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Understanding the Needs of Virtual Reality for Learning and Teaching: A User-Centered Approach

Yue Li*
School of Advanced Technology
Xi'an Jiaotong-Liverpool University
Suzhou, China
yue.li@xjtlu.edu.cn

Jiachen Liang
School of Advanced Technology
Xi'an Jiaotong-Liverpool University
Suzhou, China
jiachen.liang21@student.xjtlu.edu.cn

Yuang Zhou
School of Advanced Technology
Xi'an Jiaotong-Liverpool University
Suzhou, China
yuang.zhou18@alumni.xjtlu.edu.cn

Cheng Zhang
Design School
Xi'an Jiaotong-Liverpool University
Suzhou, China
cheng.zhang@xjtlu.edu.cn

Yong Yue
School of Advanced Technology
Xi'an Jiaotong-Liverpool University
Suzhou, China
yong.yue@xjtlu.edu.cn

Hai-Ning Liang
School of Advanced Technology
Xi'an Jiaotong-Liverpool University
Suzhou, China
haining.liang@xjtlu.edu.cn

***Abstract*—The emergence of COVID-19 has had a significant impact on the education field, leading to a surge in the adoption of online learning and teaching. The recent development in Virtual Reality (VR) and metaverse has witnessed an increasing number of online platforms being utilized in online education. In this study, we took a user-centered approach and conducted a series of survey and interview studies with students and teachers to understand their needs of VR for learning and teaching. Additionally, we evaluated existing online platforms that can serve as virtual classrooms to host teaching materials and support students in online learning. The comparison results together with the requirements we summarized offer valuable takeaways and guides for the future adoption and creation of virtual classrooms for VR-enhanced learning and teaching.**

***Index Terms*—Virtual Reality, online education, virtual classroom, virtual learning environment, metaverse**

I. Introduction

Changes in lifestyles potentially drive the technological innovation in education. Many students are becoming used to bring laptops, tablets, smartphones, and other digital devices into their learning environment. In the past three years in particular, the COVID-19 pandemic has significantly influenced the learning and teaching in higher education. Many universities had to take precautions to the pandemic, so that teachers and students inevitably became involved in online teaching and learning.

To date, videoconferencing system (e.g., *Zoom*) is still arguably the most used technology for online learning. Latulipe [6] stated that most platforms used in online teaching and learning were designed for conferences and meetings, few was designed specifically for online higher education, and none was designed specifically to support active, team-based learning in large classes. As a result, many onsite teaching strategies cannot be used for online learning, and this can make online learning a passive experience. Teachers and students have reported issues such as low student engagement, lack of interest in learning, and low learning efficiency.

After reviewing ten years of development of virtual environments in education, Mikropoulos et al. [9] noted that researchers generally acknowledge the educational value of virtual reality (VR). With the recent development of the VR technologies and metaverse environments, platforms such as *Virbela*, *Spatial.io*, and *Gather.town* have started to be used as alternative options for online learning [7]. These platforms offer a sense of spatial and social presence, as opposed to the usual online conference type platforms [6]. With the support of VR technology, students can engage in more active learning explorations, such as immersively experiencing different learning scenarios, interacting with teaching materials, and socializing with classmates more realistically. However, there are few studies investigating how students and teachers expect to use such kinds of virtual learning environment in practice. Therefore, this project aims to understand the needs and practicality of current VR technologies for learning and teaching. Specifically, we surveyed students and interviewed instructors of two exploratory modules in *Design* and *Advanced Technology*, and explored how the use of VR technology could facilitate their learning and teaching.

The contributions of our work are three-fold. First, we present a clarified understanding of the needs of VR for learning and teaching from the perspectives of both students and instructors. Second, we evaluated existing platforms as online learning tools, the results of which can be readily adopted by practitioners who are interested to use VR in education activities. Third, we discuss the implications and limitations that can serve as a guideline for the creation of VR learning environments based on our user-centered approach.

II. Related Work

In the past decade, mobile technologies and emerging technologies have expanded the means of modern education

*Corresponding author

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[1]. The development of online learning is gaining increasing attentions from education institutions, educators, and scholars. Especially during the past three years, the COVID-19 and the pandemic control have dramatically changed the teaching and learning modes in higher education institutions.

According to Meyer's [8] definition, online learning usually refers to a course that is delivered entirely online. Such courses are offered through the Internet and enable the use of web-based materials and activities, such as videos, discussions, and quizzes, etc. This flexible delivery format has shown benefits to students in balancing their lives and studies [3]. While some students are motivated in online learning environments, others may become less engaged compared to the onsite face-to-face approach [5]. This is mainly because the lack of interactivity with web-based teaching materials and the weakened social interactions.

