system usability scale (SUS). This study meets the qualifications of an exempt Institutional Review Board (IRB) at the department-level review.

Qualitative questions included: How often did you attend the weekly Check-In in Mozilla Hubs? If you only attended a few times or never, Please explain if it was technology reasons or timing. What would have increased your desire to participate in the check-in? What did you like and not like about the VR classroom? What would improve your experience using the VR classroom?

The system usability scale (SUS) was worded as follows, using a 5-point Likert scale [strongly agree 1, 2, 3, 4, 5 strongly disagree].

1. I think that I would like to use this VR classroom frequently.
2. I found the VR classroom unnecessarily complex.
3. I thought the VR Classroom was easy to use.
4. I think that I would need the support of a technical person to be able to use this VR Classroom.
5. I found the various functions in this VR classroom were well integrated.
6. I thought there was too much inconsistency in this VR Classroom.
7. I would imagine that most people would learn to use this VR Classroom very quickly.
8. I found the VR classroom very cumbersome to use.
9. I felt very confident using the VR Classroom.
10. I needed to learn a lot of things before I could get going with this VR Classroom.

When reviewing the qualitative data, responses were run through voyant-tools.org to reveal additional correlations. Each response was read and coded based on key terms. The SUS was scored according to the SUS protocol. Each response is assigned a value for the SUS score calculation. The points breakdown for the responses are: Strongly Disagree—1 point, Disagree—2 points, Neutral—3 points, Agree—4 points, Strongly Agree—5 points. Then, tabulate the overall SUS score using the following framework:

- Add the total score for all odd-numbered questions and subtract 5 from the total to obtain (X).
- Add the total score for all even-numbered questions and subtract that total from 25 to obtain (Y).

- Add up the total score of the new values ( $X + Y$ ) and multiply by 2.5.

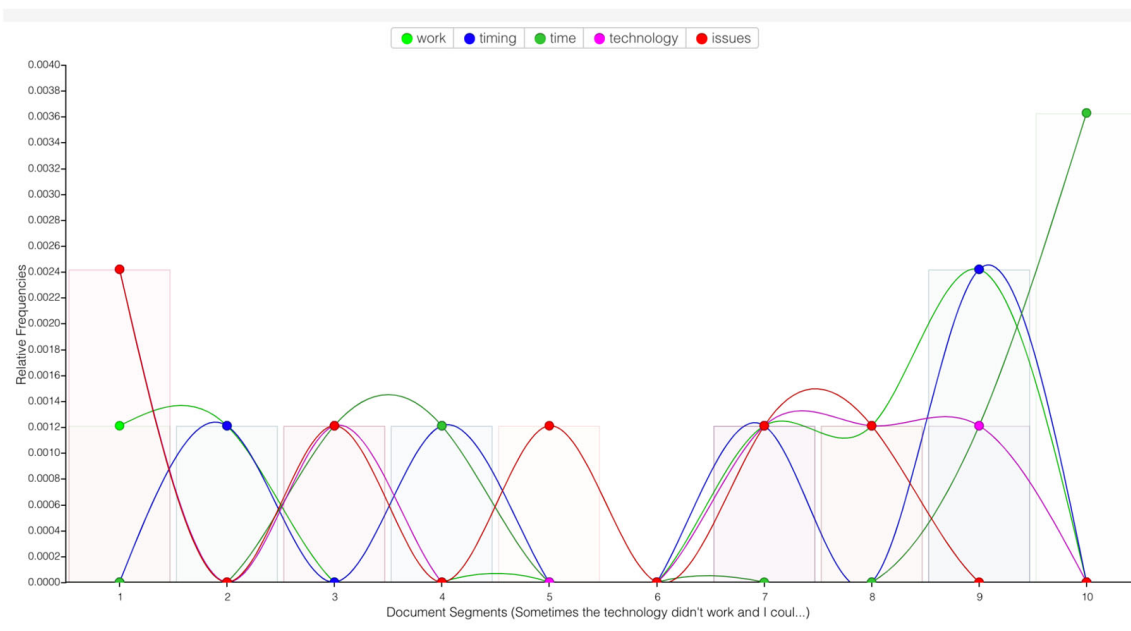
The resulting score is the SUS score out of 100, with the average score being 68. Scoring above or below the average will give you immediate insight into the overall usability of the design solution [22,23].

