Design and Development of Virtual Reality Science Laboratory on Science Education: An Analysis of Presences during Learning

Nur Effatul Fairuz Zainal Apandi, Nur Azlina Mohamed Mokmin*, and Regania Pasca Rassy

***Abstract*—The global spread of COVID-19 has resulted in the international shutdown of educational institutions, especially for science students. Education is a crucial industry that demands innovation to accomplish learning objectives and goals. Modern technology-based education has been globalized and interactive platforms allow students and educators to access, utilize, and benefit from all the educational content. The first research objective of this study is to develop a virtual reality science laboratory by utilizing the ADDIE Methodology, a popular instructional design model for instructional learning. The second objective is to analyze the presence experiences during learning sciences by using the Virtual Reality Science Laboratory by distributing a set of pretest and post-test questions to two different groups of 37 science students. Group 1, which is 20 students will learn about science through 2D videos while Group 2 consists of 17 students who will experience learning science through Virtual Reality Science Laboratory. The result shows that there is a significant level of presence between the two groups, and the VR group performs better. This study can help educators and developers design effective VR tools to learn science. For future research, we suggest including cognitive load as another variable to test with VR learning tools. This work contributes to the studies on how immersive learning can significantly affect learning towards positive longitudinal effects.**

***Index Terms*—Virtual reality, sciences, presences, The Cognitive Affective Model of Immersive Learning (CAMIL)**

I. Introduction

Most of the education sector is applying the most effective strategies for online course delivery, student engagement, and assessment administration. Therefore, even though online education poses a threat to civilization, COVID-19 institutions have adapted to invest in it [1]. Online and web-based learning systems have gained popularity because of technology development particularly when all educational activities are interrupted. During a pandemic, it enables institutions to rapidly change their blended-based learning models. The shift to online education, however, should be seamless [2]. Virtual Reality (VR) is an interactive experience that allows users to become immersed in a computer-generated environment [3]. VR offers three-dimensional virtual environments with increased interaction methods that motivate learning [4]. When you put on a motion-sensing VR headset, the real world disappears (and sometimes handheld controllers). You can enter, navigate, and engage with a 360-degree virtual world. Students can simply control the teaching process and choose the essential content based on their circumstances, satisfying both ability and need [5].

Some of the research gaps through this study, we find out the long-term effects of virtual reality exposure that cause impact visual performance and cause visual fatigue and cognitive aftereffects [6], as well as the ethical challenges include issues related to privacy, consent, representation, and bias of virtual reality technology [7]. Finally, there are recent innovations in the use of virtual reality in education including virtual field trips, which allow exploration of historical and tourism landmarks, simulation-based learning that allows learning and psychomotor skills practice in preclinical dental students such as DentalVerse [8], immersive language learning for speaking and listening, and VR in special need education for the practice of social and life skills, as well as blended learning with immersive and interactive experiences by using flipped classroom teaching method that increasing the reward mechanism of the learning process, performance and learning enthusiasm [9].

II. Literature Review

A. Virtual Reality Technology

"Virtual Programming Languages" (VPL) founder Jaron Lanier introduced virtual reality in the early 1980s. Virtual reality technology uses multimedia, computer graphics, sensor technology, artificial intelligence, and simulation technology to create three-dimensional spatial expression and a natural human-computer interactive operating environment, changing the status quo of tedious human-computer interactions.

