Examining Learning Enjoyment, Presence, and Achievement Using a Virtual Reality Pathology Laboratory by Applying the CAMIL Model in Health Education

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Abstract

It should come as no surprise that in the current digital world, schools are beginning to offer lessons that include technology in teaching and learning. Immersive technology is now being created and applied in several industries, most notably education. The majority of such tools are used in scientific and health education. This technology feels even more distinctive because of the beauty of the virtual environment that can interact with people in real time. However, there is still minimal research on the effectiveness of technology in teaching and learning the subject of pathology. Thus, this study investigated how well students learned, were present, and performed while utilizing virtual reality (VR) technology in learning about cells. This study employed a mixed-method sequential explanatory approach. The research tools included an open-ended inquiry and a questionnaire with a demographic form, as well as pre- and post-tests. The results showed that most students enjoyed learning biology using the VR laboratory, and their experience of enjoyment was at levels 1 (activity-specific) and 2 (situation-specific). Additionally, it was discovered that when students learn using VR technology, there is a high association between presence and satisfaction. Learning attainment outcomes are also improved. This indicates that there is an interaction between learning fun and success.

Introduction

Science and technology are causing the world to change quickly. Nowadays, teaching and learning are integrated with various tools, including videos, mobile applications, and immersive technologies like augmented (AR) and virtual reality (VR) (Kurniawan et al., 2019; Mokmin & Jamiat, 2021). Immersive technology combines virtual content with the real world so that users can naturally interact with blended reality. This technology takes advantage of the 360-degree space or sphere, allowing any user to see, feel, and view the content while also being able to see the items in any direction (Kumawat et al., 2020). Although there are many other ways to define immersion, in this context, it simply refers to the user's perception of themselves as a part of the virtual “world” (Pavithra, 2020). Due to its ability to engage various human senses, immersive technology has significant advantages for the education sector. The current educational multimedia systems typically only involve two of the five human senses by employing two communication channels (audio and visual), which limits the potential for learning efficiency. However, using immersive technology allows for the utilization of olfactory and haptic media (Pavithra A, 2020). There are five types of immersive technology, including 360, VR, AR, mixed reality (MR), and extended reality (XR) (Ables, 2020).

A computer-generated simulation of a three-dimensional VR environment allows users to interact with it using specialized tools such as VR headsets, haptic feedback devices, and motion controllers (Bachmann et al., 2018). The primary purpose of VR is to give users a more sensitive sense of touch, hearing, smell, and occasionally even taste (Rosenblum, 2000). VR is a general term for “near-reality,” which typically refers to a particular kind of reality imitation or emulation (Ables, 2020; Rosenblum, 2000). VR involves creating a virtual world or projection (interpolation) that appears as reality but is not actually there (Kumawat et al., 2020). It is a virtual experience that the users can view, hear, and interact with. VR usage
for learning can be investigated from various perspectives, including through its features, devices, instructional methods, and goals (Kurniawan et al., 2019).

VR has many uses, including training, education, entertainment, and therapeutic purposes (Ali et al., 2018). VR technology is used in the entertainment sector to provide interactive movies, virtual tours, and immersive gaming experiences (Billewar et al., 2022; Cruz-Neira et al., 2018). VR is also utilized in the training and treatment sectors to build simulations that let people practice skills in a secure and controlled environment, such as flight simulators for pilots (Labedan et al., 2021; Oh, 2020; Walters & Walton, 2021) or exposure therapy for those with phobias (Freitas et al., 2021). With the use of VR, educators also can recreate authentic situations like historical events (Argyriou et al., 2020) and medical procedures (Javaid & Haleem, 2020; Kan Yeung et al., 2021). Previous research has found that there are four primary purposes for using VR in learning (Kurniawan et al., 2019): a) enhancing the learning experience, b) motivating the participants, c) improving their achievement, and d) engaging them.

