VIRTUAL REALITY COLLABORATIVE PLATFORM FOR E-LEARNING: ANALYSIS OF STUDENT ENGAGEMENT AND PERCEPTIONS

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Abstract. In this paper, we discuss the potential of using virtual reality collaborative platforms for e-learning to improve the quality of online education. First, we explore the characteristics of existing online platforms that can be used for e-learning. Second, we present a method for creating a Virtual Reality Collaborative Environment (VRCE) for e-learning using an online platform, namely FrameVR. Third, an experiment is conducted to investigate participants' behavioural and emotional engagement when using Zoom and the VRCE for online learning. Valid survey data from twenty-two participants are analysed. Then, participants are interviewed about their perceptions of using a VRCE for e-learning. The results of the experiment confirm that using a VRCE can increase student engagement, especially emotional engagement compared to Zoom. However, the findings also suggest that there is still room for improvement in the use of VRCE for e-learning. Therefore, further suggestions are made on the drawbacks of VRCE to improve the user experience. This paper provides insight into incorporating VRCE to enhance the e-learning experience and contribute to the development of online education.

Keywords. Virtual Reality Collaborative Environment; E-Learning; FrameVR; Online Education; SDG 4.

1. Introduction

“New normal” is a term that has been used frequently throughout the COVID-19 pandemic. In education, this “new normal” includes a sharp increase in the use of online learning platforms, as the pandemic has led to new ways of teaching and learning. In order to continue educating students during the pandemic, educational institutions around the world have had to rely on online learning platforms. One of the most popular platforms for online education, Zoom, has seen a dramatic increase in usage, from 10 million daily meeting participants in December 2019 to more than 300 million by mid-2020 (Statista, 2021). Similar platforms such as Skype have also seen

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a significant increase in usage, with calls and meetings between Skype users increasing by 220% in recent months (Sherr, 2020). In today's world, e-learning has become a necessary resource for students and schools, and the demand for distance learning will continue to grow in the future (Gautam, 2020). While online learning has been a critical part of the educational process during the pandemic, some academics, as well as users, argue that it may have disadvantages. Most e-learning platforms offer only basic features such as video calls and text chats. Although such systems can satisfy basic communication needs, students often lack a sense of immersion and physical interaction with other users, leading to low student engagement, both behavioural and emotional (Rodgers, 2008). Studies have found that low student engagement can result in boredom, frustration, and low achievement (Lee, 2013). Since low student engagement is closely associated with low academic performance, it is important to find new strategies to improve engagement in e-learning.

In recent years, Virtual Reality (VR) technology has been extensively promoted and accepted as an important development in facilitating lifelong education (Alexiou et al., 2004). There is ample evidence that VR technology is an effective visualization tool that provides users with a more immersive experience, enables them to interact with other users in the virtual environment with a high sense of realism, enhances their creativity, and improves their work efficiency (Bucea-Manea-Ţoniş et al., 2018; Shen et al., 2019). As a result, VR technology has great potential to support online learning and improve students' experience. Various cloud-based platforms have been developed that allow users to manage online activities in the virtual environment. However, these VR platforms are mostly used for work and commercial purposes (Jaehning, 2021). The value of adopting these platforms for e-learning has not been considered as frequently. This paper, therefore, aims to explore the potential of using VR collaborative platforms for online learning, following three steps: First, we examine and compare the key features of existing VR platforms that can be used for e-learning; second, we select a VR platform, FrameVR, and use it to create a VR collaborative environment (VRCE), with which we conduct an experiment to investigate whether the adoption of VRCE for online education can improve student engagement compared to 2D video-based platforms such as Zoom; third, we carry out interviews after the experiment in order to understand students' views on using VRCE for e-learning.

