



TRAINING HIGHER EDUCATION BIOSCIENCE STUDENTS WITH VIRTUAL REALITY SIMULATOR

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Abstract:

Laboratory training is the cornerstone of science education in higher education. However, in several cases hands-on experimental procedures are not possible, and therefore technology provide alternative educational methods. One of the rapidly evolving technologies, namely Virtual Reality (VR) can offer multiple benefits in laboratory training through the development of simulations and virtual laboratories that support, facilitate, and promote an effective their learning experience. We present an empirical research carried out at the Department of Molecular Biology and Genetics of the Democritus University of Thrace during the winter semester of the academic year 2020-2021. 51 undergraduate students carried out a Virtual Reality activity aiming to train them to the use of a Class II Biosafety Cabinet (BSC) in an immersive virtual environment. Our results show that VR approach was highly and enthusiastically accepted by the students; they reported that they had an authentic learning experience which enabled them to better achieve the learning objectives. However, in some cases symptoms like dizziness and blurry image were reported most likely due to equipment, showing that improvement of the equipment used in VR is needed.

Keywords: virtual reality, learning experience, simulator, laboratory exercises

1. Introduction

During the last decade, Virtual Reality has returned to the foreground, as well as the interest for its educational use, a fact that is reflected in the rapid increase of relevant research (Nesenbergs, Abolinis, Ormanis & Mednis, 2021; Fabris, Rathner, Fong & Sevigny, 2019; Menin, Torchlsen & Nedel, 2018). Virtual Reality (VR) is defined as the creation of an artificial interactive environment or Virtual Environment that human perceives as real. The individual in a VR environment receives visual, auditory, and tactile information and responds; in addition, it is possible to control body movements

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(Blade & Padgett, 2015). VR environment can be either real or imaginary; the user interacts with it with the appropriate equipment (helmets, gloves, etc.) (Mikropoulos, 1998).

The past decade has also seen a significant increase in computing power and a reduction in the size and weight of electronics, which contributed to the rapid development of equipment capable of supporting VR applications; available equipment gets more and more user friendly while acquisition costs have rapidly risen (Bezegová, Ledgard, Molemaker, Oberč & Vigkos, 2017). Although the primary purpose of companies developing VR equipment is clearly the entertainment sector, its exploitation in other areas is inevitable. Notably, VR is also a great tool for educational use; it is directly linked to the experiential learning (Moustakas, Paliokas, Tsakiris & Tzouvaras, 2015), while, as its special features are related to basic principles of modern learning theories, it offers many possibilities in supporting the teaching process (Lepouras, Antoniou, Platis & Charitos, 2015). Virtual Environments are designed to enable users to have a specific experience in a secure setting and to be able to develop knowledge and skills (Barmpoutis, DeVane & Oliverio, 2015). Experiential learning is directly related to VR applications; David Kolb's (1984) model of Empirical Learning can be applied, as learners' involvement is immediate, and the Virtual Environment enables them to go through the four stages described in Kolb's Learning Cycle (see Figure 1).

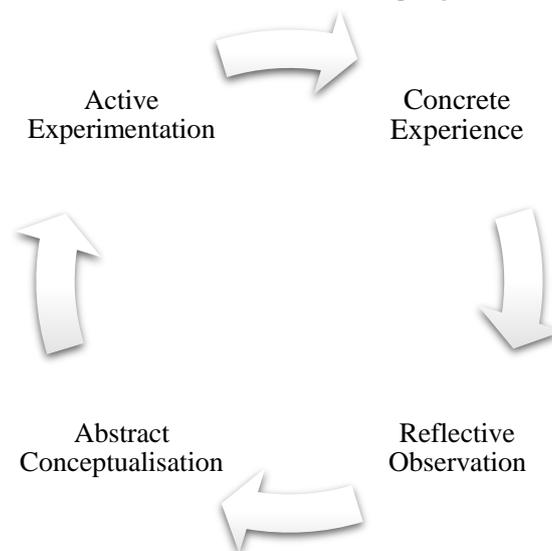


Figure 1: Kolb's Experiential Learning Cycle (Kolb, 1984, p. 33)