As part of the learning process, biology students are required to enter the pathology lab. Pathology is the discipline that focuses on disease mechanisms, which can be summed up as the study of suffering (pathos—suffering; logos—study). It includes diseases’ origin and subsequent natural histories (pathogenesis) (Mortimer & Lakhani, 2008), and some cells are usually studied in the pathology lab. Students gain knowledge of the structure and function of the human body’s cells, tissues, and organs as well as the technical components used in the pathology lab, such as tissue sample preparation for light microscopy (Donkin et al., 2019). However, there are some drawbacks experienced when studying in the pathology lab (Pengcheng et al., 2011): a) practice rounds are reduced due to the lack of an experimental venue; b) a dearth of specimens causes the lab’s inability to provide enough opportunities for students; c) students do not have enough time in the lab to review or observe specimens due to the limited number of practical classes; and d) due to the small number of experiment staff, many teachers are forced to supervise the experiment course throughout the day, which has an impact on the teaching effectiveness and the teacher’s health. Lastly, according to the researcher’s survey undertaken before conducting the research, students face difficulties remembering the structure of the cells.

In reference to the problems above, the constraints on teaching resources can be overcome by creating a virtual pathology laboratory using VR technology. To use this technology, students only need a few VR components, such as a wireless VR headset and a pair of controllers installed by the pathology lab. Thus, the shortage of instructors, scarcity of specimens, and lack of time to conduct experiments can be overcome using this technology. Students are free to explore and experiment with their specimens. This can be highly beneficial for expanding pathological experimental education and the experimental effect. This paper examines the impact of using a VR pathology laboratory on biology students’ learning achievement, enjoyment, and presence. It is hoped that this research can be useful as an idea and learning strategy for researchers and developers and generate new learning experiences for students. The research questions that will be explored are:

a. What are the results in terms of students’ enjoyment of using VR technology?
b. What level of enjoyment do students experience when learning using VR technology according to the results?
c. Is there any improvement in students’ learning achievement after using VR technology?
d. Is there any correlation between the presence and enjoyment of the students that learn using VR technology?

Virtual Reality

According to previous research, there are three categories of VR technology (Saeed et al., 2017). The first is an entirely immersive experience that immerses people in the most realistic setting imaginable, complete with sight and sound. VR headsets provide high-resolution data with a wide field of view. Large projectors and actual objects are integrated into the second category, which is termed semi-immersive. This kind of VR is typically utilized in instruction and training. The final one is a virtual experience that is not immersive, like playing a video game. Because it is more participatory and offers a complete VR learning experience, fully immersive technology is used in this study.

With the help of avatars, students can practice different tasks in VR without worrying about making mistakes. VR has been used to train nurses for clinical training, making documenting and tracking their performance simple (Shorey & Ng, 2021). By giving them the impression that they are physically present during training, VR technology allows students to study in an authentic environment. VR can also be utilized for educational tasks that are challenging to carry out in the real world, such as consulting fearful patients while treating psychiatric disorders. In another study, avatars in the virtual environment aided the patient in recognizing their moods (Li et al., 2020), enabling them to practice emotional responses. In addition to psychology, VR has helped identify and treat behavioral and drug addiction.

Virtual Reality in Biology Education

In terms of research on the use of VR technology in education (Kavanagh et al., 2017), of 99 selected works, as many as 51% were implemented in higher education, and up to 16 articles concentrated on the science field. VR was used the most in astronomy (five papers) followed by computer science (four papers). However, no analyses have been explicitly carried out in the area of biology. A recent publication (Radianti et al., 2020) showed that 38 related papers used VR technology in education, primarily in the field of engineering (24%), followed by computer science (10%) and astronomy (7%).

In comparison, biology only accounted for 5% of the total. The article also showed that VR for higher education is mainly used to teach procedural–practical knowledge (33%). The research above demonstrates that the use of VR technology in biology education is still difficult to find. Therefore, this study will be conducted in relation to biology classes in higher education.

Learning Enjoyment with VR

Hartley (2006) argued that, regarding the emotional component of learning enjoyment, the idea refers to how a subject feels, not what they think. People experience emotions daily, and crucially, they perceive
those emotions as happening to them rather than as something they choose (Ekman, 2003). During the learning process, the teacher can create joyful feelings in their students, which creates enjoyment and satisfaction. Which one, though, comes from positive emotions? According to Makransky and Mayer (2022), immersive learning experiences can improve learning over time. Immersion affects presence, which impacts enjoyment, which directly influences the immediate post-test result. Furthermore, Cheng and Tsai (2020) established that the students’ immersive enjoyment and attention experiences significantly moderated their immersive VR learning.

