Virtual Reality as Supplementary Education Tool for Pharmacology Laboratory Practical: The Effect on Student Experience, Knowledge and Confidence

Mei Kee Lee, University of Nottingham Malaysia, Malaysia
Su Ting Yong, University of Nottingham Malaysia, Malaysia
Kang Nee Ting, University of Nottingham Malaysia, Malaysia
Jing Ying Wong, University of Nottingham Malaysia, Malaysia
Nurfatin Saaidah Binti Zainal, University of Nottingham Malaysia, Malaysia
Eunice Zhi Nee Lua, University of Nottingham Malaysia, Malaysia

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Abstract
Virtual Reality is an emerging technology for immersive learning. A Virtual Reality Organ Bath Lab (VROBL) simulating the physical pharmacology laboratory practical was developed to help students to comprehend complex pharmacological principles. The study aimed to investigate the impact of VROBL adoption as a pre-laboratory experience on student learning experience, knowledge, and confidence levels. An experimental research study was conducted with a study sample of 17 health science students enrolled in a Biomedical Science module. The participants were divided into intervention (n=9) and control groups (n=8) using block randomization. The intervention group experienced virtual learning with VROBL before the laboratory session, while the control group was exposed to the software after the laboratory session. A pre-post study design was adopted, whereby questionnaires were administered before and after the VROBL and physical laboratory sessions. The completion times of physical laboratory tasks were recorded. Data collected revealed that the intervention group was satisfied with the simulation (mean±SD: 4.97±1.24) and learning content (mean±SD: 5.81±1.21) of VROBL. Furthermore, the intervention group reported an increased confidence in correctly explaining how to use the lab equipment and apparatus compared to the control group (mean: 4.77 vs. 3.50, p=0.044). The finding was supported by positive feedback of VROBL as a pre-laboratory exercise. However, there was no significant difference between both groups in knowledge quiz scores and completion times of physical laboratory tasks. Although VROBL did not improve student knowledge or performance in the physical laboratory, it had enhanced student learning experiences and confidence, which ultimately might improve student motivation and learning outcomes.

Keywords: Virtual Reality, Pharmacology, Learning Experience

Introduction

The fourth Industrial Revolution (IR 4.0) is transforming the higher education from traditional learning into technology-based learning. Educators are encouraged to gain knowledge and skills and seek alternative approaches to fully maximize the students' learning experience (Aziz Hussin, 2018). This includes the incorporation of digital technologies in higher education. In recent years, a myriad of technological innovations, including Virtual Reality (VR) and Augmented Reality (AR), have been developed and leveraged by the educators in alignment with IR 4.0 (Ikhsan et al. 2020).

Pharmacology, being a complex subject, necessitates a conceptual understanding of drug effects and interactions with biological systems. Traditionally delivered through didactic teaching, students often face challenges in grasping these concepts due to the three-dimensional nature of both drugs and biological systems. This intricacy makes effective illustration and explanation difficult in both classroom and lab practical settings. Furthermore, although essential lab skills such as the micropipetting technique are integral for science students, limitations in teaching resources often restrict the inclusion of hands-on laboratory exercises in the curriculum. Despite the widely recognized need for practical laboratory training to enhance skill acquisition, the call to adhere to the 3Rs—reduce, replace, and refine animal usage—has further limited the availability of hands-on exercises involving animals.

Virtual Reality (VR) is an emerging technology increasingly used in higher education to offer students engaging and interactive learning experiences. It enables exploration and interaction with virtual environments, simulating real-world scenarios. VR is employed for hands-on training in fields like medicine, engineering, and architecture (Bermejo et al., 2023), fostering improved learning immersion and the development of critical thinking and problem-solving skills. As VR technology advances, it plays an increasingly vital role in higher education. The 3D perspective offered by VR proves invaluable in comprehending pharmacological concepts, surpassing the limitations of traditional 2D graphics (Hanson et al., 2019, Ventola et al., 2019 White et al., 2023). In addition, VR provides opportunity for users to practice laboratory skills unlimitedly in risk-free virtual environment, reducing the use of animals in laboratory (Glassey & Magalhães, 2020).