### 3. Results

The results of the post-activity survey shed light on how students reacted to using Mozilla Hubs once a week for a full semester. While some students struggled with the modality because of technology, many also had issues that were unrelated to the modality and could have caused a drop in attendance/participation regardless of the modality. Several students appreciated the VR as an alternative to Zoom, while several students thought the check-in would have been simpler on Zoom, and one student would have preferred the whole class to be in-person F2F. Thirty-one out of thirty-five students opted to take the survey.

#### 3.1. Findings from Qualitative Data

When asked, “how often did you attend the weekly check-in”, four said a few times, nine said sometimes, one said never, five said most weeks, and twelve said almost every week. Nineteen people chose to answer: “If you only attended a few times or never, Please explain if it was technology reasons or timing. What would have increased your desire to participate in the check-in?” Twelve of those students attended sometimes/a few times/never, and seven attended most/every. After running the qualitative responses for this question through voyant-tools.org, the five most used words were work (6 uses), time (6 uses), timing (5 uses), technology (6 uses), and issues (6 uses). See Figure 1 for the collation of the most frequently used words.



**Figure 1.** Correlation of trend words created with Voyant Tools for the qualitative questions, “Please explain if it was technology reasons or timing.” and “What would have increased your desire to participate in the check-in?” [24].

After reviewing the context of each comment, seven of the students had technology issues that prevented them from attending more frequently. While seven other students had timing issues related to work schedules or personal/mental health, and time management issues. Five students fell outside the time/work category. One would have preferred

in-person, two liked/loved using Hubs, and two stopped participating because they fell behind and “did not want to participate with nothing to share”.

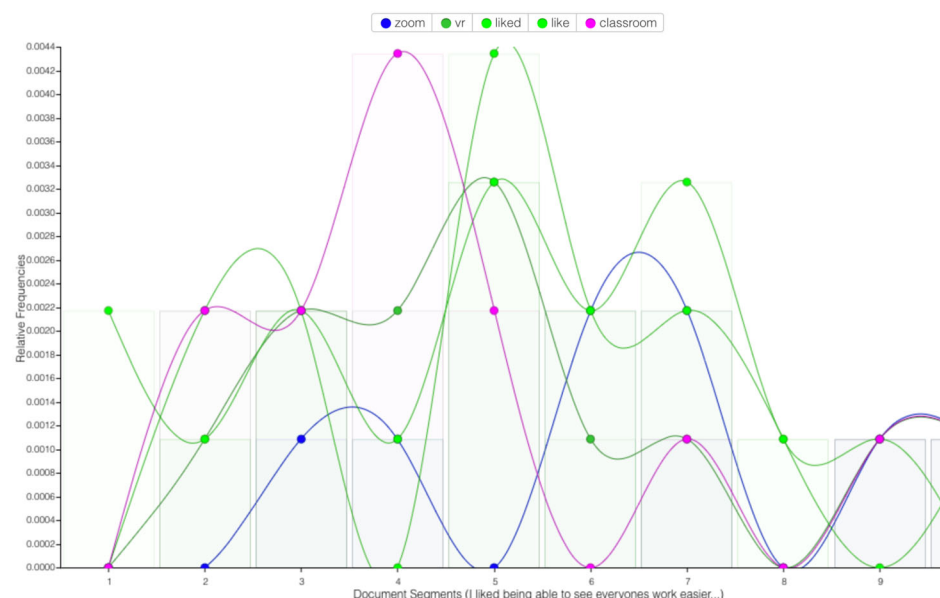
One student shared, “Mozilla Hubs was novel in the beginning, but it lost the human interaction that kept me engaged for most of the semester. Accessible, yes, but also isolating. Being able to see and hear the professor in-person and interact with my peers are a couple of reasons I enjoyed going to class.” While two students who attended almost every time shared, “I loved the check-ins and how different it was to just Zoom. Would recommend more classes try this.” and “[The] first time was confused but week after week I became familiar with it and like it”.

Technology issues included having to reload the site multiple times, getting dropped from the room, audio/mic issues, lag, not working correctly on a cellphone, or not being able to enter the room:

“From the beginning, it was a bit buggy for me. For example, the audio would cut out sometimes or just lots of lag.”; “Sometimes Mozilla Hubs does not comply with my phone. I would always get kicked out.”; “I did encounter some technology issues when using Mozilla Hubs in which sometimes it would freeze so I would have to leave and come back in. And sometimes the sound would cut off, so it was hard to understand what people were saying.”; “If it were easier to function on my phone, I would’ve been on every week”.