The target is, therefore, to enhance the learning experience of the students by exploiting VR and through immersion, to create authentic experiences that will help them transform perspectives and approaches to the learning process (Kolb & Kolb, 2012). In fact, relevant research (Moro, Stromberga, Raikos & Stirling, 2017; Jantjies, Moodley & Maart, 2018; Allcoat & von Mühlennen, 2018) show increased learning benefits as direct interaction and feedback gives participants the opportunity to apply the knowledge they gain. McCune (2009) in her research with seniors in Bioscience, argues that authentic learning experiences should have personal relevance for the students, providing them with sufficient independence and responsibility to become autonomous learners.

One of the most important benefits of VR is that it gives to the participants the opportunity to have an authentic experience in places they do not have the opportunity to visit and perform activities that would otherwise be impossible, dangerous, or expensive (Dalgarno & Lee, 2010; Chertoff & Schatz, 2015; Bailenson, 2018; Makransky, 2021). Such experiences include visiting museums, historic buildings, and events, driving vehicles, etc. In this context VR contribution to Medical Sciences, for instance in performing medical operations, (Parry, 2019) and to BioScience by carrying out experiments is particularly important. Additionally, digital recreation of the human body (Stepan *et al.*, 2017; Pulijala, Ma, Pears, Peebles & Ayoub, 2018; Maresky *et al.*, 2019) and creation of models at the molecular or atomic level (Goddard *et al.*, 2018; Makransky, Tekildsen & Mayer, 2019) give the opportunity to both trainers and learners to gain an authentic learning experience far better and more realistic than the traditionally used models. For this reason, already, these approaches are used in the teaching courses related to Life Sciences in Higher Education in several countries (Parry, 2019). These methods stimulate the interest of the trainees by increasing participation and engagement, while at the same time, they give them the opportunity to live an authentic and effective experience (Hu-Au & Lee, 2017). In other words, they create experiences that are considered better and deeper than "ordinary learning" and are the central concept in the perception of learning as learners are directly involved and understand what is important to them (Illeris, 2015).

Especially in Biosciences, many phenomena or processes are difficult to analyze and present, so the use of virtual laboratories and software simulations is suggested (Athanassiou, 2015). Moreover, in practical training, the cornerstone of bioscientists' education, VR approaches can be used additionally to train students in methods and techniques difficult or even impossible to apply in the hands-on practicals, as they are very expensive or dangerous. The recent COVID-19 pandemic, in which no laboratory practicals could be performed highlighted also the importance of on-line teaching laboratory courses. Within this framework, new teaching and learning methods that will be effective are required (Fox, 2020). For this reason, the educational use of simulators has been quite widespread during this period (Alves Bastos E Castro & Lucchetti, 2020; Patel, Miller, Schiavi, Toy & Schwengel, 2020; Tabatabai, 2020).

2. Material and Methods

The aim of this research is to study the learning experience of students in a virtual laboratory environment. More specifically we sought to understand if using Virtual Reality for educational purposes helps students to learn and operate laboratory equipment; in this case equipment that they would not be able to access in traditional laboratory practicals. To this end, the following research questions were formulated:

- How is the learning experience of the students evaluated after the adoption of Virtual Reality applications in an educational process in the field of Biosciences?
- Which could be the potential obstacles in adopting this teaching method?

Subjects were undergraduate students enrolled in the Laboratory course “Methods in Molecular Biology” of the fifth semester of the Curriculum of the Department of Molecular Biology and Genetics. This course includes a module on tissue culture techniques in which an introduction to the Biosafety Cabinets, and especially in the use of the most commonly used in tissue culture, namely the Class II Biosafety Cabinet is included; this introduction however has been so far performed during the lecture, as in the students’ training laboratories this equipment is unavailable. Therefore, this module was selected to test and assess a Virtual Reality activity.

