Remote Instruction in Virtual Reality: A Study of Students Attending Class Remotely from Home with VR Headsets

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ABSTRACT

Although video-conferencing tools are generally accepted for remote instruction, they may lack the interactivity and quality of in-person classes. As an alternative, we studied a VR classroom with students and teachers using VR headsets and Mozilla Hubs, a social VR platform. Results show that while attending remote lectures in VR can be a good experience overall, it is important to reduce technical problems and simulator sickness. Users at home may encounter more problems than those in controlled conditions due to the less consistent settings. Nonetheless, students believe prospects for remote VR classes are good. Students who reported little or no sickness gave especially high ratings of several aspects. We also provide teacher suggestions for tool requirements.

CCS CONCEPTS

• **Human-centered computing** → *Virtual reality*.

KEYWORDS

virtual reality, educational VR, teleconferencing, distance learning, remote instruction, Mozilla Hubs, COVID-19, SARS-CoV-2

1 INTRODUCTION

We present a user study of a class that was delivered remotely using the social VR platform Mozilla Hubs. Questionnaires surveyed students on their experiences viewing lectures in VR headsets, with a live teacher using a VR headset and tracked controllers to present.

In-person lectures have long been the standard method for class presentations. The spread of the SARS-CoV-2 virus recently led many universities to switch classes to remote instruction. Remote delivery has other motivations such as reducing carbon use by reducing travel [11], other benefits of eliminating travel such as saved time and geographic flexibility, and possibly reduced social stress, for example, from not having to be seen physically. Common tools for remote learning include video conferencing software such as Zoom, Skype, or Twitch. Although these tools are useful, they may lack some interactivity or quality of in-person lectures.

As an alternative, we consider that networked VR classes may benefit from increased presence (regular and social) and social interactions. Educational VR may be best-suited to environments with substantial 3D educational objects or interaction. But, it is less-commonly promoted for lecture-style classes.

For effective remote learning, factors like technical difficulties, distractions, and viewing-related discomfort need to be understood. Much prior work found that while technologies like video-conferencing may be good for remote learning, a common drawback is technical problems or distractions [4] [6] [5] [9].

Mozilla Hubs is a "social VR platform" on the Web and supports many devices [1]. Le et al. used it for an ACM UIST 2019 virtual poster session to "investigate the possibility of enhancing the social and networking aspects of virtual conferences." They observed an increased sense of presence and state that "the participants felt involved and immersed in co-watching the talks through Hubs as if they were watching the talks in the conference hall" [11].

Earlier attempts to present remote content with VR included a 2011 study wherein IBM hosted a business event in Second Life, an online 3D world with avatars, typically viewed on desktop monitors [4]. The event was reported as "fairly successful" except for technical problems. Second life was also used for the program committee meeting of IEEE VR 2009 [12]. Results suggested that not many users experienced technical difficulties, even with little experience with Second Life. Users did not prefer second life to a face-to-face meeting, likely due to the lack of presence of desktop VR.

In this paper, we detail our user study with questionnaire results, which show some pros and cons of headset VR for remote learning. We provide insight for developers based on problems and comments of students and the teacher throughout the user study. Results suggest social VR platforms can be effective for remote lectures, with the exception of simulator sickness. However, even students with negative VR experiences due to simulator sickness have high expectations for VR as a remote class platform.

2 METHODS

2.1 Overview

Our study was conducted in the context of 7 weeks of remote classes. We surveyed students in a class that met entirely in Hubs.

2.2 Class Environment with Mozilla Hubs

We chose Hubs to host classes because it is "lightweight" and compatible with many devices including mobile devices, desktops, and VR headsets. It supports customization of avatars and room content. Hubs features are rudimentary but support key aspects of remote VR classes. Features used include: upload/download of lecture slides and videos, teacher and student avatars with tracked

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Figure 1: A Lecture in Mozilla Hubs

head and hands (controllers), livestream video of the teacher, viewing capabilities like maximizing content (with a button or keyboard press), walk/fly/teleport navigation, and voice/text chat.