The virtual world, immersion, sensory feedback, and interactivity make up VR. They feel transported into this virtual world by this simulation. Immersion brings the experience closer to reality with captivating music and visuals. VR Headsets with Spatial Audio let users fully immerse themselves in virtual gaming and entertainment. The third component, sensory feedback, mimics human perception. VR enables users move, track, and change locations. VR improves force, taste, smell, and audio. Real-time, on-screen interaction immerses VR users. Users can slay monsters, shoot, kick, and select objects in the virtual world. Poetker describes mostly three forms of VR technology [10]. The first is a fully immersive, aesthetically and aurally genuine experience. VR headsets offer high-resolution, multi-perspective material. The semi-immersive version uses

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big projectors and real objects. Education and training use this VR. Video games are non-immersive. This study uses completely immersive technology since it is more interactive and provides a complete virtual reality learning environment. Students can learn by utilizing avatars and perform numerous activities without fear of making mistakes using virtual reality simulation. Using the virtual environment, nurses' performance may be easily documented and tracked throughout clinical training, according to Shorey and Ng [11] Virtual reality gives nurses the feeling of being present during training, allowing students to study in a believable and distinct environment. VR can also be used for difficult-to-accomplishing educational tasks, such as consulting nervous individuals undergoing treatment for psychiatric problems. In the study by Li *et al*. [12] avatars in the virtual world assist patients in detecting their moods, allowing them to practice emotional reactions.

B. Virtual Reality in Learning Science

Biology is one of the most fundamental aspects of learning science. Biology is a component of the science curriculum, especially in secondary schools. The study of the functioning of living organisms, such as humans, plants, and animals, makes biology one of the pillars of medical science. Regarding the genesis of life, it answers all questions presented by scientific studies. However, learning biology at the secondary school and baccalaureate level presents several obstacles, particularly in terms of teacher training and content acquisition. The physical aspect pertains to the classroom's facilities and equipment, whereas the psychosocial aspect pertains to the student's relationship or interaction with the teacher, peers, and surroundings, teacher-student interaction is essential for an effective teaching and learning process.

The global spread of COVID-19 has resulted which the course material is presented online in a manner that encourages student engagement and allows for evaluation. VR is an interactive experience that immerses participants in a computer-generated environment [13]. For instructional applications, VR provides 3D virtual environments with cutting-edge interaction techniques. Virtual reality is triggered by donning a motion-sensing VR headset (and sometimes handheld controllers), eliminating the outside surroundings. It is immediately and completely replaced with a 360-degree virtual environment that you may enter, traverse, and interact with [10]. Virtual reality could improve the teaching and learning of medicine. Multiple studies have shown that combining Virtual Reality (VR) technology with the teaching and learning of medical sciences yields beneficial results. Chen *et al*. [14] assessed the effectiveness of virtual reality (VR) in boosting students' study skills, satisfaction, performance time, and confidence. In 74% of the research examined by Samadbeik *et al*. [15] on the application of virtual reality in the medical sciences, the technology increased learning. Moreover, 87 percent of the evaluated studies revealed that medical practitioners with VR training are more accurate.

However, according to a study by Baniasadi *et al*. [16] there are some challenges and limitations that institutions and educators should consider prior to investing time and money in developing VR-based learning materials and environments for medical science education, despite numerous studies demonstrating the benefits. To be effective, VR's educational aim must be carefully considered during design and development.

C. Experiential Learning in virtual reality

The experiential learning theory was developed by Lewin, Dewey, and Piaget [17]. Experience or active learning underlies all these paradigms that allow students to encounter and reflect on an event to learn new things. This experience-based learning creates knowledge. However, learning is a process, not a product, and relearning should always be part of it. Learning inspires others and based on these assertions, four experiential learning methods were introduced which is concrete learning, reflective observation, abstract conceptualization, and active experimentation [17]. The experiential learning theory is one of the most frequently used theories for the implementation of VR in education [18]. Experiential learning requires information gain through active experimentation. Virtual reality can serve as an excellent instructional medium, putting the learner at the centre of significant learning experiences [19]. VR was also proven to boost learning motivation for courses such as science [20], engineering education [21], and chemistry [20, 21]. Several research have also examined the motivation of students to learn utilising VR for medical sciences education. In the trial, nurses were trained in childbirth education using VR. Their data indicates that, compared to traditional training, VR-based teaching motivates pupils to learn more. Another study by Sattar *et al*. [22] demonstrates a substantial difference in student motivation between VR and video and text-based learning.