Prior to the implementation of the activity, an hour-long briefing was held for all students who participated in the activity in a virtual environment. A brief introduction was made to the terminology of VR and its use in educational environments, while the necessary instructions were given regarding the process of the implementation of the activity.

The activity took place in the Laboratory of Teaching and Professional Development of Bioscientists of the Department of Molecular Biology and Genetics. Students came one by one and implemented the activity. Due to the COVID-19 pandemic, extra precautionary measures were taken for the safety of both the students and the researchers. Both the researcher and the students wore masks and protective gloves. In addition, students were given an extra mask to protect their face from coming into direct contact with the VR headset. After the completion of the activity, the equipment (controls and VR, HDM) was disinfected, as well as the space, while the ventilation of the room was constant.

Each student came in, wore gloves, mask and had a short demonstration of the use of the controls. After adjusting the equipment, the activity started. Participants were free to express themselves and ask the researcher for any clarification needed throughout the activity. They were also informed that they could request to stop the activity at any time and for any reason. During the activity the researcher was in the room, by the students in case instructions were necessary but also to prevent accidental hitting of objects as inside the virtual environment they had no contact with the outside world. By the end of the activity, students filled in the required questionnaires. The activity lasted for a total of 45-60 minutes (briefing-activity-questionnaires).

2.1 Hardware

Commercial equipment was used for the implementation of the VR activity. HTC Vive Virtual Reality equipment was used, connected to a laptop computer with an Intel i7 - 9th gen processor, with 16GB RAM, GTX 1660Ti graphics card and Windows 10 operating system.

2.2 Software

For the selection of the software, and in order to meet the needs of the specific module, we selected the application LabTraining VR: Biosafety Cabinet Edition; it has been developed by the CDC (Centers for Disease Control and Prevention), the United States official organization for biosafety and does not have special requirements for pre-existing

knowledge. LabTraining VR: Biosafety Cabinet Edition was one of the free applications tested, as there was no funding available. In addition, being an application from developed by the CDC it was the first one to be further tested. by faculty members and teaching assistants of the Department of Molecular Biology and Genetics with tissue culture experience who teach the relevant module. As this assessment showed that it met the requirements of the module and that the learning experience of students could be studied, the necessary clarifications were made to the researcher regarding the important points that should be highlighted to the students during the activity.

The LabTraining VR: Biosafety Cabinet Edition was downloaded via the Steam service (release 3/8/2020) where it is available for free. It should be noted that at that time it was only working with the HTC Vive VR equipment. (<https://store.steampowered.com/app/1337060/>)



Figure 2: Class II Biosafety Cabinet in virtual (left) and a real (right) environment

The application simulates the process of preparing a Class II Biosafety Cabinet for tissue culture work and is divided into three main parts. In the first part, the user becomes familiar with the virtual environment by repeating a series of steps on how to move in the virtual environment and use various objects. In the second part, the user is transferred to the virtual laboratory, different parts of the Safety Cabinet as well as the mode of operation are discussed and the subject is guided to perform the necessary procedures for the use of the BSC. In the third part the user is asked to repeat the procedures learned without guidance. After completing the tasks, the user is informed about his performance (score 100).

2.3 Activity

The version of LabTrainer VR that was used included the following sections:

- a) The user started with the learning of the parts of the Class II BSC and its operation. Then he/she was transported to the training room; a virtual character instructed the subject to become familiar with the use of the VR equipment and at the same time to perform the procedures required before entering the tissue culture laboratory (remove any accessories, wear the lab coat, goggles, and gloves). After completing these steps, the student could enter the laboratory.

b) In the laboratory, the user performed a series of tasks required to operate the BSC cabinet and to prepare the cabinet for tissue culture work. The user could move into the virtual environment and he/she worked in front of the BSC; he/she received instructions from the virtual character on the actions needed to perform in order, namely.