During the COVID-19 pandemic, students had restricted access to the laboratory due to physical distancing. To complement the physical pharmacology laboratory practical, we developed a prototype of VR Organ Bath Lab (VROBL) that mimics the physical laboratory practical with the aim to stimulate students' interest and engagement in the laboratory. To date, there are limited studies on the impact of using VR laboratory to supplement pharmacology laboratory, especially in Malaysia. Thus, our study aimed to investigate the effects of VROBL as a pre-laboratory exercise on students' learning experience, knowledge, and confidence levels.

Methods

Ethical approval was obtained from the University of Nottingham Malaysia Ethics Committee (ELZN090222). This study took place in the University of Nottingham Malaysia. Inclusion criteria were Year 2 students aged 18 years and older and enrolled in a Biomedical Science module, namely Pharmacological Basis of Therapeutics. Monetary compensation was provided for study participation. Study sample of 17 health science students were recruited voluntarily and divided into intervention (n=9) and control groups (n=8) using block randomization. The intervention group engaged in virtual learning with VROBL about 1 to 3 days prior to the laboratory session, while the control group did not experience VROBL before the laboratory session. A pre-post study design was adopted, where 7-point likert scale survey questionnaires, ranging from 0 to 7 (extremely dissatisfied to extremely satisfied) were administered before and after the VROBL and physical laboratory sessions. Four questionnaires were adapted from Cheesman et al. (2014) and administered using the online questionnaire service, Qualtrics. Data collection took place from March to April 2022. Participants were asked to complete the questionnaires based on their groups as follows:

Questionnaire 1: VROBL User Experience Survey (administered to intervention group only immediately after the VROBL)

Questionnaire 2: Confidence Survey (administered to both control and intervention groups immediately before the physical lab)

Questionnaire 3: Knowledge Quiz (administered to both control and intervention groups immediately after the physical lab)

Questionnaire 4: VROBL Perception Survey (administered to intervention group only immediately after the physical lab)

The data were collected anonymously. Informed consent was obtained from every respondent and the data were kept confidential. Completion times of individual participant for physical laboratory tasks were recorded to compare students' performance. The control group participants were given the opportunity to experience VROBL after the laboratory to avoid disadvantages. Quantitative data analysis was performed through Independent Sample T-Test using GraphPad Prism softrware. Data are presented as mean ± standard deviation (SD). A p value >0.05 was considered statistically significant.

Results

Our results indicated that the intervention group had an overall positive user experience with VROBL (Figure 1). The participants expressed satisfaction with the simulation software and quality (mean±SD: 4.97±1.24) and the educational content of VROBL (mean±SD: 5.81±1.21). One participant suggested to improve the sensitivity of the touchpad in the simulation while another participant reported glitches in the VROBL. 75% of the participants were satisfied with the explanation of the laboratory procedure in VROBL (mean±SD: 5.88±1.25). Majority of the participants (87.5%) were satisfied that VROBL has increased their interest in the organ bath laboratory (mean±SD: 5.88±1.13) and helped them to visualize the concepts related to the laboratory procedure (mean±SD: 6.00±1.07). Besides, 62.5% of the participants found it challenging to navigate and master the VROBL.

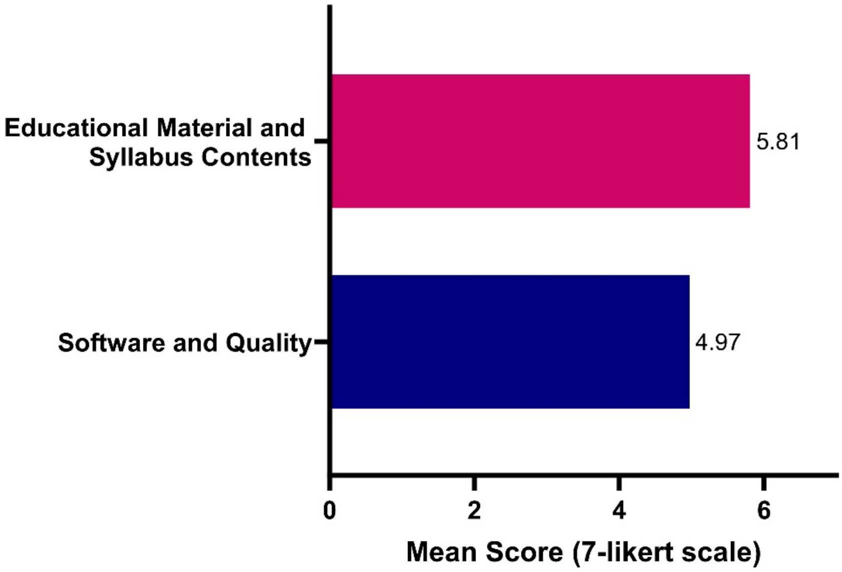

Figure 1: User Experience of VROBL on the software quality and content.