D. Cognitive Affective Model of Immersive Learning (CAMIL)

According to the Cognitive Affective Model of Immersive Learning (CAMIL), immersive media will assist individuals in learning more efficiently than less immersive media. This principle claims that adopting the principle of multimedia design improves the effectiveness of the immersive virtual learning environment [23]. Immersive learning is defined by the extent to which visual, auditory, and tactile cues originate from a virtual environment rather than the real world. The foundation of this ideology is motivation, curiosity, and multimedia learning. As depicted in Fig. 1, the CAMIL consists of six emotive and cognitive components that may lead to Immersive Virtual Reality (IVR)-based learning outcomes. Interest, intrinsic motivation, self-efficacy, embodiment, cognitive load, and self-regulation are the variables. According to Makransky and Mayer [24] the implementation of good teaching approaches within virtual environments can enhance learning. This theory outlines six cognitive and affective elements by which the affordances of presence and agency can result in learning outcomes. As represented in Fig. 1, these include interest, intrinsic motivation, self-efficacy, embodiment, cognitive load, and self-regulation as relations between the various variables in CAMIL. However, in this study, will focus on the user presence scale and experience while using Virtual Reality Science Laboratory.

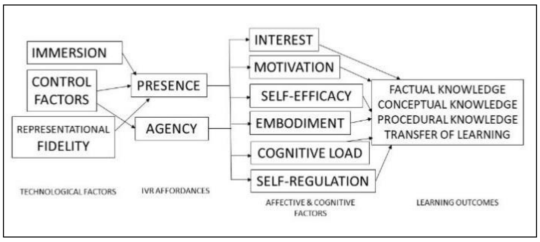

Fig. 1. The relations between the different variables in the CAMIL.

E. Presences in Virtual Reality

Despite its extensive use, Virtual Reality hasn't been the subject of much research because it needs interaction between users and a virtual environment. The environment feels more realistic when there is a presence, which allows the user of the virtual reality environment to concentrate on what is going on rather than searching for holes in the illusion. For instance, displaying elements like actual limitations or apparatus awareness can reduce this subjective illusion. The sense of presence a patient experiences while using VR can also be influenced by social (interactions with VR characters) and internal (personality qualities or immersion propensity) aspects [25]. After the respondents explore the virtual reality science laboratory, their levels of presence are measured using a questionnaire.

III. Application Design

A. Virtual Reality Science Laboratory

The design and development processes are carried out utilizing the ADDIE methodology, a popular instructional design model for instructional learning technologies. VR Laboratory provides highly motivating 3D virtual worlds with advanced ways of interactivity for learning Science. The student will utilize a motion-sensing VR headset and handheld controllers to navigate a 360-degree virtual laboratory using the teleport function while wearing a motion-sensing VR headset. Students can interact with 3D models of pathology objects, such as cancer cells, microbes, and bacteria, and view educational videos for each pathology field. Therefore, students have complete control over their learning progress and can choose relevant courses based on their own circumstances.

B. Hardware

We used the HTC Vive (HTC Corporation, USA) to allow participants to interact with the HTC Vive is a Head-Mounted Display (HMD) with a field of vision of 100 degrees, a resolution of 1,080 × 1,200 pixels per eye, and a refresh rate of 90 hertz. The HTC Vive was outfitted with a wireless adaptor that let users to navigate the virtual world without being attached to a computer. In addition, two HTC controllers, two Vive trackers on the feet, and one Vive tracker on the trunk were used to operate an avatar and interact with the virtual environment. Two lighthouse cameras monitored the HMD and trackers in opposing corners of the three-by-three-meter playing field.

C. Virtual Reality Science Laboratory Development Platform

Virtual reality was created for the virtual medical system using Unity. First, develop a virtual medical model. Photoshop can texture this virtual medical model created in Blender. It's laborious. Modeling takes time. Blender can create a virtual medical scenario, which Unity can synthesize. Then, the roaming module function of the virtual medical scenario is implemented using the predesigned code.

