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Virtual Reality for Synchronous Learning in Higher Education

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Abstract. Numerous studies have demonstrated the effectiveness of Virtual Reality Learning Environments (VRLEs) to empower education by providing immersive, interactive experiences that improve student engagement and learning outcomes. Our work aims at investigating VRLEs as a means for addressing the shortcomings of synchronous online education and supporting engaging and experiential learning activities in the context of higher education. We compare Desktop VR versus Immersive VR in synchronous, multiuser learning scenarios. Our field study has shown no significant differences with respect to the overall learning experience between the two experimental conditions although resulting in different levels of immersion.

Keywords: Virtual Reality · Virtual Reality Learning Environments · higher education · synchronous learning · VRChat

1 Introduction

Virtual Reality Learning Environments (VRLEs) have been proven effective in bridging the gap between online and conventional learning since the virtual environment (VE) mimics real-world imagery and context [3]. VRLEs may be experienced via standard computer screens, yet they are far more effective in their immersive form [2], i.e., when users wear a head-mounted display (HMD) to experience the sensation of leaving their physical setting and being transported to the virtual environment [4, 14].

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VRLEs represent a growing trend in education. Recent studies have demonstrated their capacity to support the student learning process and course learning outcomes, mainly due to their positive impact on student performance and engagement. VRLEs enable students and instructors to control their avatars in 3D simulated classrooms or laboratories, interact with the environment, communicate and collaborate with peers and engage on educational tasks providing and receiving real-time feedback. VRLEs effectively support the learning process for nearly any concept (existing or imaginary) enhancing the experiential element of the learning process. It is noted that VRLEs may be used either as a standalone learning tool or as a complement to traditional physical classroom teaching methods [5].

Further to enhancing academic performance, VRLEs may also: counter the sense of social isolation experienced in online learning; solve the shortcomings related to overcrowded practical classes or lack of specialized lab/machine equipment; offer high-quality visualizations which are not attainable in the traditional classroom; support field visits to sites which are not accessible due to economic, time or safety restrictions; increase students´ engagement and motivation in almost any field of study by bringing them closer to a friendly and familiar environment; decrease the potential risk of physical harm for students when handling real materials or testing machines.

Notwithstanding the intensive academic research activity in the field, studies pertinent to the use of VRLEs in the context of synchronous learning are still limited. To this end, we employ the VRChat[1] platform to support the creation of VRLEs tailored to higher education institutions (HEI). VRChat is a free-to-use multiplayer online Social VR platform [2]. VRChat allows users to share public or private rooms and supports up to 40 concurrent users per room. It enables developers to design their own rooms, providing several affordances such as avatar and environment customization, animation design, interaction and sound design, real-time communication among room participants. Those features highlight VRChat as a cost-effective, yet powerful platform for powering multiuser learning courses.

Our work aims at investigating the effectiveness of VRLEs in the context of HEIs, as a means for addressing the shortcomings of synchronous online education through enhancing the sense of ‘togetherness’ and providing technological means to support engaging and experiential learning activities. Moreover, our research addresses various educational challenges dealt with VRLEs: enhancement of student engagement, provision of real-time feedback, support of field visits to inaccessible sites, empowerment of student motivation and safety in learning activities. Finally, by conducting a pilot study, we bridge the gap between academic research and practical application of VR technology in education, enabling better understanding of its benefits and challenges and fostering the translation of research findings into practical considerations.

The remainder of this article is structured as follows: Sect. 2 reviews related research. Section 3 describes the design and development of our VRLE and presents our experimental methodology. Section 4 discusses the results of the study. Finally, Sect. 5 concludes our work and provides directions for future work.

[1] VRChat, https://hello.vrchat.com/.

2 Literature Review

Comparing Desktop VR (dVR) and Immersive VR (imVR) in learning environments has attracted considerable research interest in the past. Kozhevnikov et al. compared imVR and dVR learning environments for relative motion problem-solving [6]. The results of a between-subjects study with 37 students showed that both environments contributed to relative motion problem-solving, while students experiencing the imVR environment performed better on solving two-dimensional relative motion problems [6]. Lee et al. investigated the impact of using an interactive imVR environment against a linear dVR render capture of it on learning experience and knowledge acquisition while training 36 medical students on fluid flow through pipes. The participants of this between-subjects study highlighted imVR as more interesting and enjoyable, and reported higher levels of attention and knowledge acquisition [7]. Liu et al. compared imVR and dVR environments for filmmaking education through a between-subjects study with 39 participants revealing that both technologies led to positive learning experiences, with imVR resulting in increased perceived realism and enjoyment [8]. Silva et al. tested the effect of using imVR and dVR on user motivation towards an educational game on biology through a between-subjects study with 60 participants. The results of the study showed that using imVR led to increased motivation towards the learning experience [1]. Finally, Nikolic and Windess integrated imVR and dVR in an experiment of spatial understanding by simulating design mistakes in virtual environments. The between-subjects study involving 32 students showed that those using imVR performed slightly better than those using dVR on spotting spatial design mistakes [10].