Recently, virtual reality (VR) has been applied in various fields of education. VR technology is known for its strength in simulating a realistic and immersive 3D environment [2]. It affords high interactivity with virtual objects and users in the same environment. Such features could potentially benefit online learning in improving student engagement. Various studies have explored the applications and benefits of VR in different scenarios, such as vocational training, education, and entertainment. Several studies have investigated the usability and acceptance of VR applications, but there are few systematic studies on how VR technology is needed and can be applied for higher education purposes. This direction of VR education is well worth being investigated.

Metaverse is another trending topic. It is essentially a shared virtual environment that highly links with and supplements the real world. A large number of platforms that can provide virtual environments have emerged [7]. These platforms offer new possibilities for online teaching. Sriworapong [11] compared three platforms (*Spatial.io*, *Gather.town*, and *Zoom*), and found these platforms capable of offering effective interactions. Eriksson [4] used *Mozilla Hubs* as an alternative online learning platform, and demonstrated that the use of VR in online learning did not negatively affect learning outcomes, and but provided high social presence. Latulipe [6] evaluated a 2D virtual environment, *Gather.town*, and showed that students rated highly on the sense of place, engagement and smooth interactions with each other.

Previous work has shown three limitations. First, many studies shown the effect of applying VR technology to online teaching, but ignored the preliminary work to clarify the actual needs. The requirements of different stakeholders (students and teachers) have not been well understood. Second, previous work studied several existing platforms and showed some empirical work, but there is a lack of holistic view of existing technologies. The degree to which they can be used to support learning and teaching is not well understood. Third, many online platforms for education have been developed and evaluated, but very few studies related to VR online learning took place in China. The location contexts of the use of education technology are worth considering. Therefore, it is necessary for us to clarify the real needs of users for VR in teaching and learning activities, taking into account the different contexts of use, the stakeholders, and the potential limitations.

III. Methodology

This project aims to understand the needs of VR for learning and teaching. Specifically, we select two taster modules in our university as the testbed: DES001 Explore Design, and SAT001 Explore Advanced Technology. These two modules are FHEQ 3 modules which introduce the basic concepts and disciplines to first-year university students, so that they could better make a major selection for the following years of study. As such, the modules were taught by instructors from different disciplines, such as Urban Planning and Industrial Design in DES001, and Computer Science and Electrical and Electronic Engineering in SAT001. The delivery of these two modules was entirely online.

We took a user-centered approach and conducted a series of survey studies with students and interviews with instructors to explore how VR could be applied to facilitate their learning and teaching. Based on the results and findings from the surveys and interviews, we performed system evaluations on several existing online platforms that could be used for teaching and learning. We compared the differences in the platforms and evaluated them against the dimensions specified from stakeholder requirements.

IV. Results and Analysis

A. Student Survey

We conducted an online survey targeting the students enrolled in two taster modules. Participants took an average of 2 minutes to complete the survey. The survey data was analyzed using IBM SPSS Statistics. An overview of the analysis results can be seen in Fig. 1.

1) Participant demographics: In total, we received 36 complete responses (14 females and 22 males), included 12 students from DES001, and 24 students from SAT001. Their ages are between 18 and 21 (M=18.83, SD=0.70). The two primary grades of respondents were freshman (69.44%) and sophomore (27.78%) (shown in Fig. 1a, Q3). Almost all respondents (97.22%) used PC and mobile devices in their daily learning activities (shown in Fig. 1a, Q4). No one has used VR technology during their learning. As for the preferences of respondents for online and onsite learning, more than half of them (55.56%) chose onsite learning.

2) VR technology experience: More than half of the respondents (61.11%) have not used VR devices before (see Fig. 1b, Q6). In terms of the familiarity with VR, 69.44% of respondents are slightly to somewhat familiar with it (M=2.72, SD=1.03) (see Fig. 1b, Q7). The results of Q8 showed that all of the respondents (100.00%) agree to use VR technology in their learning. Specifically, they acknowledged VR's features in immersion (29.17%), interaction (33.33%), and imagination (37.50%) (see Fig. 1b, Q9). Based on the results, we found that (1) some students have used VR and have some knowledge about VR, and (2) students have intense interest in VR and