D. Virtual Reality Science Laboratory

The Virtual Reality Science Laboratory general lab is shown in Fig. 2, which is divided into five sections that contain 3D objects, videos, and infographics. Fig. 3 shows the Cell and Bacteria section room, in which students can learn about the labeling of plant and fungal cells, as well as important notes and descriptions of animal, plant, and fungus cells. The Cancer and Inflammation Section room in Fig. 4, is specialized to cancer, inflammation, and tumors. This room has three-dimensional objects, videos, and a discussion of inflammation, tumor, and cancer stages. Fig. 5, shows the Human Vein and Skeleton Section labeled for a better understanding of human anatomy in general. While in Fig. 6, students can learn about tumor genesis from the 3D infographics poster. Lastly, as shown in Fig. 7, the Pathology Section will let users roam and have brief information about the pathology lab process through videos, also some 3D objects of laboratory tools, as well as sample viewing through a virtual microscope.

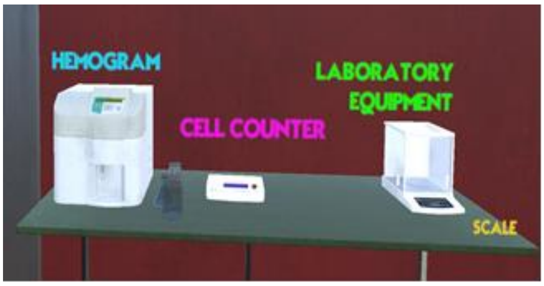

Fig. 2. General view of VR science lab.

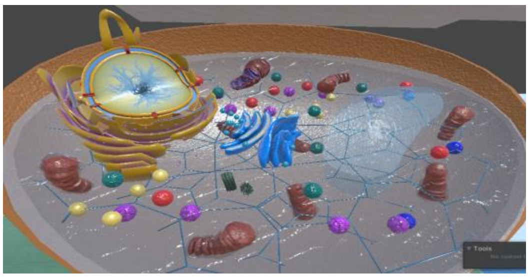
Fig. 3. Cell and bacteria section.

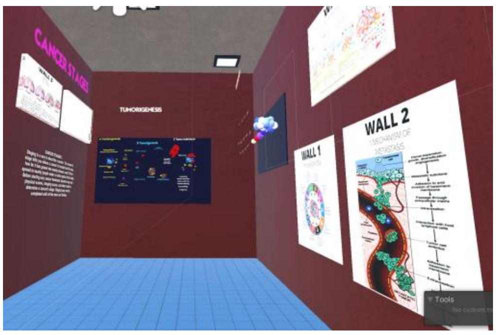

Fig. 4. Cancer and inflammation section.

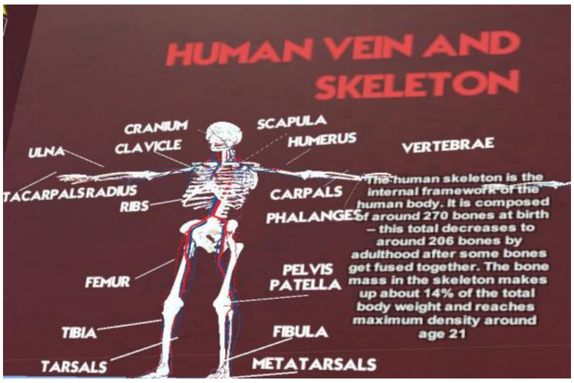

Fig. 5. Human vein and skeleton section.