According to Ekman’s studies (Ekman, 2003), there are many enjoyable feelings, and it can occasionally be challenging to predict when and which one will occur. Social connections can be used to characterize learning enjoyment as a pleasant experience. Goodenow (1992) suggested that satisfaction and belonging go hand in hand. Figure 1 below describes four generality levels defined by the hierarchical model (L1 to L4, where L1 is the level with the lowest degree of generality) (Goetz et al., 2006). Each level has a trait feeling linked to it.

Figure 1 above presents a hierarchical model of the experience of enjoyment, where each level describes a type of experience of enjoyment. Starting from the lowest, which is L1, this concept presupposes that pupils would feel pleasure from engaging in activities relevant to their environment (level of generalization L1). “I enjoy using different strategies when I am studying” is a level L1 sentence that expresses enjoyment. Individual dispositions to respond to certain events within an academic context with a specific level of satisfaction are defined as situation-specific experiences of enjoyment (level of generalization L2). Statements like “I look forward to learning” or “I like the classes” reflect these situational satisfaction experiences. Learning, teaching, tests, and events outside the classroom are the categories used to classify enjoyment-related circumstances that occur in a school context (e.g., school outings or sports competitions).

On the next level, this model infers that, under the assumption of reciprocal causation, context-specific sensations of delight may both be a cause and a result of life enjoyment (level of generalization L3). Individual preferences in responding to environments, such as school, family, and peers, with a certain level of enjoyment are known as context-specific experiences of enjoyment. This model also includes enjoyment-related experiences from autonomous academic tasks in addition to these social contexts. “I enjoy going to school,” “I enjoy being with my family,” “I appreciate being around my friends,” and “I prefer being alone” are all context-specific expressions of enjoyment. The top of the hierarchical paradigm is occupied by the enjoyment of life, which is the most broadly applicable level of enjoyment (level of generalization L4). A person’s generalized inclination to enjoy life is called their enjoyment of life (e.g., “On the whole, I love my life”; compare this to highly generalized self-esteem statements like “On the whole, I am content with myself,” according to Rosenberg, 1965). In this study, enjoyment is one of the variables that will be examined.

**Presence in VR**
There are many definitions of presence, according to experts. A frequent definition of presence is the feeling of “being there” in a virtual world (Berki, 2019; Skarbez et al., 2017). This experience of “being there” can be defined as how real or natural the environment feels and whether the person experiencing it believes they are present in the location that is being shown. In other words, presence describes the extent to which a person perceives themselves as “there” in the virtual environment, despite being aware that they are not physically present. The depth of immersion corresponds to the level of presence experienced in a virtual environment (Bohil et al., 2014). In this view, the concept of presence is different from that of immersion, which refers to the capabilities of VR technology, in general, to isolate the user from the outside world from an objective standpoint (Moghimi et al., 2016). To increase the impression of immersion and realism in the virtual environment, presence is a crucial component of VR (Riches et al., 2019; Skarbez et al., 2017).

There are several studies regarding the presence of the use of virtual technology in education, including that conducted by Dawley and Dede (2014), which found that the usage of virtual reality simulation (VRS) among nursing students is supported by situational learning theory, which confirms that VRS can offer different environments for learning situated through a variety of virtual contexts that give the user a sense of presence or “being there” and thus the ability to learn in contexts that make sense and are distinctive. In another work, Kizilcec et al. (2017) discovered that students who had a strong sense of presence in a virtual environment while learning a physics subject made noticeably more significant learning gains than those who felt a weaker sense of presence. In this research, the technology used is VR, and the presence of the user is examined when using this technology. So, in this evaluation, presence is used as a variable in addition to enjoyment and learning achievement.

The Cognitive Affective Model of Immersive Learning (CAMIL)

The term “virtual reality” (VR) refers to a complex media system that includes both a technological setup for sensory immersion and a method of advanced content representation. VR can emulate or imitate actual and made-up worlds (Mikropoulos & Natsis, 2011). VR can be accessed through various displays, including a desktop computer, a head-mounted display (HMD), or an autonomous virtual environment like a cave (Buttussi & Chittaro, 2018). The Cognitive Affective Model of Immersive Learning (CAMIL) predicts that immersive media will enhance learning more than less immersive media. According to research, immersive VR refers to VR using an HMD (Makransky & Petersen, 2021). Using the multimedia design principle improves the efficiency of the immersive virtual learning environment (Makransky & Petersen, 2021). How much a virtual environment provides visual, aural, and haptic cues, as opposed to the real world, defines immersive learning. Motivation, curiosity, and multimedia learning are the foundations of this philosophy. Effective teaching strategies in virtual environments can enhance learning (Makransky & Mayer, 2022).