Figure 1 shows a Hubs lecture. There was a mix of students using desktop VR and headset VR during this lecture. The image shows a lecture screen (uploaded PDF content) near its center, uploaded video objects to the right of the screen, a teacher avatar near the bottom right of the screen, a live-streamed webcam view of the teacher to the left of the screen, and student avatars in the virtual room. Some students are floating (fly-mode) for a better view.

The teacher used a Vive Cosmos headset to present in VR. Lectures introduced VR devices, their relation to human senses, and interface topics. Student occasionally presented their own content related to their semester projects, which were either game-type projects or independent studies with implementation.

Each student in the study attended with a headset on the day of the main questionnaire. Various headsets were used: five Oculus Quests (four standalone and one PC-driven via Oculus Link), four Oculus Rift CV1s, one Oculus Rift S, one Windows Mixed Reality HP headset, one Windows Mixed Reality Odyssey+ headset, and one HTC Vive. All of these devices have 6-degree-of-freedom tracking and 2 hand controllers. We believe 6-dof head tracking is essential for a good experience, because 3-dof devices suffer from a visual-proprioceptive mismatch that contributes to motion sickness.

2.3 Participants

The study includes 11 undergraduate and 2 graduate students. One additional student attended but was omitted from the study due to severe technical problems reported as network failures. All students were pursuing computer science degrees, and most identified as senior-level students. Although our users are not representative of the general population, they are an important demographic group for the early adoption of emerging technology and due to the growth of this major at universities. Most students had limited prior VR experience and the study shows a range of results.

6 of the 13 students never used virtual reality before (outside of the class), with 4 others having used VR more than 20 times and the remaining 3 having used VR a median of "3 to 5" times. Only 3 students had ever used VR chat-rooms outside of class. None had used VR to watch or give formal presentations. 10 of 13 students had given in-person formal presentations in regular classes.

11 of 13 of students had prior experience with video tools like Skype, Zoom, and Twitch. 10 had prior experience using these tools to watch a formal presentation. However, most students (8 of 13) had never used such tools to give a formal presentation.

Students' other classes used non-VR remote delivery in parallel with our class. 9 students took at least one live video class with a teacher and students seeing each other, 6 students took at least one live video class with only teacher-to-student video, 8 students took at least one pre-recorded video class, and 9 students took at least one other type of class including: other uploaded content only (3 responses) and project classes with no lecture content (1 response).

2.4 Procedure

On selected days, students answered questionnaires with 7-point ratings, 4-point ratings, and short answer items. Usually, 7-point items were those ranging from negative to positive. 4-point items were used with text specified for each rating option.

2.4.1 Background Questionnaire. All students answered a background questionnaire once in the second week of remote lectures.

2.4.2 VR Viewing Questionnaire. The main questionnaire was given during the last 15 minutes of a class attended with VR headsets. It asked students to reflect on experiences from that day. We included our own questions and abbreviated versions of: immersive tendencies (ITQ) [14], SUS-Presence [13], Networked Minds Social Presence [8], and simulator sickness (SSQ) [10].

To manage distribution of limited VR headsets, 5 of the 13 students took the questionnaire in the second week and the others in the fifth week. The later group includes 4 of 5 students who reported high sickness and tended to give low headset ratings (Section 3.1). This may be related to a varying VR experience level among students. Class duration was 75 minutes.

2.4.3 Final Questionnaire. A final questionnaire was given once on the last day of class (week 7). For this questionnaire, students were asked to reflect on their overall experience of the entire semester.

3 RESULTS

Before discussing main questionnaire items (Fig. 2), we note key observations from simulator sickness questions. Students encountering sickness were able to switch to desktop viewing.

3.1 Simulator Sickness

Simulator sickness is an important consideration for VR. In extreme cases, it makes VR unusable. Even minor cases of sickness may degrade the VR experience. Unlike lab settings, a home setting for VR does not allow consistent control over devices and conditions, leading to additional concern about sickness.