Based on the results of the aforementioned studies, we conclude that imVR achieves more enjoyable and effective learning experiences compared to dVR. It is worth noting though that the results of most studies show only marginal differences. Additionally, researchers comment on the usability shortcomings of imVR [8], indicating a steeper learning curve compared to using dVR systems, and the simulation sickness incidents which may occur while using imVR [10]. Notably, the examination of related work indicates a clear pattern with regards to experimental design, as most studies adopt a between-groups methodology to avoid repetition and obtain more accurate results. Another interesting remark is that all studies focus on single-user experiences, highlighting an evident research gap as regards pertinent studies on multi-user contexts.

3 Research Methods

Our work compares the imVR and dVR versions of our VRLE with respect to several aspects. We investigate differences in usability, simulation sickness, motivation to use the learning environment, and immersion. To address our research objectives, we designed and developed a VRLE whose theme centers around on Ancient Greek technology.

3.1 Materials and Apparatus

The scenario of this study involves an introduction to the Ancient Greek Technology artifact Aeolosphere, a primitive steam engine. Additionally, it covers Phyctories, a visual signal communication system based on torches placed in a specific order to represent letters, thus enabling communication over large distances. The functionality of both artifacts, along with a PowerPoint presentation system, has been simulated within a VRChat world created using Unity and VRChat SDK supporting both imVR and dVR conditions. This virtual environment allowed multiple users to access it simultaneously, each represented by an avatar while allowing real-time voice communication. Users were able to attend a Powerpoint presentation about the artifacts (see see Fig. 1a). They were also able to interact with them, i.e., to start a fire at the bottom of the Aeolosphere so as to examine its functionality (see Fig. 1b) and utilize Phyctories (see Fig. 1c) to communicate in groups over distance (see Fig. 1d).

For the imVR condition, the Meta Quest 2 HMD was chosen. This device is not only affordable but also boasts commendable technical specifications, rendering it an attractive option for the average consumer desiring to delve into imVR experiences. However, as it is untethered (i.e., not linked to a computer), there is a notable compromise in graphics quality due to its limited processing capabilities. The experiment took place in a spacious office (around 30m2). Thus, the risk of injury from participants bumping into furniture or walls was minimized. In the dVR condition, the participants used computers equipped with 31-inch monitors.

3.2 Participants

The study targeted students in the Departments of Primary Education. Those individuals not only belong to our primary target audience, but also represent future educators, thereby offering valuable feedback on the pedagogical implications of the project. To recruit participants, an invitation was sent through social media platforms to students of the Departments of Primary Education at the Universities of the (name has been omitted for the blind review) and the (name has been omitted for the blind review). The invitation detailed the objectives and methodologies of the research, emphasizing that no prior experience with HMDs or imVR applications was necessary for participation. The recruitment process resulted in a cohort of 48 participants, who were subsequently divided into two distinct groups (imVR and dVR). Prior to the commencement of the research, the University's Ethical Committee issued its approval. Furthermore, all participants were briefed on the nature of the research and formally provided their consent.