Research Methodology
Research Design

This study was a mixed-method research design that used a sequential explanatory approach. In this design, the researcher first collects quantitative data, analyzes it, and then collects qualitative data to explain the quantitative results. Students were asked to voluntarily participate in this study using pre- and post-tests and open-ended questions as the research instruments through Google Forms. Research questions 1 to 3 were analyzed using descriptive analysis, and the last one was assessed with the inferential statistic using Kendall’s tau-b assumptions. Kendall’s tau-b correlation coefficient is a nonparametric indicator of the strength and direction of a relationship between two variables assessed on at least an ordinal scale (Laerd Statistics, 2018). When data fail one or more of the assumptions of this test, it is regarded as a nonparametric alternative to Pearson's product-moment correlation. Kendall’s tau-b (τb) correlation coefficient was also used because the amount of data was not too much. According to (Laerd Statistics, 2018), it is also helpful as an alternative to the nonparametric Spearman rank-order correlation coefficient (especially when researchers have a small sample size with many tied ranks). Lastly, the open-ended question was evaluated using thematic analysis to support the findings from other research questions.

Population and Sampling

The population in this study was undergraduate students majoring in biology at one of the public universities in Malaysia. When selecting the sample, first-year biology students were chosen through random sampling; only 20 students turned out for data collection.

<table>
<thead>
<tr>
<th>Eligible criteria</th>
<th>Ineligible criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-year university students</td>
<td>3rd-semester students and above</td>
</tr>
<tr>
<td>Biology students, or</td>
<td>Have an issue with using HMD</td>
</tr>
<tr>
<td>Students who have previous knowledge about prokaryotic and eukaryotic cells</td>
<td>Have a physical issue</td>
</tr>
<tr>
<td>Have no issue with HMD</td>
<td>Not able to attend the VR lab physically</td>
</tr>
</tbody>
</table>

The table above shows the sample criteria for participants selected to contribute to this study. As for the exception for students who were not majoring in biology, if they had studied prokaryotic and eukaryotic cells before, we prioritized students who had no issues with HMD and could physically attend the VR lab to carry out this research.

Research Procedure
The procedure in this study started with the poster distribution, carried out one week before this study. The students willing to participate in the research completed the registration via Google Forms. Then the students were invited and required to attend the VR lab so the research could be conducted. After the students gathered in the VR lab, they completed a pre-test by answering questions through Google Forms. Next, the students were given 30 minutes to study and explore the pathology lab using VR. Lastly, after the students finished the intervention, they returned to fill out the post-test in Google Forms.

There are several rooms in the pathology lab, including the cells counter or room. The cells counter explains specific parts of the cells. The cells are shown as 3D objects with a label on each part. Students can walk inside the cells counter and explore all the cells inside.

**Instrument Development**

This research used four instruments: a demographic form, pre-test, post-test questionnaire, and open-ended questions that an expert had validated. The primary data were obtained from the pre- and post-test results and supported by information from the demographic form and open-ended questions. The pre- and post-test questions were analyzed using Excel and the open-ended questions with thematic analysis.

a. Demographic form

The demographic form contained student data, which helped us learn about their background to support the results of this study.

b. Pre-test

The pre-test contained general knowledge questions about prokaryotic and eukaryotic cells. These were in the form of drop-down and multiple-choice questions taken from the biology learning module with the cell and structure sub-topics. It focused on prokaryotic and eukaryotic cell material, as seen in the image above. This question was given to find out the students’ prior knowledge before carrying out an intervention using VR technology.

c. Post-test

The post-test questions were given after the students learned to use the VR tool. The questions presented were similar to the pre-test ones, but there were also additional questions about learning experiences, including learning enjoyment. The learning enjoyment questions were adapted from previous research (Makransky & Mayer, 2022). Below is an example of learning enjoyment using a Likert scale.

d. Open-ended questions

At the end of the session, students were asked to fill in open-ended questions in the form of paragraphs, and students were able to share their opinions and experiences of using VR. The questions were given as shown below.