We initially observed a few students reporting notable sickness, so we investigated sickness and its correlation to other items. Our abbreviated SSQ included 5 key symptoms, rated 1 to 4. Questionnaire responses indicated that 9 of 13 students experienced at least slight "general discomfort". Two students gave maximum ratings (rating 4): One for fatigue, headache, and difficulty focusing or concentrating; and the other for general discomfort only.

For each student, we computed a sickness score as the average of the 5 symptom ratings. Figure 3 shows that as sickness increases, a

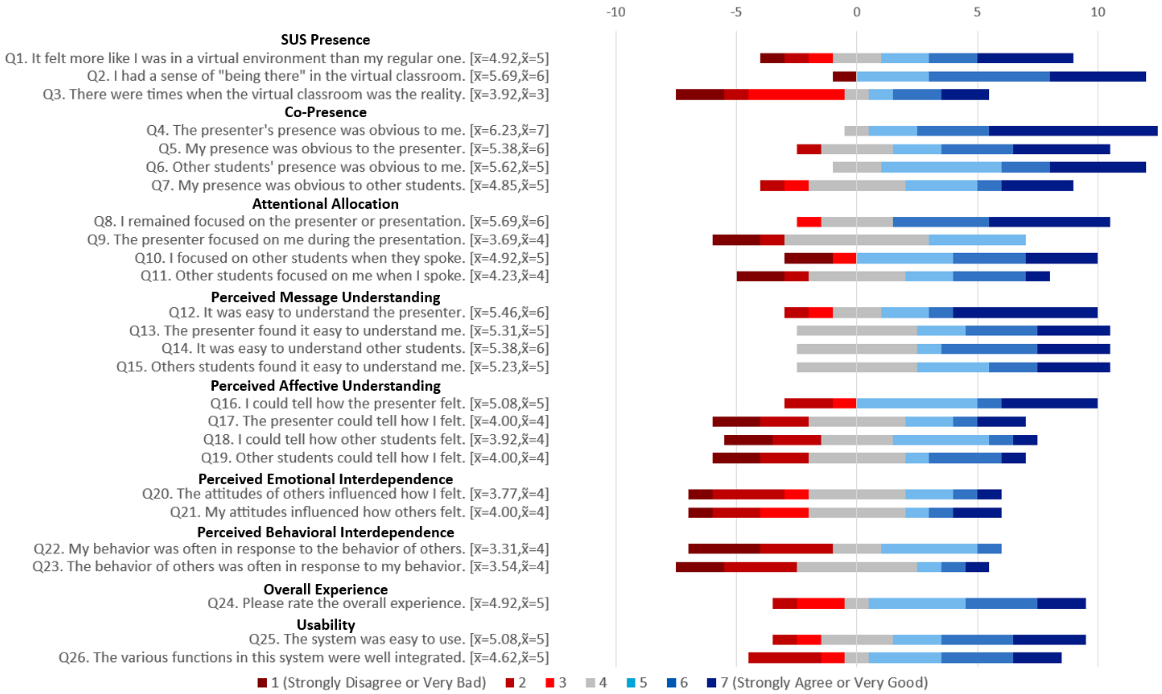

Figure 2: Diverging Stacked Bar Charts, Counting Responses to Main Questionnaire Items

rating of overall experience decreases (Q24). Notably, all users with sickness score below 2 gave positive overall experience ratings, but only one user with a higher score gave a positive overall rating.

Statistically, very strong negative correlations were found between sickness score and usability (Spearman r_s=-.830, p=.000) and between sickness and a perceived message understanding score that summed relevant questions from Fig. 2 (r_s=-.801, p=.001). We found strong negative correlations between sickness and overall experience (r_s=-.792,p=.001), SUS presence (r_s=-.719,p=.006) and co-presence (r_s=-.623, p=.023).