2. VR Collaborative Online Platforms

2.1. FEATURES OF VR COLLABORATIVE PLATFORMS

We examined eight online VR collaborative platforms which are acknowledged by mainstream media, such as Forbes (Forbes, 2020). These platforms were reviewed and compared based on two main criteria: (1) general features and (2) VR feature availability. In addition to general features such as screen sharing, a notable feature of these platforms is the availability of avatars. Unlike 2D video-based platforms such as Zoom; some VR platforms allow users to create their own 3D avatars before joining a VR online meeting. These avatars represent the individual participant and can be controlled to interact with other users and the virtual environment. Not only does the use of avatars provide an entertaining experience for users, but there is also clear evidence that avatar-based virtual events provide other advantages. For example, research by Casanueva and Blake (2001) has shown that using avatars in virtual environments can create a high degree of co-presence, that is, the feeling that one is in the same place as the other participants and interacting with real people. In addition, another study has found that the use of avatars can help users who are reluctant to express themselves in physical spaces to present their opinions in virtual spaces (Blake and Moseley, 2010). Furthermore, platforms such as FrameVR and Mozilla Hubs allow users to customize their virtual environment by uploading a model created with 3D programs such as SketchUp and Blender. Users can create 3D objects and import them into the virtual environment. This feature can be helpful for lectures in subjects such as architecture. Here, a building model can be presented to students virtually so that they can understand the building structure more easily and directly (Arslan and Dazkir, 2017). The availability of the features of the various online platforms is summarized in Table 1.

Table 1. Existing VR collaborative online platforms

Platform	General Features	VR Features Availability		
	Main Content Sharing Methods	3D Object		Environment
		Avatar	Custom	Custom
Shapespark	Hyperlinks, uploading files (PDFs, video), material configurator	Limited	-	Limited
FrameVR	Whiteboard, files sharing (PDFs, 2D images, video, audio), text/ audio chat, screen sharing	√	√	√
Mozilla Hubs	Whiteboard, 2D images, video, screen sharing, text/ audio chat	√	√	√
MootUP	Images, video, audio sharing, desktop sharing	√	√	Bespoke
Spatial	Handwriting, post-it notes, screen sharing, uploading files (PDFs, images, video)	√	√	Bespoke
MeetinVR	Whiteboard, post-it notes, uploading files (subscription required), text/ audio chat	√	√	-
Glue	Uploading files (images, video), text/ audio chat	√	√	√
Engage	Video, website streaming, text/ audio chat	√	√	Bespoke

2.2. CREATION OF A VRCE FOR E-LEARNING

While most VR collaborative platforms have built-in environments that allow users to easily and effortlessly launch online events, these built-in settings are often limited. Users can only select a few types of environments from the built-in sources (e.g., museum, gallery, and office). Finding an appropriate environment for an activity with a specific purpose (e.g., an online course) might be difficult for users. In addition, theses built-in settings often offer only basic features such as screen sharing, which may not be sufficient for managing more complex activities. Due to the drawbacks of built-in settings, we designed a VRCE specifically for educational purpose using a platform that supports custom environments. In this case, we used FrameVR because it is more accessible compared to other platforms. It does not require user registration and can be used for free. The procedure for creating a VRCE using FrameVR is shown in Figure 1: First, we created a 3D model of the lecture hall using Blender, a modeling tool that best supports the GLB format required by FrameVR. Next, the model in GLB format was uploaded to the FrameVR cloud and converted to a virtual environment. Then, we set up the environment with built-in features that can be used for online courses (e.g., image sharing and whiteboards).

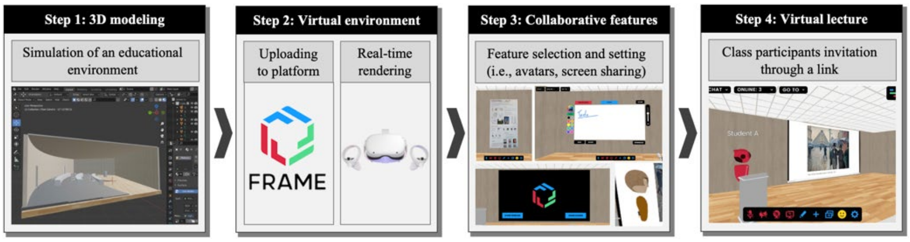

Figure 1. Process of creating a VR collaborative environment for e-learning

3. Methods

An experiment was conducted to investigate whether the use of a VRCE in online education can improve student engagement compared to a 2D video-based platform such as Zoom. We simulated the scenario of an online course under two different conditions (1) a VRCE and (2) Zoom. Each participant experienced both conditions in random order. A questionnaire survey was distributed to measure their engagement. Then, we interviewed participants about their perceptions of the advantages and disadvantages of using a VRCE for online courses and how they would like to see the VRCE evolve to improve the user experience.