When asked “What did you like and not like about the VR classroom?”, students had more positive than negative responses.

After running the qualitative responses for this question through voyant-tools.org, the five most used words were liked (16 uses), like (14 uses), classroom (13 uses), vr (12 uses), and Zoom (8 uses). See Figure 2 for the correlation of trend words.



**Figure 2.** Correlation of trend words created with Voyant Tools for the qualitative question, “What did you like and not like about the VR classroom?” [25].

Some students liked the idea of the VR modality but disliked the technological issues they encountered: “I thought it was a different way of learning! It definitely kept me more engaged.”; “I liked being able to see everyone’s work easier, but the difficulties with the site and having to learn an entirely new program on top of the other ones we were learning was a lot.”; “I liked that we got to share our progress without having to show our face and I disliked that the screen was small, so it was harder to see the presentations.”; “I liked that it was a more interactive way to approach the classroom setting. The biggest issues I had with the VR classroom did not really have to do with the classroom itself, I’ve experienced a few technical issues on my end that made the VR classroom a little difficult”.



Multiple students compared it to Zoom modalities:

"I like it because I learned new methods for education communication in technology not only Zoom class that we used to, but also it gives us the vibe we are in VR class room. I really do not have things that I do not like"; "I liked how we used something different and fun instead of just using Zoom, which does get boring from time to time."; "I liked that it was more interesting than the monotony of Zoom. I felt that audio was an issue for other students, though."; "I liked that it was a nice alternative to a Zoom meeting. I think being online in Zoom for two years gets very tiring, so personally, I like that this is a breath of fresh air."; "I liked the being able to see everyone virtually, and I did not dislike anything about it, but I do not think it offers anything that Zoom would not."; "I liked the idea of something knew other than Zoom but I think there may be better ways and software to accomplish this".

While some students commented on how they enjoyed that the VR modality reminded them of a video game, one student commented on how they disliked the game aspect. One student stated their preference for in-person F2F modality:

"I liked the fun factor that it adds. Each person being their own avatar and navigating a big open space. I loved it!"; "I liked how it was like playing a sort of video game but in a classroom"; "I liked that it was available without VR goggles, but I feel the experience would be better with VR goggles. Hopefully, with the amount of attention VR has been getting for use other than games will help bring more affordable options."; "I just did not really care for the video game format of the VR classroom. I like Zoom check-in better."; "I missed interacting with people and being in an actual physical environment that was meant for learning".

Students also commented on liking the flexibility the VR modality provided as well as it being a quick way to receive feedback and ask questions to acquire clarification as a group: "I loved the flexibility it offers to students who may not be able to attend physical class. I also really like the concept of it because I feel like it connects students who may have a fear of presenting, or who may struggle more in a typical classroom setting." Unfortunately, audio issues and the inability to see well were also problems: "Every time I joined the audio would start going static after just a few minutes in the VR classroom. I would have to close out the page and come back in for it work again, and then the problem would just continue repeating. I've tried fixing the audio settings in my devices, tried many different earbuds/mics, and several different devices like an iPad, phone, laptop, and had the same issue with all of them."; "I liked the space, but when we had to see something on the virtual board, it was hard to see."; "I like that the VR classroom made it easier to ask questions and receive feedback. It was hard to look at the screen with the slides as you needed to be at a certain angle".

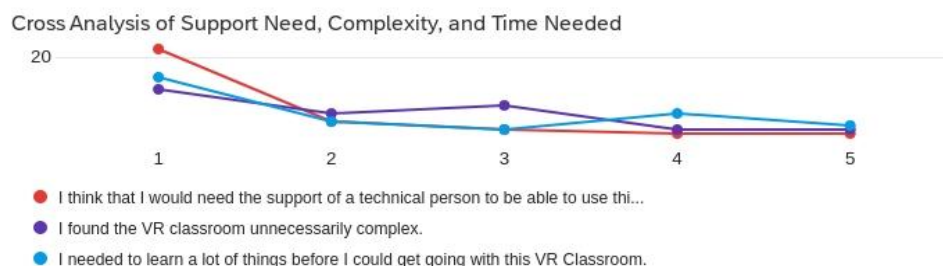
These frustrations lowered students' feelings of engagement and reduced participation, especially among students joining with mobile devices. In future research, asking what device students joined on, what their internet speeds were, and if the connection was stable could verify if technological issues were related to the device type and/or poor internet connections. However, an even more interesting line of questions would look into the reason for device choice. Several students expressed the need to use mobile based on their work or athletic practice schedule conflicting with the class time. It is possible that even if students have access to higher-powered devices, they might still choose a lower-powered mobile device because of the location they join the class from. When asked what could improve their experience with the VR classroom, several mentioned phones. "I think if I used my laptop instead of my phone."; "If it was easier to use on cell phones,"; "I always got distracted and wanted to walk around. Additionally, It's not very mobile user friendly".