There was no significant difference in the average score of the confidence questionnaire between control and intervention groups (Figure 2). However, the intervention group did exhibit an increased confidence in one of the questions in confidence questionnaire, namely confidence in correctly explaining how to use the lab equipment and apparatus compared to the control group (mean±SD: 4.77±1.20 vs. 3.50±0.54, p=0.044). The time taken to complete the physical laboratory task was not significantly different between the control and intervention groups (857.2 seconds vs 853.5 seconds; p>0.05). Notably, there was no significant difference in the average score of the knowledge quiz between the control and intervention groups (mean±SD: 6.63±1.69 vs. 7.75±1.39, p>0.05) (Figure 3).

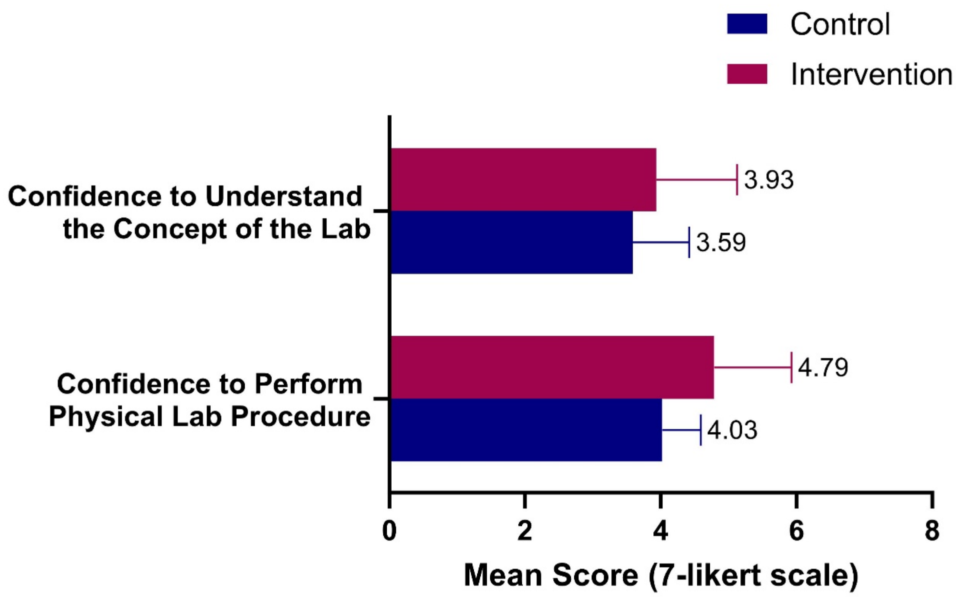

Figure 2: Average scores on the confidence questionnaire, consisting of 20 questions - 10 related to understanding lab concepts and 10 pertaining to confidence in performing physical lab procedures.

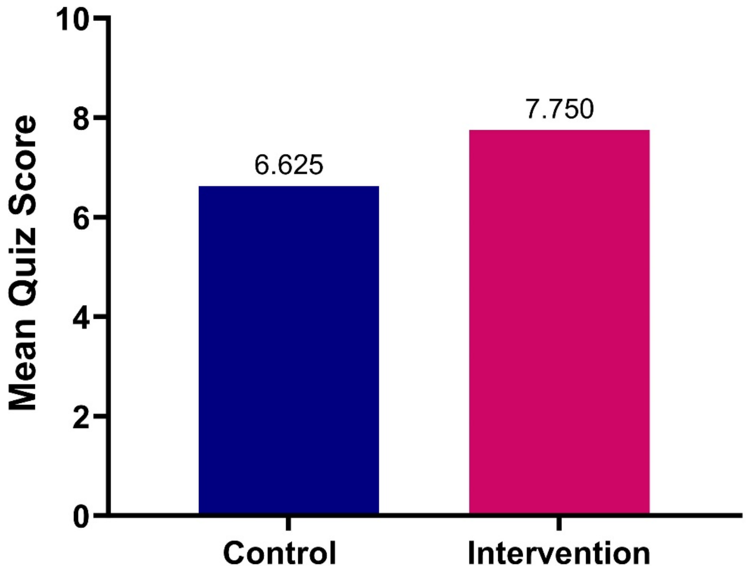

Figure 3: Average scores of the knowledge quiz between the control and intervention groups.