However, some question groups did not correlate much with sickness, suggesting students were not just answering all questions the same way. For example, we did not find notable correlation between sickness and an additional "prospects" rating about expectations of VR being good for education (r_s=.055,p=.859). This could indicate that students believe their experience is not indicative of the future of VR. Other items that were less correlated with sickness include attentional allocation (r_s=-.472,p=.103) and perceived behavioral interdependence (r_s=-.474,p=.101).

We did not find significant correlation between sickness and prior experience level with VR (r_s=-.194,p=.525) or with a score summing two questions about general mental and physical wellness on the lecture day (r_s=-.501,p=.081). Pragmatic readers may note the latter as "near significant" and weakly suggesting a relationship.

Sickness did not appear tied to any particular device type. The average sickness scores of at least 2 occurred with Oculus Rift CV1 (3 of 4 such devices) and Oculus Quest (2 of 5).

Due to these results, some following discussions mention sickness-adjusted results in addition to full results (Table 1). Adjusted scores remove students with a sickness score of 2 or more. We believe this is useful for speculating about future VR experiences with improved devices and visual techniques to reduce sickness.

Table 1: Unadjusted/Adjusted Subscale Scores

Subscale	Mean	Median	Adjusted Mean	Adjusted Median
Overall Experience	4.92	5	5.88	6
SUS Presence	4.85	5	5.25	5.33
Co-Presence	5.52	5.75	6.03	5.88
Attentional Allocation	4.63	5	5.13	5.25
Perceived Message ...	5.35	5.75	5.91	6.25
Perceived Affective ...	4.25	4.25	5.06	5.25
Perceived Emotional ...	3.88	4	4.38	4.25
Perceived Behavioral ...	3.42	4	3.88	4.25
Usability	4.85	5	5.81	6

3.2 Overall Experience

Measuring overall experience allows us to gauge the general impression that students have of the VR lectures. When looking at the results for Q24, we see that 9 of 13 students rated their overall lecture-viewing experience positively.

If high-sickness cases are removed (Table 1), only positive responses remain, with a mean rating of 5.88 and a median of 6.

Additionally, the final questionnaire asked students to give an overall rating of headset VR as a medium for remote classes. Results were similar, with 8 of 13 ratings being positive. There was one neutral and two negative ratings. We asked students how often they experienced a glitch that substantially degraded the headset experience (7-point ratings from Never to Very Often): 5 students

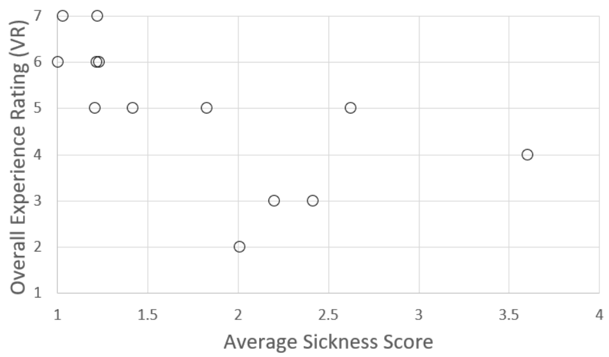

Figure 3: Overall Rating (Q24) vs. Sickness Score

reported substantial glitches (rating above 4. Mean rating was moderate: 3.54).

The final questionnaire also asked students: if all glitches were fixed, how would they rate headset VR as a medium for remote classes overall. The responses showed improvement with 11 of 13 responses being positive. The other two responses are split with one negative and one neutral rating. This suggests that students believe fixing glitches would lead to a better overall experience.

3.3 Comparison to In-Person (Real Life) Class

Figure 4 (top) shows responses comparing in-person lectures to the Hubs lecture viewed with a headset. On average, students appear neutral about which class type is better, although they lean slightly towards liking in-person class more. Students may also lean slightly toward feeling more confident in Hubs than in in-person lectures, although a larger study is needed. This could be because they do not have to be seen physically, being represented as avatars.