### 3.2. Findings from Quantitative System Usability Scale (SUS) Data

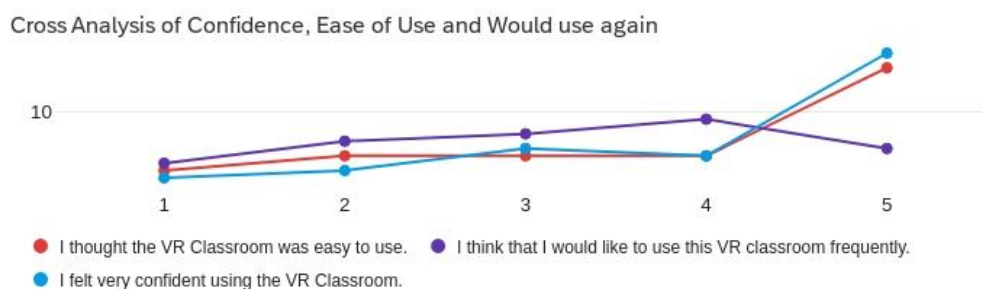
After calculating the SUS score for each student's response, the participants were almost equally divided above and below the average 68-point score for decent usability of the Mozilla Hubs web-based VR classroom experience. Fifteen scored it above 68, 13 scored

it below 68, and three scored it at 67.5. The mean SUS score was 69.8. It should be noted that there may be a slight variance in the mental model of how students answered the SUS; some may have looked at it purely as evaluating the tool, while others may have viewed it through how it was used in class. For instance, one student who said they never attended the synchronous group check-in gave an SUS score of 85 based on interacting with the VR classroom asynchronously but not its performance during a synchronous meeting with multiple participants interacting since they did not attend group check-ins.

In response to the statement, “I think I would like to use this VR classroom frequently”, thirty-one students (45%) strongly agreed/agreed, eight (25.8%) were neutral, and nine (29%) disagreed/strongly disagreed. When asked if they found the VR classroom unnecessarily complex, four (13%) strongly agreed/agreed, nine (29%) were neutral, and eighteen (58%) disagreed/strongly disagreed. Yet, twenty (64%) strongly agreed/agreed that the VR classroom was easy to use, with only four students (12.9%) neutral, and seven (22.6%) disagreed/strongly disagreed. When asked if they would need a technical support person to use the VR room, students strongly disagreed, with twenty-two (71%) strongly disagreeing and four (12.9%) disagreeing. Only three (9.7%) were neutral, and two agreed/strongly agreed; one each, representing 3.2%. Figures 3 and 4 show a cross-analysis of how the students answered multiple SUS questions overlaid with each other.



**Figure 3.** Cross Analysis of SUS questions showing the correlation between Support need, Perceived Complexity, and Time needed to learn the system. Numbers one-five correlate to student answers on a Likert scale.



**Figure 4.** Cross Analysis of SUS questions showing the correlation between confidence, ease of use, and desire to use the system again. Numbers one-five correlate to student answers on a Likert scale.

While the students thought the classroom was easy to use and did not need technical support for the most part, they also were less sure that the functions of the VR classroom were well integrated, remaining largely neutral. While thirteen students (22%) agreed/strongly agreed that the various functions in the VR classroom were well integrated, the exact same amount was neutral (thirteen); only five (16%) disagreed, and none strongly disagreed. When asked if there was too much inconsistency in the VR classroom, students heavily disagreed, with seventeen students (56.7%) disagreeing/strongly disagreeing, eight feeling neutral (26.7%), and five (16.7%) agreeing/strongly agreeing. Students strongly agreed that most people would learn to use this VR classroom very quickly, with twenty-three students at 74% agreeing/strongly agreeing, only three (9.7%) feeling neutral, and five (16.2%) disagreeing/strongly disagreeing. When asked if they found the virtual reality classroom cumbersome to use, seven, or 22.6%, agreed/strongly agreed; seven (22.6%) were