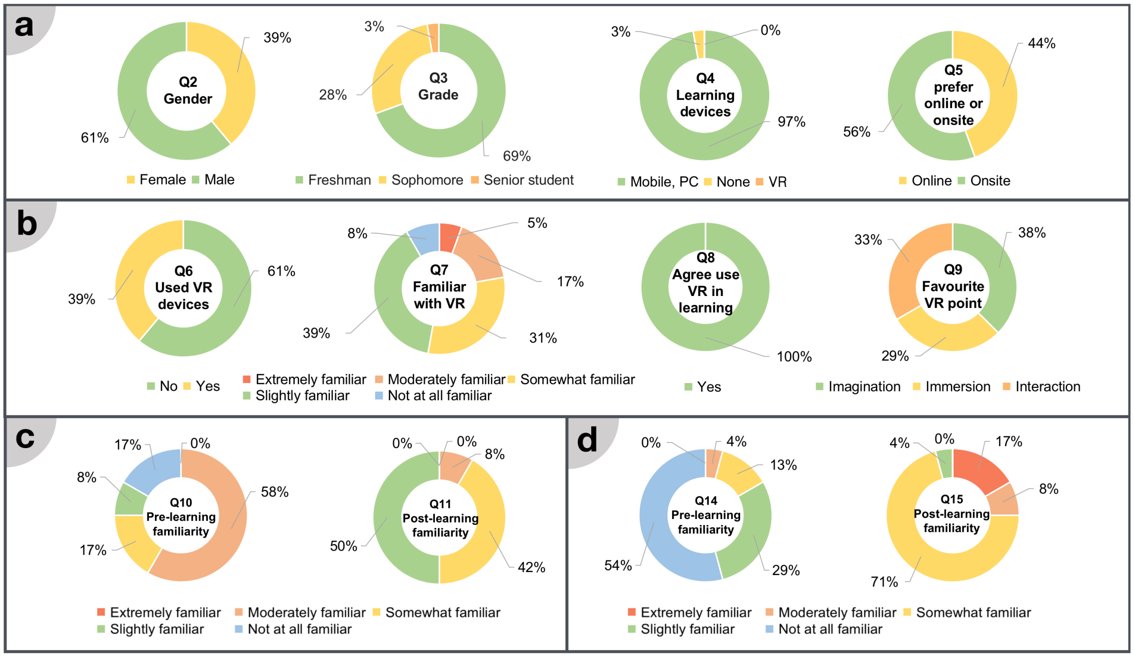

Fig. 1. Survey results of (a) Demographics, (b) VR technology experience, (c) DES001 module experience and (d) SAT001 module experience.

look forward to using it for their learning, regardless of their familiarity with VR.

3) Module experience: We compared students' familiarity with the module content before and after learning and there were significant increases in both DES001 (t=-5.745, $p<0.001$) and SAT001 (t=-10.378, $p<0.001$). Students were slightly familiar with DES001 (M=2.17, SD=1.19) and SAT001 (M=1.67, SD=0.87) before taking the modules, but somewhat to moderately familiar with them after learning, with average ratings of 3.67 (SD=0.65) and 3.38 (SD=0.81) for DES001 and SAT001 respectively. Still, there is room for improvements. Among the subjects covered in the teaching of DES001, Urban Planning Design (50.00%), Architectural Design (25.00%), and Civil Infrastructure (25.00%) are the most recognized by students for integrating VR into the online learning activities.

B. Instructor Interview

We conducted face-to-face interviews with four instructors, each interview lasted approximately half of an hour. The interviews were semi-structured and had three sections; (1) general questions about teaching and learning, (2) module related questions about their previous experience and observations, and (3) VR related questions about their expectations of the technology use. The interview data was analyzed using *Theme-Based Content Analysis (TBCA)* [10], which is a summarized approach that can be applied from requirements analysis to system evaluation. We focused on the issues that instructors encountered when using current online platforms and the areas that they expected to improve.

Specifically, we identified three themes that summarize the issues that instructors encountered when teaching online. First, with **students** (N=6). Instructors reported issues about the lack of interaction with and feedback from students (I1, I2, I3, I4); students in their first year being unfamiliar with online platforms (I4); and finding it more difficult to stimulate student interest online compared to onsite teaching (I4). Second, with **technology-enhanced teaching** (N=6). Instructors raised concerns about being struggled to keep updated with new technologies (I1); being unsure about how VR can support teaching activities in practice (I1, I2, I3, I4); and worrying that the need of hardware devices (such as VR headset) with emerging technologies could bring extra burden (I1). Third, with **exiting online platforms** (N=4). Instructors commented that some existing online platforms sometimes break down due to technical issues such as poor network (I1); In addition, many advanced features have complex settings that require significant time to set up (I1, I3); and multiple platforms required in online delivery are sometimes incompatible (I1).