3.1. MATERIALS AND EXPERIMENTAL SETUP

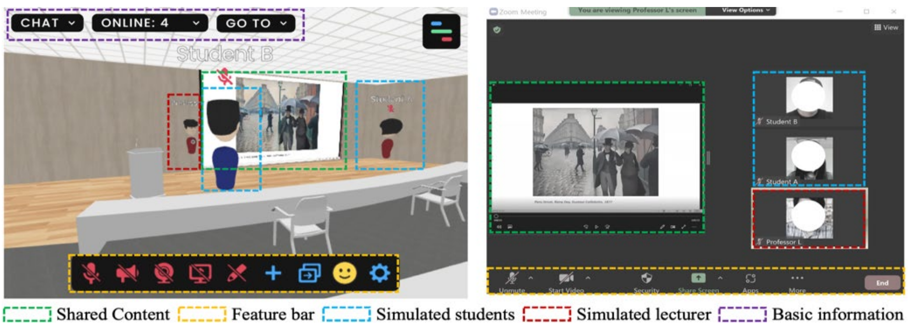

Figure 2. Experimental conditions and user interface, VRCE (left) and Zoom (right)

To ensure realistic experience, two simulated students and one simulated instructor were placed in each condition. The user interfaces of the two experimental conditions are shown in Figure 2. The VR tool used for the experiment was Oculus Quest 2. The Oculus Quest 2 system consists of a head-mounted device and two wireless controllers.

The computer used to access FrameVR and share/control VR in real-time was a Gigabyte RP75 with Intel Core i7 processor and a NVIDIA Geforce RTX 3070 graphics card. The Zoom version was 5.8.3.

3.2. QUESTIONNAIRE

Student engagement in both experimental conditions was measured using a self-report questionnaire. Existing literature on student engagement views it as a "meta-construct" that includes *behavioural* (e.g., participation, effort, and attitude), *emotional* (e.g., positive reactions to school and a sense of belonging), and *cognitive* (e.g., willingness to continue working on an assignment) engagement (Finn, 1989). However, Skinner et al. (2008) found that in-class student engagement is only reflected in their behaviour and emotions. Since this paper relates to student engagement during the e-learning process, only behavioural and emotional engagement are discussed here. To ensure validity and reliability, all the measurement items were taken from previous literature (Skinner et al, 2009). A total of ten items were used, five of which measured participants' behavioural engagement, while the remaining five measured emotional engagement. The items were measured on a seven-point Likert scale. The details of these items can be found in Table 2.

Table 2. Student engagement questionnaire items

Factors	Item No.	Item Description
Behavioural Engagement	BE1	I could freely communicate with others.
	BE2	During the lecture, I wanted to express my opinions to others.
	BE3	During the lecture, I wanted to ask questions to an instructor.
	BE4	During the lecture, I listened to the lecture very carefully.
	BE5	Overall, I could fully concentrate on the lecture.
Emotional Engagement	EE1	I felt enjoyment in this environment.
	EE2	I felt interested during the lecture.
	EE3	I felt comfortable during the lecture.
	EE4	I got involved during the lecture.
	EE5	Overall, listening to the lecture was fun.

3.3. PARTICIPANTS

This experiment targeted students who have used and are familiar with e-learning systems. Participants were recruited through posts in university group chats. A total of twenty-two participants were recruited for the experiment. The personal details of the recruited participants are as follows (1) age: from 25 to 42 (M = 29); (2) degree: four of them are undertaking undergraduate degree and eighteen of them are studying a master's degree or Ph.D.; (3) major: twenty of them are from departments related to interior design, two participants majored in architectural engineering; (4) gender: thirteen participants are female, nine participants are male.