neutral, and seventeen (54.8%) disagreed/strongly disagreed. When asked if they were confident using the virtual reality classroom, twenty-two students (73.3%) agreed/strongly agreed, five (16.7%) were neutral, and three (10%) disagreed/strongly disagreed. The last SUS question stated, “I needed to learn a lot of things to get going with this VR Classroom”. Nineteen students (61.3%) disagreed/strongly disagreed, two (6.5%) were neutral, and ten (32.3%) agreed/strongly agreed.

#### 4. Discussion

Overall, the students enjoyed using the VR classroom. Still, audio issues seemed to be the most significant pain point mentioned by students. The audio issues seem to result from a lack of headphones, incorrect audio settings to use the headphones or not giving the browser permission to use the microphone/speaker. While the overall response was positive, there are several areas for improvement from both the student and instructor perspectives. Social, web-based VR offers promising potential for blended learning. Designing a human-centered virtual environment and considering all participants’ total user experience is critical to a successful learning tool.

While seven out of thirty-one students cited technology issues including having to reload the room, audio/microphone issues, lag, and issues with using mobile devices, no one used or had access to head-mounted displays. While students can join a web-based VR experience from their phone, the immersion and usability of the interface on a small screen are very different from the immersive experience of an HMD, where the room responds naturally to head movement instead of trying to navigate on a small phone screen with your fingers. Future studies will need to look more closely at comparing students using HMD, Laptops, tablets, and phones, and additionally having students record their connectivity speed and if they have a stable connection. Similar audio issues and instances of participants being dropped from a Hubs VR room were also noted in a 2021 study by Eriksson, in the paper title, “Failure and Success in Using Mozilla Hubs for Online Teaching in a Movie Production Course”. Erikson outlines two main audio issues mentioned by multiple students, including poor audio quality or crackling and issues with the spatial audio and distance from the speakers [8]. The survey for this study did not specifically ask about audio issues, so while many students mentioned them, they did not specify the root of the audio issues. However, despite telling students to use headphones with a microphone, students would frequently attend just using their computer microphone and speakers. When un-muted, the lack of headphones created considerable feedback. Students could also individually turn the volume up and down on the avatar who is speaking; however, many did not remember or know that they could do this. Students did not always state they were having audio issues while the problem was happening, but reported it after the fact, making troubleshooting difficult. Sometimes, audio issues were discussed during the class, and often solutions were found. For instance, about halfway through the semester, the instructor’s right headphone would cause a static issue that only the other participants in the room could hear. This problem was solved by only using the left earbud for the rest of the semester.

Regarding the timing issues, either conflict with work, family obligations, mental health issues, or time management issues, which were not related specifically to the modality, may have affected attendance/participation regardless of class modality. Similar issues with disengagement and low attendance are discussed in McMurtrie’s 2022 article titled, “A ‘Stunning’ Level of Student Disconnection”, published in *The Chronicle of Higher Education* [26].

Many of the issues discussed by the student participants come back to frustrations involving audio and feelings of disconnection instead of immersion because of audio issues. Listed below are areas for improvement to create a better user experience with the Mozilla Hubs system:

1. Turn off positional audio during presentations and turn it back on for breaking into groups.

2. Have a very clearly defined use and reason for meeting in the VR space.
3. Removing unnecessary objects to reduce loading issues for mobile participants.
4. Take advantage of the media frames feature for screen-sharing presentations.
5. Using the objects menu to streamline the viewing of presentations from various points in the room.
6. Keep meetings short to avoid lag and the need to refresh the browser.
7. Having a separate viewing room for posted recordings or PDFs and an interaction room for meetings in order to limit load when joining as a group.

Additionally, make sure students have access to the tech they need to join web VR successfully. Access to a stable internet connection, quality headphones, with a microphone that works with their device. A device that can handle running web VR through its browser, ideally, access to head-mounted displays could give students additional immersion. Conducting multiple demonstrations and running in-person tests could also greatly improve the user experience for students. While a demonstration was led on how to use the Mozilla Hubs classroom, the students would have benefited from additional demonstrations and multiple test days when they all joined the VR classroom together while they were also physically present in the same room. Mystakidis (2021) discusses the importance of higher education in building up students' digital skills to better prepare them for VR technology.