When asked for a positive aspect of the VR lecture vs. in-person lectures, responses included: it was more engaging/interactive (4 responses), not having to leave home (2 responses), it was easy to use (2 responses), having the ability to see embedded videos directly and get a better view (1 response), increased confidence speaking up (1 response), and the ability to come back and view lecture content (1 response). Surprisingly, some of these responses reported VR as more engaging/interactive than real-life. Other positive aspects suggest convenience of attending lectures in networked VR.

Students listed the following as negative aspects of the VR lecture compared to in-person lectures: technical difficulties (7 responses like this), VR fatigue (1 response), feeling of isolation (1 response), distraction (1 response), seeing own avatar (1 response). So, about half of the students had technical difficulty to some extent. Students listed difficulties as audio glitches, video glitches, and lag.

3.4 Comparison to Video-Conferencing Class

Figure 4 (bottom) shows responses comparing video-conferencing to the Hubs lecture viewed with a headset. We see that results are much more one-sided than the comparison to in-person classes. All questions had a mean response of 6 or more and a median of 7.

When asked for a positive aspect of the VR lectures vs. video-conferencing lectures, responses mentioned: not having to be seen or not having to use a webcam (3 responses like this), it is more interactive/engaging (3 responses), less distraction (2 responses), being able to see slides as if it were a "regular class" (1 response), being able to gesture (1 response), "actually being there" (1 response), and ease of use (1 response). Preference towards VR lectures appears to come from not having to be seen on a webcam and increased interactivity/engagement.

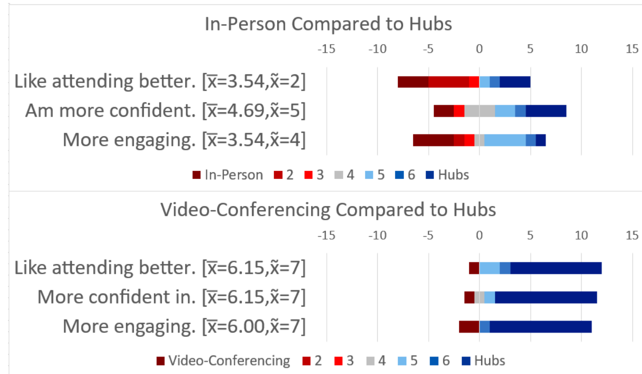

Figure 4: Responses Comparing In-Person Lectures to Hubs (top) and Video-Conferencing Lectures to Hubs (bottom)

In terms of negatives of VR classes compared to video-conferencing classes, student responses included: technical difficulties (5 responses like this), discomfort from the headset (2 responses), distraction (1 response), load times (1 response), and VR fatigue (1 response). Again, most negatives of VR come from technical difficulties.

3.5 SUS Presence

Presence in a (virtual) classroom is arguably the most notable feature that VR can add to remote lectures. Q1 and Q2 had mostly positive responses (8 and 12, respectively). Q2, in particular, which very directly asks about presence, had only one response below 5. So, even when students indicated the virtual classroom was not their reality (Q3, 7 negative responses), they still tended to report positive presence in the VR classroom.

With high-sickness cases removed, all questions had higher mean response, with no very negative ratings. Adjusted Q2 had no negative ratings, suggesting that students without high sickness all had a sense of "being there". The mean of the presence subscale increases from 4.85 to 5.25, and median increases from 5 to 5.33.

3.6 Co-Presence

Co-presence is the "degree to which the observer believes he/she is not alone and secluded, their level of peripheral or focal awareness of the other, and their sense of the degree to which the other is peripherally or focally aware of them" [8].

We believe co-presence is important in classes by promoting more engagement with the teacher and students. Students will likely not be prompted to interact with others if they are not aware of others' presence or if they don't think others are aware of them. Students may not feel like they belong to a university if they do not experience co-presence. With many universities recently switching to remote classes, this sense of belonging could be vital.

Items about being aware of others (Q4, Q6) were rated positively, with no negative responses and 3 neutral responses. So while Q5 and Q7 are less positive on average than Q4 and Q6, we see that students generally felt a sense of co-presence in both directions.