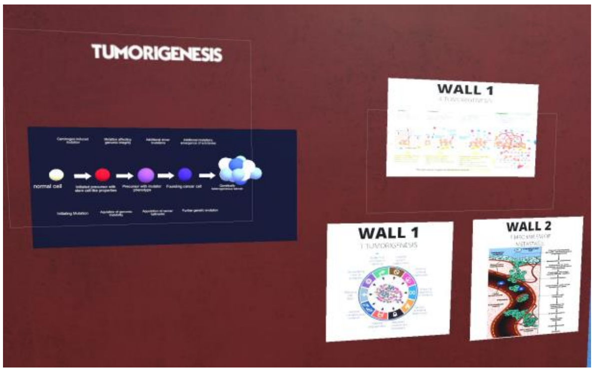

Fig. 6. Infographic of tumor genesis.

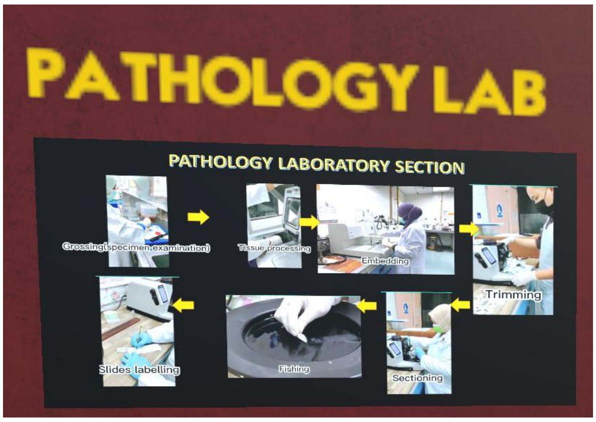

Fig. 7. Pathology section.

IV. Research Methodology

A. Research Design

This study uses a descriptive quantitative methodology to address the research topics. As research instruments, a Google form, a pre-posttest, and open-ended questions are used to obtain students' voluntary participation in the study.

B. Population and Sampling

In this study, we evaluate participants' level of experience in using Virtual Reality Science Laboratory and their presence experience towards application while studying sciences. The study was conducted by distributing a set of questions to two different groups of 37 science students. Group 1, which is 20 students will learn about science through 2D videos while Group 2 consists of 17 students who will experience learning science through Virtual Reality Science Laboratory. After each of the sessions, a set of questions will be given to both groups.

C. Instrument

The instrument used for collecting data for this research is an online questionnaire, chosen as it is a simple and inexpensive method. The questionnaire consists of two parts: Part A and B. Part A of the survey collects data on respondents' background, which is name, student number and course. Part B of the survey asks respondents six questions (3 Questions for each group) about their presences experiences while learning on 2D video and virtual reality science laboratory, and they are asked to rate their answers based on a Likert scale that ranges from strongly disagree to strongly agree. Table I displays the questionnaire structure.

TABLE I: Students' Feedback—Questionnaire Part B (Likert Scale)

Questions	
Group 1 (Video)	1. The "Cell Structure and Function" video seems to help me to visualize the cell itself better 2. My experience learning with "Cell Structure and Function" video similar as learning in the actual classroom 3. The "Cell Structure and Function" video attracts my attention for learning about topics
Group 2 (Virtual Reality)	1. The virtual science laboratory seems real to me 2. The virtual science laboratory gave me the feeling of being there myself 3. My experience in the virtual science laboratory seemed as though I was there in the real world

V. Content of Result and Discussion

A. Content of Result

There are three outliers for this data collection. Therefore, the total collected is 37. Group 1 is 20, and group 2 is 17.

H_0: There is no significant Different between Group 1(Video) and Group 2(VR) in the median mark score.

A non-parametric test was carried out for the data that has not been distributed normally. A Mann-Whitney U Test was run to determine if there were differences in the mark score between Group 1(Video) and Group 2 (VR).