In a blended hybrid learning environment, web-based VR supplements face-to-face (F2F) instruction, video conferencing, and the use of learning management systems like Canvas or Blackboard. VR is an additional tool to offer a flexible and diverse way of meeting that can increase presence and immersion in remote learning. Creating and using VR to teach requires careful planning to ensure the modality fits the activity and that the total user experience has been considered for the students.

## 5. Conclusions

Virtual reality (VR) is a technology that can be used to enhance classroom learning. It can be useful for teaching and learning in a blended environment. Virtual reality (VR) is an advanced technology used across different sectors. In education, virtual reality technology is a way for teachers and students to create a simulated three-dimensional world. Web-based social VR is a subset of desktop-based VR and virtual worlds. This work has looked at how extended reality can pair with a blended classroom model.

The main finding relates to the responses of students from three different upper-division design classes who met over Mozilla Hubs every Wednesday for a whole semester. Overall, the students enjoyed using the VR classroom, but audio issues seemed to be the most significant pain point. While the overall response was positive, this study identified several areas for improvement from both the student and instructor perspectives. Designing a human-centered virtual environment and considering all participants' total user experience is critical.

The results of the post-activity survey have shed light on how students responded to using Mozilla Hubs once a week for a full semester. This study shed light on the implications of the practical use of VR in a blended classroom. While some students struggled with the modality because of technology, many had issues that were unrelated to the modality and that could have caused a drop in attendance/participation regardless of the modality. At the same time, seven out of thirty-one students cited technology issues including having to reload the room, audio/microphone issues, lag, and issues with using mobile devices. Similar audio issues and instances of participants being dropped from a Mozilla Hubs VR room were noted in the study by Eriksson. Students did not always state that they were having audio issues while the problem was happening but reported it after the fact, making troubleshooting difficult. Virtual reality is not a new concept; the accessibility of VR technology has dramatically increased in the last few years. In education, virtual reality technology is a way for teachers and students to create a simulated three-dimensional world [4]. Hardware, like head-mounted displays (HMD), has become more cost-effective, yet it is not commonly owned by the masses like a smartphone. Any device

capable of connecting to the internet could run a web-based VR experience. Web-based VR offers unique access across multiple devices, including phones, tablets, laptops, and head-mounted displays (HMDs).

This study was limited to only one semester and the hardware that the students already owned. By providing access to more robust hardware like hotspots, headphones with microphones, or even HMD, there could be an improvement in participation due to lower frustration levels. Additionally, more information should have been collected on the types of connections, hardware used, and audio issues students experienced.

To conclude, future research should look at web-based VR and how educators, designers, and developers can address digital equity issues to provide positive learning experiences for all students. Designing a human-centered virtual environment and considering all participants' total user experience is critical to the success of a learning tool. While students can join a web-based VR experience from their phone, it might not be the best option. The immersion and usability of the interface on a small screen are very different from the immersive experience of a head-mounted display (HMD), where the room responds naturally to head movement instead of trying to navigate on a tiny phone screen with your fingers. Creating and using VR to teach requires careful planning to ensure the modality fits the activity and that the total user experience has been considered for the students.

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**Institutional Review Board Statement:** This study was reviewed at the department level and noted as exempt, as it was conducted in the normal flow of a classroom setting, and students could opt in by providing feedback in the form of an optional post-activity survey. No identifying information was requested in the data. The study was conducted in accordance with the Declaration of Helsinki and approved as exempt by the Department Chair of Art, Design, and Art History at California State University—Fresno. Full Ethical review and approval were waived for this study. As the study was conducted as a class activity in an established educational setting involving normal educational practices. Students were notified about the study before data collection and that their participation was voluntary, as per Section 3.4.4: Obligations of Investigators Regarding Informed Consent from the “Policy and Procedures for Research with Human Subjects” document at Fresno State.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data available at <https://voyant-tools.org/?corpus=de37481557034c9cfaa4f86f00d582a4&panels=cirrus,reader,trends,summary,contexts> (accessed on 17 January 2023). And <https://docs.google.com/spreadsheets/d/1tciZPjiiE6MYfWd3qeM6d52jHZQa65MOQSY0zhggFEE/edit?usp=sharing> (accessed on 17 January 2023).

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