- 1) Identification of the parts of the Class II BSC,
- 2) Startup process of the Class II BSC,
- 3) Regulation of air flow in the chamber,
- 4) Disinfection of the chamber,
- 5) Proper arrangement of the necessary equipment in the working space of cabinet.

The user performed the above procedures with guidance through the application, while he/she could at any time monitor his/her progress.

c) Following completion of the training, the user was asked to repeat the procedure without assistance. Upon completion of this part the user received the result of the evaluation for each task.

2.4 Data collection: Procedure, sample, and research tools

51 students, of which 21 were male (41.2%) and 30 female (58.8%) were included in this research. The majority (66.7%) had no previous experience with VR equipment, while 52.4% of the male had previously used VR equipment, mainly in combination with video games consoles; only 20% of female had experience with VR equipment.

After completing the activity, the students filled in questionnaires about the learning experience they had. More specifically, for the evaluation of their learning experience the participants completed the WBLT (Web-based Learning Tools) questionnaire (Kay, 2011; Allcoat & von Mühlennen, 2018). The participants were asked to answer 13 questions on scale 1 (strongly disagree) to 5 (strongly agree) and the questions are grouped into three axes, Learning, Design and Engagement. Specifically, learning is assessed by questions 1-5, design by questions 6-9 and engagement by questions 10-13. The questionnaire also included two open-ended questions that aimed to report the positive and negative points of the experience they had.

3. Results

Descriptive data analysis was performed with SPSS (version 27.0) statistical analysis software.

The Web-Based Learning Tools or WBLT (Kay, 2011) questionnaire was used with 13 questions on a scale of 1-5 (1 = Strongly disagree, 5 = Strongly agree). Internal consistency was calculated using the Cronbach's Alpha Internal Consistency Index. For the Learning factor it is $\alpha = 0.795$, for the Design factor $\alpha = 0.829$ and for the Engagement factor $\alpha = 0.927$. For all three factors, the Cronbach α internal consistency index was very high (> 0.70). The averages of the three axes are shown in the table below.

Table 1: WBLT questionnaire axis

	Mean	S.D.
Learning	4.80	.371
Design	4.79	.449
Engagement	4.88	.462

In the Learning axis, the participants believed that the way the activity was built, helped them learn in an easier way. Regarding the Design of the learning object, students also did not face any problems and found the activity well-organized and friendly to use. Finally, the Engagement with the learning environment seemed excellent and they enjoyed the whole process. This reflected the satisfaction of the participants; it is noteworthy that the highest average was recorded in the question about their desire to use the application again. In Table 2 the questions and the average score for the responses in each one of them are presented.

Table 2: Evaluation of the application WBLT (N=51)

		Mean Score	S.D.
Learning			
Q1	Working with the learning object helped me learn	4.82	.434
Q2	The feedback from the learning object helped me learn	4.78	.461
Q3	The graphics and animations from the learning object helped me learn	4.78	.461
Q4	The learning object helped teach me a new concept	4.76	.681
Q5	Overall, the learning object helped me learn	4.84	.418
Design			
Q6	The help features in the learning object were useful	4.76	.551
Q7	The instructions in the learning object were easy to follow	4.76	.586
Q8	The learning object was easy to use	4.78	.461
Q9	The learning object was well organized	4.86	.601
Engagement			
Q10	I liked the overall theme of the learning object	4.76	.651
Q11	I found the learning object engaging	4.86	.601
Q12	The learning object made learning fun	4.94	.420
Q13	I would like to use the learning object again	4.96	.280

4. Qualitative data analysis

The participants recorded the positive and negative points of their experience and through the thematic analysis of the answers separate thematic axes emerged.