In addition, we assessed the intervention group's perception of VROBL after completing the physical laboratory session. Overall, participants provided positive feedbacks on the VROBL expressing acceptance and acknowledging its usefulness as a tool for studying pharmacology (Figure 4). Qualitative feedbacks on VROBL are listed in Table 1. Overall, participants believed that VROBL, when provided as a pre-laboratory exercise, helped familiarize them with the physical laboratory procedure and reduced anxiety through pre-exposure to laboratory procedure. Besides, one participant recommended that a training session on how to use the VR controllers before VROBL may be helpful.

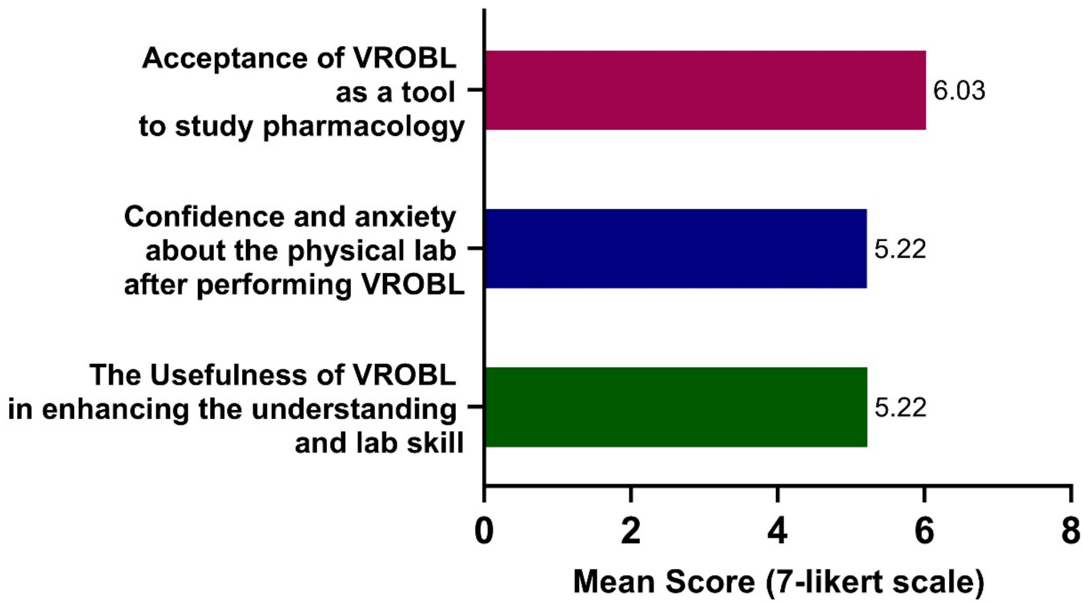

Figure 4: The intervention group's perception of VROBL
after completing the physical laboratory session.

How does VROBL experience affect the understandings and skills in performing hands-on laboratory tasks?	
1.	It helped me understand most of the experiment but I messed up the sequence of adding carbachol to the organ bath, which is my fault anyways. Overall the VR experience was great and helped me a lot
2.	It allows for familiarity
3.	Provide more help in calculations rather than the experiment set up
4.	VROBL helped me get used to how to administer carbachol into the organ bath and helped me visualise what an organ bath looked like and work.
5.	Give me heads up
How do your VROBL experience and its realism affect your confidence and anxiety in performing the hands-on laboratory tasks?	
1.	Less anxiety making the same mistakes
2.	I guess it's based on mindset? If you are confident that the VR helped you for the hands on lab experiment, then its easier
3.	The VROBL did help me understand what to do during the physical practical, and so was less worried about if I made a mistake. I think the VROBL can be improved by adding features that happen in real life, such as adding the pipette tips, throwing away the used tips, and allowing us to make mistakes and troubleshoot it (e.g. if we put the wrong concentration of carbachol)
4.	It helps me in knowing things I need to do during lab
How does your VROBL experience affect your confidence in answering the quiz questionnaire?	
1.	Not much, lesser exposure to quiz during VR. But the analysis of procedure helped alleviate anxiety answering quiz questions.
2.	Virtual is not the same as reality? Virtual gives me more confidence than reality
How can we use VR-based learning to improve your learning in this module?	
1.	Before face to face lab sessions
2.	Although VR is easy to use after we get used to it, I believe it was a bit hard to understand the VR controls the first time I used VR. Therefore I think we need a session to get used to the VR controls and features
3.	An extra exercise before doing real work

Table 1: The intervention group's feedbacks on VROBL and suggestion for improvement.