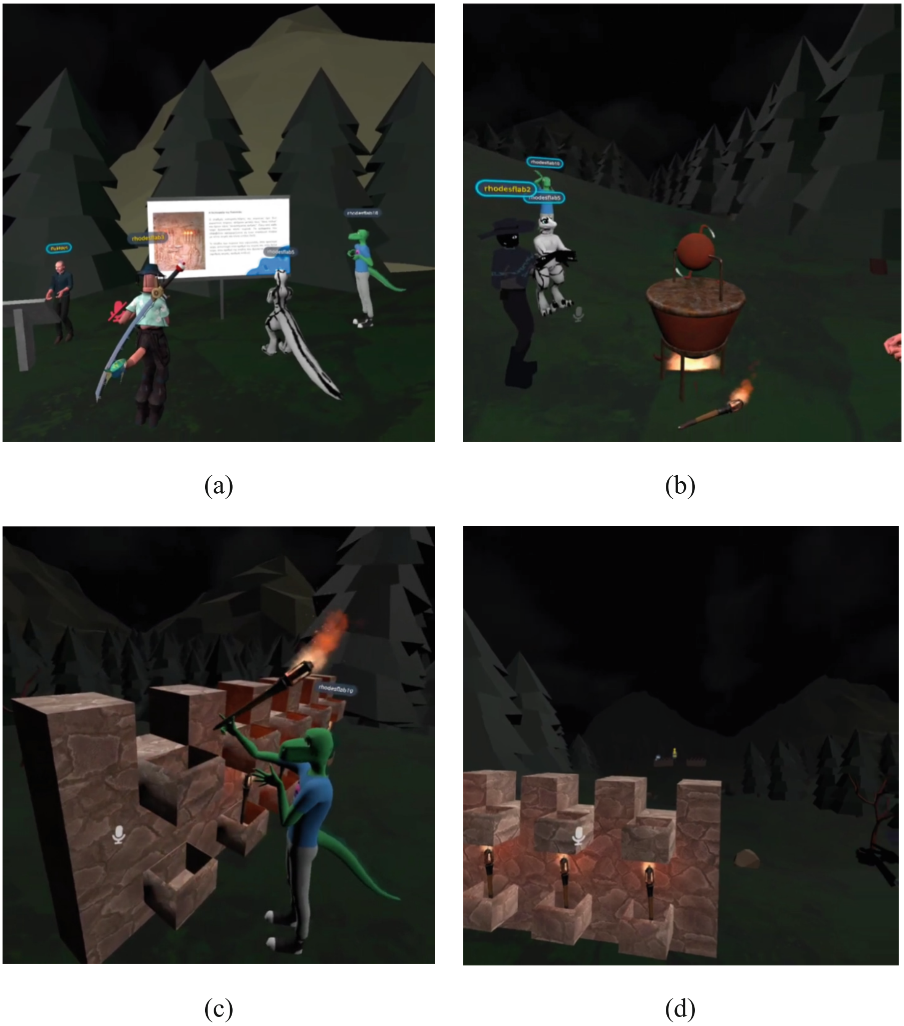

Fig. 1. (a) Users attending a Powerpoint presentation delivered by an instructor (b) Users discussing the functionality of the Aeolosphere; (c) User manipulating a Phyctoria torch; (d) Users communicating over distance using Phryctories.

3.3 Instruments

A questionnaire was distributed to participants to collect data concerning their perceived learning experience. It included the items in the Metaverse Learning Experiences Scale (MLES) that was formulated to assess users' experience across diverse Metaverse applications, including imVR [3]. Although MLES captures ten factors, for the purposes of this study the following factors were selected: simulator sickness (four items), motivation (three items), perceived ease of use (three items), immersion (four items), perceived feedback and content quality (three items), perceived quality of the interaction (three items), and positive emotions (four items). Four additional items were included with the intent of recording demographic details of the participants, namely their gender, age, prior experience in using VR, and prior experience in playing games. The questionnaire was made accessible online using Google Forms.

3.4 Procedure

The participants of the imVR group were briefed on what to expect and how to navigate and interact within the application. Subsequently, the HMDs were distributed, while adjustments were made to the straps and interpupillary distance to enhance visual quality. A 15-min acclimatization period was allocated, facilitating the participants' familiarization with the virtual environment. This preliminary step was necessary since the majority of participants had no prior experience with imVR and HMDs. In the subsequent phase the participants were invited to proceed to the main area for attending the lecture, which had two stages. In the first, one of the authors assumed the role of an instructor who introduced the mechanism of the Phryctoria using a PowerPoint presentation embedded in the application. Then, the participants collaboratively exercised what they had learned, by using the torches of the Phryctoria for transmitting and receiving messages. Finally, assisted by the instructor, the participants observed and discussed the functionality of an Aeolosphere. Both stages lasted for about 25 to 30 min, a duration deemed sufficient for a comprehensive experience. Next, the questionnaire was distributed. Participants completed the questionnaire using computers stationed in an adjacent office. In anticipation of potential severe simulator sickness, participants were advised to remove their HMDs and take a rest should they experience significant discomfort. Conversely, those experiencing minor or mild symptoms retained the discretion to either continue or withdraw from the experiment at their convenience. Regardless of their choice, all participants had to complete the questionnaire. This mandate was rooted in the hypothesis that simulator sickness could profoundly impede the learning experience. A similar procedure was adapted for the dVR group. Far fewer instructions were provided, given that just the mouse was used for navigating and interacting with the application.

4 Results

Cronbach's α was used to examine the questionnaires' internal consistency. As, in all cases, the α was above the recommended minimum value of .70 [12], the internal consistency was considered satisfactory. Following that, seven new variables were calculated, representing the average score per factor, per participant, and the data were imported to SPSS 29 for statistical analyses. Table 1 presents descriptive statistics for the participants' demographics and for the study's variables. To have a clear picture regarding the differences between imVR and dVR conditions, it was considered necessary to control the effects of age, gender, experience in VR, and experience in playing games, as these could have an impact on the results. Because of that, an Analysis of Covariance (ANCOVA) was deemed the appropriate statistical procedure. Before proceeding, it was checked whether the data were suitable for this kind of analysis. As problems were noted in the normality of the data, it was decided to proceed using Quade's (1967) nonparametric analysis of covariance test of equality of conditional population distributions, which is the non-parametric equivalent of ANCOVA [11]. Table 2 presents the results of the analysis.