Table 3: Positive and negative points of the experience

Item	Indicative quotes
In your opinion, what were the positive points of the experience you have gone through?	<p><i>"It was interactive and much more interesting than learning these steps from a lecture"</i></p> <p><i>"It was a very enjoyable way to learn some things that we could only see theoretically."</i></p>

"It was an unprecedented experience and very enjoyable. I learned the procedures quickly and easily. "I would like to use such an experience again."

"I was learning while having fun, mostly interacting with the virtual environment was natural and I was also given the opportunity to do something that would not otherwise be possible and to get acquainted with it."

"I find this teaching method absolutely fun and engaging, through which one easily loses a sense of time and learns by playing."

In your opinion, what were the negative points of the experience you have gone through?

"Until I got used to it, I could see blurry, and I was a little dizzy, but after I got used to it, I no longer had any problems."

"The only downside I would characterize is the 'heavy' equipment of the mask, which may have been a little cumbersome and a little stressful." "The negative points of the experience are initially that you lose the interaction with the rest of my classmates as this experience is individual."

"Mild headache, heavy head and dizziness."

As for the positive aspects of the experience, the students focused on the emotional and learning factors. They showed great satisfaction and enthusiasm; the majority described the experience as pleasant and fun. Regarding the learning part, they considered that with such methods they had the opportunity to learn by playing in a safe setting, while the power of the image and the interactive environment gave them the impression that they were learning better. As for the negative points of the experience, these mainly concerned technical issues as well as physical symptoms. Several users noticed problems in focusing on the images and the letters, and as a result they saw things a bit blurry, while others found the equipment heavy, which at some point became tedious. Finally, several users reported dizziness.

4. Discussion and Conclusion

Our small-scale study shows that using VR in higher education is an interesting practice; it has a very positive effect on the mood and the emotions of the participating students, as it has also been pointed out in similar research (Allcoat & von Mühlennen, 2018; Greenfeld, Lugmayr & Lamont, 2019). Students want to get in touch with new ideas in the educational process and embrace these activities with satisfaction and enthusiasm. Pleasure and fun were reflected in both quantitative and qualitative indicators. A possible explanation for the high enthusiasm of the participants was the unprecedented experience that motivated them. In addition, their freedom in the virtual environment was diametrically opposed to the strict protocols in the traditional laboratories, this was pointed out by the participants. The positive evaluation of the learning tool is important because if it offers an authentic and engaging learning experience then students are led to greater engagement, pleasure and interest in the learning object (Fabris *et al.*, 2019).

Regarding the negative points of the approach, we argue that technical limitations can affect the authentic and consequently the learning experience. The blurred vision

reported by several participants, was mainly due to the adjustment of the equipment as, in most cases it was corrected following our intervention and adjustment. The other symptoms, namely dizziness and heavy head detected were also like those reported in the literature and their effect was transient without significantly affecting the overall learning experience (Ames, Wolffsohn & Mcbrien, 2005; Moro, Stromberga, Raikos & Stirling, 2017; Servotte *et al.*, 2020). However, it should be noted that all participants completed the activity, and no one interrupted it.

Overall, the present teaching experience was assessed as a very positive one, and the students reported that this approach was effective and helped them to learn better and to be prepared for laboratory work. This is an important issue especially in experimental fields like the Biosciences, in which the contribution of Virtual Reality can be catalytic. VR activities can be used to teach students difficult concepts and processes (e.g., DNA, structure of proteins, complexes, etc.) but also to train them in experimental methods that are either expensive, time consuming or even dangerous, and therefore, a hands-on approach cannot be used. The implementation of this research coincided with the outbreak of the COVID-19 pandemic that brought higher education institutions, faculty and students face to face with new challenges; in this context laboratory courses faced the biggest problems; thus, the development and operation of virtual practicals that provides an alternative method can also be suitable for extreme situations like the COVID-19 pandemic. To conclude, our study showed that VR based learning methods in practical training in Biosciences, this along the development of better and affordable equipment will pave the way for the development of VR educational tools that will significantly improve student learning.

Conflict of Interest Statement

The authors declare no conflicts of interests.

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