**Results**
Demographic Form

Before students completed the pre-test, they filled in the demographic form to provide their background information in more detail. According to the results of the data collection, there were a total of 20 students who participated in this study, 15 of whom were female, and five of whom were male. As can be seen in Fig. 4 below, the area of study of all participants included biology, with 75% (15 participants), 10% entomology and parasitology (two participants), and biology in education (1 participant), translation with interpretation (one participant), and computer science (one participant).

Research Question 1

In reference to the first research question: “what are the results regarding students’ enjoyment of using VR technology?” the results from the questionnaire regarding student learning enjoyment when studying prokaryotic and eucaryotic cells using the VR pathology lab are shown in Fig. 5 below.

The results from the first question regarding enjoyment can be seen in the picture above. It shows that as many as 75% of students (15 participants) stated that they strongly agreed that they liked learning science through VR, 10% of students agreed (two participants), 5% said they disagreed (one participant), and the rest strongly disagreed (two participants).

Figure 6 above depicts the answers to the second question on the questionnaire regarding the enjoyment for students when studying biology using VR technology. The results show that 70% (14 participants) of students strongly agreed that it is fun for them to use VR to learn about science subjects, while 15% (three participants) agreed, 5% (one participant) disagreed, and 10% (two participants) strongly disagreed with that statement.

After cross-checking with the answers in the questionnaire to the open-ended questions for students who answered strongly disagree (S10 and S11), positive results were found. Student S10 said, “Yes, because it gives a clearer picture about what I learn,“ and student S11 stated, “Yes. It was more fun to integrate technology into learning sciences.” It can be concluded that both students had good experiences in their enjoyment. In this case, there is a discrepancy in the answers between the Likert scale questions and the open-ended questions for both students. Then the student who answered disagree (S16) noted that he did not enjoy learning to use VR because he was not familiar with the existing controller, so it confused him, and the 360\(^0\) visualization provided by VR made him distracted because when he moved a little, he could see another view of the VR. “I do not think I enjoy the learning session in VR because even though it gives a specific structure of the organelles, it moves around too much, and the control is quite confusing to use. Hence, it quite bothered me to learn the information provided in the VR,” he said.

On the other hand, two students (S2, S4) agreed that using VR helps them visualize the material so that it helps them remember the components of the cell easily, and the learning atmosphere feels more natural. Lastly, as many as 15 students strongly agreed that they enjoy learning using VR. There are four themes created from the answers of these students: a) VR helps them to visualize the learning material, b) VR
creates an enjoyable learning environment, c) VR provides a new learning experience for students, and d) the views inside the VR (the virtual environment) are excellent.

**Research Question 2**

Research question 2 assessed students’ levels of enjoyment in learning using VR technology based on the hierarchical model of the experience of enjoyment by Goetz et al. (2006). The five themes identified from the answers to the open-ended questions regarding the students’ enjoyment, which are described in the results of research question 1 above, can be grouped into the levels in the table below.

<table>
<thead>
<tr>
<th>Level of experiences of enjoyment</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 – Activity-specific experiences of enjoyment</td>
<td>Helps visualize clearly</td>
</tr>
<tr>
<td></td>
<td>New learning experience</td>
</tr>
<tr>
<td></td>
<td>Views</td>
</tr>
<tr>
<td>L2 – Situation-specific experiences of enjoyment</td>
<td>Enjoyable learning</td>
</tr>
<tr>
<td></td>
<td>Feels real</td>
</tr>
</tbody>
</table>

In relation to the results above, we can refer to Fig. 1, which explains that there are four levels of enjoyment, starting from the lowest level, L1, to L4. We can see that the levels of experiences of enjoyment of the students when learning cells using VR pathology laboratory were L1 and L2 based on the thematic analysis of the open-ended questions. L1 is based on the belief that students would like to participate in activities related to their surroundings, and the L2 is the individual propensity to react to various academic situations with a particular degree of delight, termed the situation-specific experience of enjoyment. The details of the results are show in Fig. 7 below.

The first was L1, involving “activity-specific experiences of enjoyment.” At this level, there were a total of 15 participants who specifically indicated that the experience they felt referred more to the new activities or learning strategy they undertook by learning biology using VR. Four participants were at the L2 level, representing “situation-specific experiences of enjoyment.” This was shown from the statements given, which implied they were comfortable in learning situations incorporating the virtual world inside VR technology.