3.4. EXPERIMENT PROCEDURE

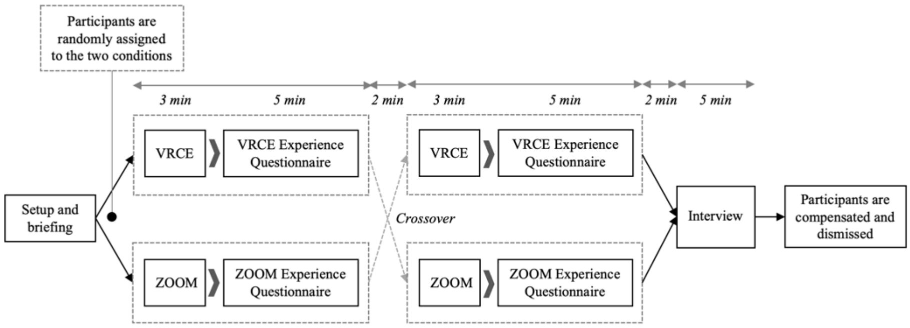

Figure 3. Experiment procedure

As shown in Figure 3, participants were randomly assigned to one of the experimental situations (VRCE then Zoom or Zoom then VRCE). This procedure was conducted following similar experimental studies by Azmi et al. (2020) and Hong et al. (2019) in order to eliminate any sequence effects. In previous studies, a two-minute pause between environmental situations was recommended to reduce the carryover effect. During the experiment, participants were asked to pretend to attend an online lecture. A three-minute pre-recorded lecture video was shared and played to simulate the course content. To encourage interaction, we included a quiz in the video. The quiz was suggested based on the video content, and participants were asked to answer the quiz verbally if they wished. It should be noted that participants wore a head-mounted device during the VRCE (Figure 4). After participants experienced each situation, they were given a questionnaire to measure their sense of engagement. After they completed the questionnaire, we conducted a short interview in which we asked them about their perceptions of the advantages and disadvantages of both methods for online courses and how they would like to see the VRCE evolve to improve the user experience. Upon completion of the interview, participants were rewarded and dismissed.

Figure 4. Participant experiencing two experimental conditions, VRCE (left) and Zoom (right)

4. Results

4.1. STUDENT ENGAGEMENT

Valid survey data from twenty-two participants were analysed using Jamovi (ver.1.6). We used descriptive statistics, reliability analysis, and the t-test to assess if there were significant differences in student engagement between VRCE and Zoom. A p-value < 0.05 was considered statistically significant. Internal consistency of the measurement scale was checked by Cronbach's alpha values. The results of the reliability test show that the Cronbach's alpha of all variables was above 7.0: VRCE-BE (0.7793), VRCE-EE (0.7979), Zoom- BE (0.8777), Zoom- EE (0.7861). Therefore, all scales used in the study were internally consistent and reliable. The results of the t-test comparing behavioural engagement between VRCE and Zoom showed that BE1 and BE2 were significantly different: BE1 ($t = .8742$, $p < 0.05$), BE2 ($t = 2.5578$, $p < 0.005$), stating that participants showed more positive attitudes toward communicating and expressing their ideas when using a VRCE for online courses. It was also found that all emotional engagement variables were significantly different in the two settings: EE1($t = 7.5450$, $p < 0.001$), EE2($t = 4.9271$, $p < 0.001$), EE3($t = -2.3090$, $p < 0.05$), EE4($t = 2.4081$, $p < 0.05$), EE5 ($t = 4.0005$, $p < 0.005$), indicating that participants showed a higher sense of enjoyment and involvement in e-learning in the VRCE.

4.2. STUDENT PERCEPTION

We conducted short interviews to explore participants' views on using (1) Zoom and (2) a VRCE for online learning. Although the majority of participants indicated that Zoom is an effective tool to support their learning process during the pandemic, some of them highlighted drawbacks. One of the most common responses from participants was related to the difficulty of interaction between instructors and students. For example, one participant reported, "when I use Zoom, I cannot physically interact with my instructors and fellow students. It is even more difficult to have a real conversation, so I feel isolated from the others" (P14). In addition, one interviewee noted, "I find it very difficult to concentrate in online lectures via Zoom...not being in a designated space like a classroom, I get distracted easily, especially when taking an online course from home" (P4).