Instructors also expressed their expectations on the use of VR in teaching activities. Specifically, the requirements can be categorized into three themes: media and interaction support, device and capacity, and virtual environment. First, **media and interaction support** (N=13). It is expected that the VR learning environment could support the sharing of common documents formats of documents and recorded videos (I1, I2, I3, I4), ideally 3D models as well (I3); instructors would like to interact with students in real time, using text chat, voice chat, and video streams (I1, I2, I4), and to be able to create their own avatars (I1, I4); They would also like to organize discussion and tutorial activities (with 20-30 students) during the seminar time (I1, I2, I3). Second, **device and capacity** (N=12). Ideally, the VR learning environment should support commonly used devices (e.g., PC and smartphones) without purchasing additional devices (e.g., VR headsets) (I4); it should be compatible with other teaching software and support cross-device access (I1, I2, I4) and an easy access

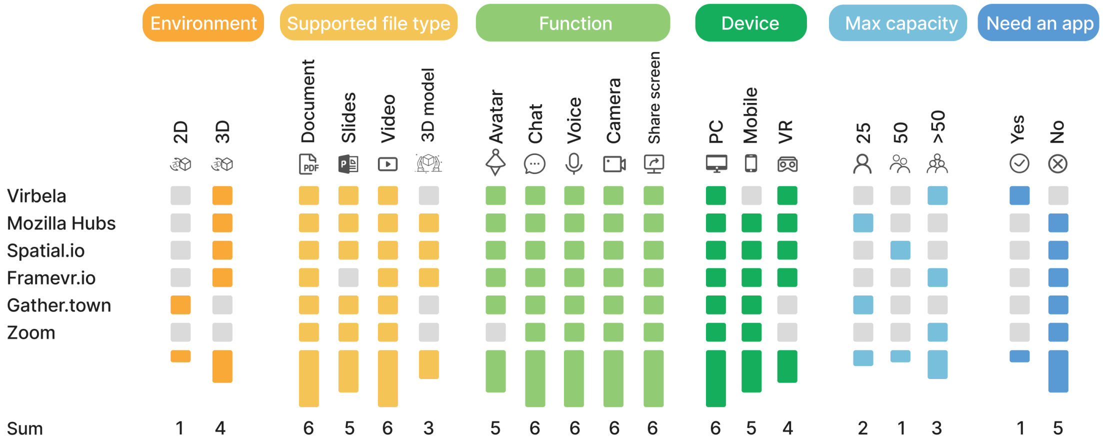

Fig. 2. The results of the comparison of six platforms from six dimensions. Different colors represent Environment, Supported file type, Function, Device, Max capacity, and Need of an app respectively.

without downloading another application (I4). Considering the class sizes, instructors would like the VR system to support a large capacity of people (e.g. up to a class size of 400 they have had) (I1, I2, I4), and ensure a low network latency (I1, I2, I3, I4). Third, **the virtual environment** (N=9). Instructors envisioned a virtual space that can host the teaching materials with a spatial layout (I1, I2, I3), and to have engaging and interesting environments that students are willing to explore (I1, I2). They also mentioned that the system should support the customization of the virtual environment based on different teaching topics (I1, I2, I3, I4).

C. System Evaluation

Based on the requirements specified above, we did a broad search and narrowed down to five platforms that can be used as virtual classrooms for students' online learning, including *Virbela*[1], *Mozilla Hubs*[2], *Spatial.io*[3], *Framevr.io*[4], and *Gather.town*[5]. As a baseline comparison, we also include *Zoom*[6] in our evaluation. The platforms were evaluated against the important dimensions identified in the surveys and interviews, which include *environment*, *supported file type*, *function*, *device*, *max capacity*, and *the need of an app*. The comparison results are shown in Fig. 2.

1) Environment: Most existing solutions support a 3D environment, only *Gather.town* provides a 2D virtual environment. These platforms all support the hosting of teaching materials with a spatial layout and offer certain degrees of customization.

2) Supported file type: We list the file types that are often used in online teaching, including PDF document, slides, videos, and 3D models mentioned by one of the instructors (I3). All platforms support PDF and video files, which could help instructors present course documents and recorded videos for online teaching. Most platforms support the viewing of slides, except for *Framevr.io*. In response to the requirement raised by I3, we found that *Mozilla Hubs*, *Spatial.io* and *Framevr.io* support the upload of 3D models.