Negative co-presence responses may indicate that a few students feel isolated, which was also suggested in a response comparing in-person lectures to Hubs, where a student stated that they "felt sort of isolated". It appears that even when students feel others are present, a few do not expect that others see them as present.

When high-sickness cases were removed, no negative responses remained for any co-presence question, with the mean of each question's responses increasing.

3.7 Attentional Allocation

Attentional allocation "addresses the amount of attention the user allocates to and receives from an interactant" [8]. Attentional allocation results let us know if students are able to focus on others when they speak, and if they think others focus on them.

Q8-Q11 address attentional allocation. Responses about focusing on others (Q8 and Q10) were more positive on average than their counterparts (Q9 and Q11). This echoes the previous result about Co-Presence. In a lecture, the student's ability to focus on others is arguably more important than believing others focus on the student, as a student mainly needs to focus on the teacher presenting to multiple students.

3.8 Perceived Message Understanding

Perceived message understanding tells us if students understand the teacher and if they think the teacher understands them. While the responses for Q12 - Q15 were positive on average, we were surprised to see that the question about understanding the presenter received the only negative ratings of the group. This did not repeat the pattern in Co-Presence or Attentional Allocation. Considering the question style, answers may reflect factors such as audio quality in Hubs, and most of the speaking was by the presenter.

With high-sickness cases removed, we again saw less neutral and negative ratings, and the mean response was slightly higher.

3.9 Perceived Affective Understanding

Affective understanding is "the user's ability to understand an interactant's emotional and attitudinal states as well as their perception of the interactant's ability to understand emotional states and attitudinal states"[8]. It is important, for example, to know if the audience understands a presenter's attitude (e.g., if the presenter is more serious about a topic, students may focus more).

Q16-Q19 show the responses for questions regarding perceived affective understanding. We see that with the exception of Q16 being positive on average, Q17-Q19's ratings indicate that on average, students are not confident about affective understanding. There may be some cues missing due to the simplicity of the avatars compared to real life. Slightly higher ratings in Q16 could reflect that the teacher's voice was the one heard often.

3.10 Perceived Emotional Interdependence

Emotional interdependence is "the extent to which the user's emotional and attitudinal state affects and is affected by the emotional and attitudinal states of the interactant" [8]. Engagement between student and teacher is important in educational environments.

Q20 an Q21 have average responses of 3.77 and 4.00. The results suggest that, overall, student attitudes are not clearly affecting each other. However, responses range from very negative to very positive, so there is much variation in reported experiences.

3.11 Perceived Behavioral Interdependence

Behavioral interdependence is "the extent to which a user's behavior affects and is affected by the interactant's behavior" [8]. Related engagement between participants may be helpful for education.

We see very similar results in Q22 and 23 to those of Q20 and 21, but with the responses leaning slightly more negatively.

We also considered how students moved their avatars in responses to other avatars. The final questionnaire asked students how often they move their avatar when someone enters their personal space and how much they position their avatar to avoid invading someone else's personal space. The mean responses (on a 7 point scale from never to very often) were 5.46 and 5.31, respectively. This shows that students were making conscious decisions about moving their avatars based on the behavior of others.

When asked what other things made them move their avatars, students responded: to get a better view of lecture content (7 responses like this), to hear better (6 responses), and accidental movement (2 responses). So, a main reason for students moving their avatars is for better visuals or audio. Visual factors may include limited resolution of headsets and other avatars occluding sight. Audio changes are related to Hubs' spatial audio, which lowers audio levels with distance. Students may prefer just moving to adjusting volume level sliders on avatars. VR lectures could be enhanced with software that better optimizes audio levels and that renders occluding avatars in a see-through or minimized manner.

3.12 Usability

For deployment to a wide range of students, it is important for remote instruction tools to be easy to learn and use. Responses to Q25 and 26 were overall more positive than negative. Furthermore, after removing high-sickness cases, there were no negative responses, resulting in a high scores (mean and median scores increased from 4.85 and 5 to 5.81 and 6). Usability rating was very strongly correlated to sickness (see Section 3.1).