Distributions of the mark score was statistically significantly Different between Group 1 and Group 2, $U = 238.5$, $z = 2.141$, $p = 0.036$. The median for the mark score was statistically higher in Group 2 (93.3) than in Group 1(83.4). Therefore, the decision according to Table II Hypothesis test summary, is to reject the null Hypothesis. Table III shows the Independent-Samples Mann-White U Test summary, while Fig. 8 shows the distributions of the two group, lastly the Table IV shows the mean, standard deviation and median report. Group 2 (VR) outperformed Group 1 (Video) in mean and median scores. The standard deviation also measures score dispersion within each category. Group 1 had a greater standard deviation than Group 2, indicating more variation in scores. The mean score of both groups is 87.211, representing the average performance throughout all observations.

TABLE II: HYPOTHESIS TEST SUMMARY

Null Hypothesis	Test	Sig.	Decision
The distribution of Mark is the same across categories of Group.	Independent-Samples Mann-Whitney U Test	0.036[a]	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is 0.050.
a. Exact significance is displayed for this test.

TABLE III: INDEPENDENT-SAMPLES MANN-WHITNEY U TEST SUMMARY

Independent-Samples Mann-Whitney U Test Summary	
Total N	37
Mann-Whitney U	238.500
Wilcoxon W	391.500
Test Statistic	238.500
Standard Error	31.997
Standardized Test Statistic	2.141
Asymptotic Sig.(2-sided test)	0.032
Exact Sig.(2-sided test)	0.036

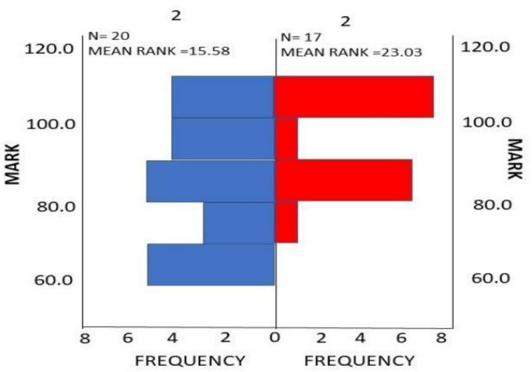

Fig. 8. Distributions of the two group—Independent-Samples Mann-Whitney U Test.

TABLE IV: THE MEAN, STD. DEVIATION AND MEDIAN REPORT

Group	Mean	N	Std. Deviation	Median
1	83.000	20	13.4060	83.350
2	92.165	17	8.5712	93.300
Total	87.211	37	12.2042	86.700

B. Discussion

Therefore, we can conclude that the group that learned with VR have higher levels of presence than group that learn science through 2D video. Overall, this finding supports the immersion principle in multimedia learning. Markasky also stated that, learning experience with higher immersion creates higher levels of presences [24]. The finding also supports the study that revealed the less learning immersive configuration such as video revealed a lower learning outcome, and it is less immersive and produces a lower level of virtual presence compared to high-end VR systems [26]. Finally, the main purpose of this research is to systematically use the immersion principle in multimedia learning to understand how virtual reality can affect the level of presence in science learning.

VI. CONCLUSION AND FUTURE WORK

This study are done to investigate the effectiveness of VR apps that apply the immersion principle in multimedia learning. We measure the level of presences during learning science by comparing two groups in learning. The result show that there is significantly level of presences of two group, and the group of VR perform better. This study can help educator and developers in designing effective VR tools to learn science. For future study, we suggest to include cognitive load as another variable to test with VR learning tools. Virtual reality is not a permanent solution, but it is a potent instructional tool for specialized learning applications. It has been explored in Medical Science due to its utility in Pathology education. The future of virtual reality hinges on its continued integration into curricula and technological advances that enable shared simulations of therapeutic encounters. The continuous development of education is indisputable, and technology plays a crucial role in bringing about positive changes that offer opportunities and strategies in creating an innovative and captivating learning environment for students in the present era [27].This will enable large-scale, location-independent delivery of high-quality interprofessional education and will transform the education of the future.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Effa and Regania conducted the research, Azlina and Regania analyzed the data; Lastly, Effa wrote the paper. All authors had approved the final version.

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