3) Function: Avatar is an important feature of the metaverse [7]. Unlike *Zoom*, the five virtual platforms allow users to create their own avatar characters. In the meantime, they all support text and voice chats as the basic means of communication. Users' social presence can be increased when they can hear the voices of others and see their faces. All virtual platforms support them to turn on their cameras to show their faces. We also looked into screen sharing as this is often needed in online teaching. All platforms offer this function.

4) Device: All platforms support PC access. Except for *Virbela*, the other five platforms could be accessed with mobile devices. *Gather.town* and *Zoom* are 2D-based, thus do not support VR devices.

5) Max capacity: The maximum capacity of the platform determines the number of students that can be involved in an online learning session. *Zoom* can host up to 200 people, *Framevr.io* recommends access for no more than 150 people, while *Virbela* supports up to 1,500 concurrent users. The capacity of 50 in Spatial.io meets the requirement to organize seminar sessions, but not large classes. Similarly, spaces with up to 25 users (i.e. *Mozilla Hubs* and *Gather.town*) are more suitable for small-classroom teaching activities. Nevertheless, many platforms offer upgrade plans that support a larger capacity with charge.

6) Need of an app: The need of additional apps may hinder user acceptance and user experience. Most platforms are web-based and do not need an app, except for *Virbela*.

V. Discussions

In this section, we discuss our results and findings from the student survey, instructor interview, and usability test. We summarize the lessons learned and offer suggestions from three perspectives: students, instructors, and technical support.

[1]https://www.virbela.com/
[2]https://hubs.mozilla.com/
[3]https://www.spatial.io/
[4]https://learn.framevr.io/
[5]https://www.gather.town/
[6]https://zoom.us/

A. From the perspective of students

Our survey data demonstrated that slightly more students prefer onsite learning than online learning. It is expected that both ways will coexist in the future way of learning and teaching. There is a need to find ways to engage students in online learning, and VR was shown to be a potential effective approach. More than a third of the students have used VR and they are slightly to somewhat familiar with VR. Students highly support the use of VR in online learning, especially in design related subjects. However, not every student has a VR device. Compared to immersive VR that requires the use of head-mounted displays, taking advantages of the devices they use (e.g. PC and mobile devices) and web-based virtual environments seem to be a reasonable approach for online learning in the near future.

B. From the perspective of instructors

Instructors are keen to improve student engagement in online learning. In the meantime, they are also are concerned about practical issues that come along with emerging technologies, such as the supported media, devices, capacity, compatibility, and the need of additional efforts. Instructors liked the social features in VR, which is consistent with Latulipe's [6] finding that teachers are keen to restore the social attributes missing in online learning. Some instructors mentioned that using avatars could make students more willing to talk in the class, but turning on the camera will make them feel more respected.

Among the five virtual platforms we analyzed, those that can meet the identified instructor requirements are *Spatial.io* and *Framevr.io*, but different choices could be made if the requirements change. For example, *Gather.town* could be a good option for students that prone to have simulator sickness with 3D images. When being asked whether it is feasible to use VR in teaching, a typical answer was *'it is feasible but should be applied wisely'*. Overall, instructors expect VR technology to be used as a teaching support tool to make lessons more interesting, but not overwhelming.

C. From the perspective of technical support

Depending on the level of technology adoption, instructors may set up a virtual classroom themselves, or have a team that can provide technical support. There are some common limitations in existing platforms that should be aware of. First, we observed a long loading time when trying to access the platforms without a VPN in China. The network connection is an important issue to address before use. Second, most platforms require certain manual efforts in the spatial set up. Currently, there is no automatic way to populate teaching materials in the virtual environments. Future work should improve the workflow to improve the technology adoption. Third, similar to Eriksson's [4] findings, few platforms have appropriate virtual space set up for large lectures. The widespread application of VR in online learning is still largely limited by technical issues such as network bandwidth and 3D rendering capabilities of current devices.

VI. Conclusion and Future work

In this study, we collected survey responses from students and conducted interviews with teachers to investigate their needs of Virtual Reality (VR) for learning and teaching. We evaluated existing platforms against the criteria specified from stakeholder requirements. We show that the use of VR in learning and teaching activities should provide appropriate media and interaction support, consider the availability of devices and the system capacity, and make use of the spatial layout and social features afforded by the virtual environments. In our future work, we plan to develop virtual classrooms based on the specified requirements and apply them in the teaching of the two taster modules. We are also interested to find out the main factors that influence students' motivation to use VR for online learning.

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