3.13 Feature Helpfulness

The VR Viewing questionnaire asked students to rate the helpfulness of 12 features (4-point ratings from Not to Very). The top 5 most helpful features (by mean response) were: a pointer used by the presenter (the presenter used a Hubs marker tool that emits a ray), the presenter's avatar, live (real-time) communication, embedded videos, and the presentation slide display. These results show that students value presentation features the most. The 3 least helpful features, by mean, were the student's hand gestures, other students' hand gestures, and the live video stream of the instructor. Features with intermediate ratings were: the student's avatar, the presenter's hand gestures, the chat feature, and having room-like surroundings.

3.14 Technical Problems/Distractions

The VR viewing questionnaire asked students to report the extent to which they experienced certain distractions or problems (4-point ratings from Not to Very). Technical problems asked about were: audio glitches, video glitches, problems with a display device, and problems with an input device. Distractions asked about include: noise in the real environment around the student, shifting attention to other activities in the surrounding environment, distractions from other objects or features in the virtual room, distractions from people's avatars, shifting attention to other activities on the computer, and electronic alerts such as: phone, email, messages.

The technical problems reported as most extreme were audio and video glitches. Other technical problems such as problems with display/input devices were minimally reported. The most highly reported distraction was noise in the real environment around the student. All other distractions were minimally reported.

In addition to the distractions listed in our question, students reported the following: checking the time with external tools like SteamVR, choppy audio, and switching between Hubs rooms.

3.15 Teacher Suggestions

Although the main goal was to understand student experiences, we noted teacher suggestions about how the tools could improve. Hubs was missing some features common to real classrooms, and adding them would help lecturers. These include a clock and a duplicate view of the slides (lecture screen) visible to a teacher who is facing the audience. Hubs did not provide standard or scripting features to add such objects. The Hubs drawing mechanism, being a marker that generates 3D geometry, was found awkward for lecturing, and a good whiteboard-type mechanism would help the teacher with live problem solving or extending lecture content. Students would also benefit from easy note taking while in headsets, such as a keyboard-in-VR injection [7] or a virtual notepad [3]. Students need a way to get the teacher's attention that is independent of microphone volume or motion. Students were able to type in chat, but the text could appear below the field of view and be missed by the teacher, and text would vanish after some time. Hubs mechanisms for placing and moving uploaded content were less developed than in typical 3D software, and teacher setup effort could be reduced by a simpler way to arrange or switch uploaded content.

4 CONCLUSION AND FUTURE WORK

Based on student responses, we found that attending class remotely with VR provides a good overall experience. On average, we see positive ratings for presence, co-presence, attentional allocation, perceived message understanding, overall experience, and usability.

Simulator sickness appears to be a critical factor in student experiences. Students reporting low sickness also report good experiences in the VR classroom. Students encountering high simulator sickness should consider other viewing options such as desktop viewing. Simulator sickness is a major topic in VR research, and future systems may reduce sickness with device improvements or visual techniques for reducing motion sickness during navigation. We note our results show much more sickness than the live-guided educational VR environment by Borst et al., which found minimal reported symptoms [2]. We believe the contributing factors are the relatively uncontrolled home setups and longer duration.

Technical difficulties and distraction are common obstacles for remote classes [4] [6] [5] [9]. Audio and video glitches were commonly reported (Section 3.3; Section 3.4; and Section 3.14). We believe this is related to students' low experience with VR devices and the widely-varying home computing environments (considering better results from more controlled setups, e.g., [2]).

Our results indicate that some students value not being seen on video (Section 3.4). The inclusion of avatars may help relieve social pressure. We are investigating additional study data to consider the significance of avatars to students.

Hubs lacks some basic lecture features like a clock, a whiteboard-type mechanism, and student note-taking (Section 3.15). Other social VR platforms like AltspaceVR, Engage, VR Chat, etc. provide different features and have varying levels of accessibility in terms of cost and portability.

Future work will analyze additional data acquired during the VR lectures to compare different viewing modes and class activities.

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