While some participants identified that there were some barriers to using Zoom for online learning, a large percentage (81%) stated that using a VRCE enhanced their learning experience compared to Zoom. The advantages of VRCE were described with reference to several aspects. First, avatars played an essential role in creating social experiences for users. Some participants noted that avatar-based platforms helped them foster their sense of connectedness. They also found that they were able to express themselves more freely than when using Zoom for an online learning. One participant reported, “when I have questions, I find it difficult to ask for help when I use Zoom for online learning. But after the experience of attending lectures using VRCE today, I think avatar-based platforms help me to enhance the sense of connectedness and promote interaction with other avatars.” (P8). Another participant pointed out that “VRCEs would make the learning experience richer, ... engaging ... When I see an avatar with a professor's sign, I could feel a higher sense of motivation and enjoyment in learning" (P2). In addition, one of the reasons that nearly half of the participants (48%) gave regarding the benefits of employing VR in online learning was that a VRCE increases concentration, "puts learners in an immersive environment and provides an all-around realistic experience of a lecture. While [they] are easily distracted by the surroundings when using Zoom, the headset eliminates all external distractions and helps [them] concentrate" (P1). Despite these benefits of using a VRCE for e-learning, participants further made other suggestions to improve the learning experience. Suggestions mentioned by them were "interpersonal" (P10), "the inability to take notes" (P8), and "the bulkiness of the VR headset" (P3) as examples.

5. Discussion and Conclusion

5.1. DISCUSSION

The results show that students are more engaged in e-learning when using a VRCE setting compared to Zoom. Specifically, students are found to be more willing to communicate with others and express their opinions in a VRCE setting. In addition, using a VRCE for e-learning significantly improves students' emotional engagement. For online lectures, students perceive the VRCE setting to be more comfortable and enjoyable than Zoom. Although there is great potential for the use of VRCEs in online education, there are some areas of VR, which could be further improved by IT specialists. Based on our analysis of student feedback on the use of VRCEs for e-learning, there are three main ways to improve student experience. First, non-verbal cues could be added for better interaction between simulated users. Behavioural techniques such as gestures, eye contact, and facial expressions play an important role in communication and effective class management as they convey additional information to others (Petrie et al., 1998). Besides the possibility of using custom avatars, providing natural and realistic-looking avatars would be key to improving the user experience in VRCEs.

Second, it is suggested to provide note-taking features to help students attend lectures more efficiently. A study by Chen et al. (2019) investigated the use of an "interactive note-taking interface (iVRNote)" to address the challenge of taking notes while wearing a head-mounted display. The introduction of iVRNote in VRCEs would further enhance the learning experience for students. In addition to taking notes, other functions such as voice recording or screenshots could also be created in VRCEs.

Third, students would be more likely to accept VRCEs as a learning tool if the head-mounted display was lighter and smaller. However, this should not be seen as a hindrance as technology is constantly evolving. For example, VR glasses, such as the Huawei VR glasses, are being launched. Unlike the Oculus Quest, which combines a computing unit and a battery in the headset, the Huawei VR glasses do not contain such components (Skarredghost, 2021). Hence, it is important to highlight that technological development may contribute to the improvement of the online learning system, as e-learning takes into account both the technology and the user's perspective.

5.2. CONCLUSION

According to the United Nations, nearly 1.6 billion children were out of school by April

2020 due to the COVID -19 pandemic. Never before have so many children been out of school at the same time. Therefore, as part of the goal of quality education (SDG 4), it is important to help countries implement innovative solutions for delivering education remotely, leveraging high-tech, low-tech, and no-tech approaches to ensure that education never stops. In this context, e-learning is a promising solution to help students continue their studies during the pandemic. Currently, most e-learning systems offer only basic features such as video calls and text chats. Although such systems can meet basic communication needs, they often lack immersion and physical contact with other users, which can lead to low student engagement. In this paper, we present a method for creating a VRCE for e-learning using an online platform, namely FrameVR, and confirm that using a VRCE can make online courses more engaging. There is a great potential for using VR technology to enhance the e-learning experience.

Some limitations should be discussed. First, this study only examined a small number of participants. A more comprehensive experiment can be conducted in the future with a larger group of participants in different demographic contexts (e.g., age groups, degree levels). Second, participants experienced the pretend lecture through a three-minute video, which is a relatively short period of time compared to a real course. Participants' perceptions and attention problems might be less likely to manifest in such a short period of time. Future research could extend the duration of the simulated sessions to more accurately capture participants' responses. Third, as a pilot study to explore the potential of VR technology for e-learning, only a small number of participants (two simulated students per class) were included in the experiment. In a later experiment, more students can be included to simulate a realistic teaching scenario. We could also investigate how architecture-related students would perceive the use of other features, such as custom 3D objects, to enhance their learning experience. A more holistic approach to exploring the views of users of VRCEs would provide an opportunity to promote quality education alongside immersive learning experiences.

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