Discussion

To the best of our knowledge, this is the first report on the impact of the application of a VR pharmacology laboratory as pre-laboratory exercise on students' experience, confidence and knowledge.

Positive feedback on the explanation of the pharmacology laboratory procedure in the VROBL may be the key to the intervention group's increased confidence to explain the experimental procedures correctly. This is in line with the study by Cheesman et al. (2014) in which the students have demonstrated increased confidence in performing the physical laboratory procedures after completing the VR laboratory. Design of VR contents is a major part of the VR implementation, as Jiang et al. (2021) suggested that their participants were more interested and engaged when the content is relevant. The clear and detailed explanation of the laboratory procedures in VROBL could ensure that the participants were able to follow procedures and reduced their anxiety for physical laboratory. In contrast with previous study showing that technical problems and time needed to learn to navigate the VR applications could cause a loss of interest and engagement (Cheesman et al., 2014), our study showed that participants had gained interest in the organ bath laboratory after VROBL session, which potentially has reduced their anxiety in turn. Notably, intervention group has significantly higher confidence in correctly explaining how to use the apparatus and equipment in the experiment. This may be because VROBL provided a simulated laboratory environment and guided them through the experimental procedures in simulated environment. Notably, most participants in both control and intervention group were not confident (Figure 2; mean score 3.59 vs 3.93) in the understanding of organ bath laboratory concept. This finding indicates that the familiarization with laboratory procedure may not improve the understanding of the theory or principle.

A study by Pan et al. (2016) demonstrated that visual quality and interface performance affect users' sense of presence experienced in the simulation. The glitches and lack of sensitivity of touchpad in VROBL may affect users' overall experience and engagement. Besides, more than half of the participants did not find it easy to navigate and use the VROBL. This might be due to the technical problems and glitches in VROBL. Hence, this should be improved to enhance user-friendliness of VROBL for better user experience.

The lack of significant differences in knowledge quiz scores between the control and intervention groups may be attributed to the small sample size of the study cohort, limited by the constraints of the Covid-19 pandemic and the necessity for physical distancing. Only 35 students were able to participate in the physical laboratory practical sessions, and we had recruited 48.6% (17 out of 35) of the cohort into the study. While most studies showed that VR applications could increase students' interest and motivation in learning, evidence showed that VR applications are not necessarily useful for gaining knowledge, and might even have detrimental effects depending on the design and subject (Cheesman et al., 2014, Hamilton et al., 2021). In this study, we do not advocate for VROBL to substitute the physical laboratory, but instead as a pre-laboratory exercise to supplement the physical laboratory. Undeniably, VR simulations are seldom too animated and lack realism. Hence, VR simulation can only be used as a complement to student learning instead of a substitution (Herga and Dinevski, 2012).

Despite the limitation of small sample size and the technical problems of VROBL, our students highly endorse VROBL as a pre-laboratory exercise, enabling safe practice and fostering familiarity with the physical laboratory. While traditional learning methods remain indispensable, a blended learning approach, integrating digital technology into didactic teaching and laboratory practicals, holds great potential for enhancing students' engagement and learning experience (Balakrishnan et al., 2021).

Conclusion

In conclusion, the participants have demonstrated positive user experience and satisfaction with VROBL developed and used as a pre-laboratory exercise to supplement a physical pharmacology laboratory. While the VROBL did not demonstrate a substantial impact on students' pharmacology knowledge, it enhanced the learning experience and confidence to correctly explain the use of lab equipment and apparatus. The participants believed that VROBL helped to relieve their anxiety by allowing pre-exposure to the physical laboratory procedures. This improvement in student experience and confidence may, in turn, positively influence motivation and overall learning outcomes. Feedbacks gathered from the study's feedback are important in refining the VROBL and integrating it into the curriculum of health science students in the future.

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Contact email: meikee.lee@nottingham.edu.my