Table 1. Descriptive statistics for the study's variables

Variable	**imVR** (n = 22)		**dVR** (n = 26)	
Males/Females	5/17		6/20	
Age (16-19, 20-24, 25-20, >30)	0, 14, 2, 6		6, 11, 2, 7	
Used VR (never, once, experienced)	3, 18, 1		12, 8, 6	
Play games (no, now-and-then, regularly)	11, 9, 2		10, 9, 7	
	M	SD	M	SD
Ease of use	4.06	0.53	4.04	0.68
Immersion	3.80	0.98	3.78	0.70
Perceived content quality	4.48	0.57	4.51	0.40
Interaction	4.00	0.65	3.95	0.56
Motivation	4.50	0.59	4.45	0.72
Simulator sickness	2.26	1.00	1.83	0.88
Positive emotions	4.67	0.46	4.43	0.54

Table 2. Quade's ANCOVA results

	Ease of use	Immersion	Perceived content quality	Interaction	Motivation	Simulator sickness	Positive emotions
dfh	1	1	1	1	1	1	1
dfe	46	46	46	46	46	46	46
F	0.02	0.51	0.06	0.07	0.44	1.58	2.828
p	.903	.480	.812	.797	.509	.216	.099

Note. dfh and dfe are the hypothesis and error degrees of freedom

Taking together the above results and for answering the RQs[EF1], the following can be noted:

- In both experimental conditions, the mean scores of the examined variables were rather high (very close to or above the value of 4.00). Consequently, one can assert that participants exhibited a high degree of motivation and immersion regardless of the VR system employed. Additionally, participants perceived the applications as interactive and easy to use, assessed the quality of feedback and content as satisfactory, and reported the elicitation of positive affective responses. An exception to this trend was simulator sickness; with a mean score approximating 2.00, it was found that symptoms were generally mild and not pervasive among participants.

- No significant differences were observed between imVR and dVR in any of the evaluated factors. It is therefore reasonable to conclude that the levels of immersion and motivation, as well as the positivity of the affective responses, did not vary between the two conditions. Moreover, the severity of simulator sickness symptoms was comparable across both VR modalities. Furthermore, participants rated both imVR and dVR as equally easy to use and interactive, and they perceived no difference in the quality of feedback and content provided by each system.

These findings underscore the equivalency in user experience facilitated by both types of VR in the context of the study's parameters.

5 Conclusions

This study focused on the use of VRLE in higher education and examined factors that affect their use by students. Specifically, we designed a VRLE featuring Ancient Greek technological inventions and examined whether there were differences regarding particular factors when users interacted with the content in imVR and dVR conditions. These factors were the following: ease of use, immersion, perceived content quality, interaction, motivation, simulator sickness, and positive emotions.

One of the conclusions drawn from the analysis of the results is that the sample had very positive perceptions with respect to the aforementioned factors from the use of our VRLE. In addition, the results showed that the VRLE is acceptable in terms of sickness, considering that most of the students did not report significant symptoms. These findings support those of recent studies, which advocated the importance of factors such as ease of use, immersion, perceived content quality, interaction, and motivation in VRLE adoption in education [8, 9, 13].

Another important finding emerging from our study is that students' perceptions do not differ as to the version of the VRLE they used (i.e., imVR or dVR version). This finding contradicts those of past studies which found that when users used the imVR they have slightly better learning outcomes and improved experience compared to those using dVR [6, 7, 10]. This means that students adopt positive perceptions about the ease of use, immersion, perceived content quality, interaction, and motivation of VRLE both for the imVR or dVR versions.

Overall, the results of our research are encouraging as regards the future use of VRLE in higher education. They contribute to the literature regarding the factors related to users' experience and interaction with imVR or dVR learning environments. However, it is interesting to note that the current research has two limitations. The first relates to the convenience sampling. Another limitation is that students' interaction with the particular VRLE used in this study was based in a controlled lab environment. The use of VRLE in regular learning conditions for an undergraduate or postgraduate course and the measurement of the factors cited in this study using a larger sample could have revealed additional important information regarding its use by students. Therefore, future studies should take the aforementioned limitations into account. In addition, this study can be further improved if future focus is geared to students' interaction with other virtual environments in different subjects, and also examines whether students' related experience and perceptions from these interactions present a statistical difference between imVR and dVR versions.

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