**Research Question 3**

The third research question aimed to determine how students performed on the test after learning with VR compared to previous learning before VR technology (learning achievement). The results of the data analysis show that of all the participants, 70% had an improvement in their post-test, and the other 30% had no improvement because, on the pre-test, their scores reached the maximum score, as in their post-test. None of them experienced a decrease in post-test scores. The figure below illustrates the students’
learning performance according to the results of the pre- and post-tests, which are grouped based on their area of study.

We can see that 65% (13 students) have improved in their learning; eight were biology students, two were entomology and parasitology students, and the rest were one student in each area of study. The remaining 35% (seven students), who were all biology students, showed no improvement in their learning. This result was due to their high prior knowledge. They had already achieved the maximum score when they answered the pre-test questions. So, when looking at the post-test results, there is no visible improvement.

Research Question 4

The last research question aims to assess the correlation between the presence and enjoyment of the students learning using VR technology. The results are shown in the table below.

<table>
<thead>
<tr>
<th>Presence</th>
<th>Enjoyment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kendall’s tau-b</td>
<td>Kendall’s tau-b</td>
</tr>
<tr>
<td>Presence</td>
<td>Correlation Coefficient</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Enjoyment</td>
<td>Correlation Coefficient</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
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</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

Table 3 above shows that Kendall’s tau-b correlation was run to determine the relationship between presence and enjoyment amongst the 20 participants. There was a strong, positive association between presence and enjoyment, which was statistically significant, $\tau_b = .778, p = .000$.

Discussion

In line with the research question, these findings show positive results for the use of VR in learning biology on students’ enjoyment. Students feel that VR has helped them visualize the learning material better and more clearly. This is in line with previous research, which found that using immersive technologies, such as VR, can help individuals better understand and visualize information (Tamayo et al., 2020). VR in learning also fosters positive emotions in students, and they feel fun, enjoyment, and satisfaction while learning. This is also reinforced by previous research (Allcoat & von Mühlener, 2018),
which found that VR significantly affects participants’ moods, with individuals’ overall positive feelings rising and their overall negative emotions falling.

The level of experience enjoyment based on the enjoyment hierarchy (Goetz et al., 2006) obtained from the use of VR in studying biology for undergraduate students shows that it is only at levels 1 and 2, with level 1 involving the activity-specific experience of enjoyment. So, the enjoyment students feel is more related to the experience of learning while using new things, in this case, VR technology, that they have never had before. The other is level 2, which indicates the situation-specific level of enjoyment, referring to the virtual world experience they can have when utilizing VR.

This study also found that most of the students had an improvement in their learning achievement. Students felt that using VR to learn the parts of the cells helped them to remember and visualize them clearly because of the 3D objects and labels on each part of the cells. According to previous research, this is closely related to students’ enjoyment. Enjoyment has been linked to improved student learning achievement (Goetz et al., 2006; Valiente et al., 2012). So, if students enjoy learning, there will be an improvement in their learning achievement. This implies that VR headsets may enhance learning (Allcoat & von Mühlenen, 2018).

Lastly, this study also found a strong positive correlation between enjoyment and presence in students when learning about biology using a VR laboratory lab. This is because the greater the accuracy the students perceive in the virtual world, the more they enjoy being in it. According to Kim et al. (2021), enjoyment is included in one of the effects of presence, and this shows that if students enjoy it, they already feel a good presence in their learning, which is why they can derive pleasure from it.

**Limitations And Suggestions**

There were several limitations involved in conducting this research. The first was the fact that the participants were an uneven number of students from several areas of study, which has resulted in slightly ambiguous data. Further research should focus on only one field of study. The second was the small number of students who participated; if this analysis had involved more participants, the resulting data would likely be better. This research was only conducted for a short time. Future investigations might be carried out over a longer time to obtain a clearer picture and more discernable learning outcomes. In addition, the high prior knowledge of some students caused any learning achievement to be invisible in their test results. Lastly, in future studies, researchers or developers can improve the VR environment by making it more interactive by allowing the user to interact with the 3D objects in the same way that students can hold and move 3D objects around.

**Conclusions**

VR is one of the immersive technologies that has become widely used in education in the current era. VR has also been implemented in various areas of education, one of which is biology. This study aimed to
examine the enjoyment of students during their learning experience using VR and assess the results of their learning performance and whether there is a change after learning to use VR. The results of this study indicate a positive impact on students’ enjoyment when studying biology using a new learning strategy, VR technology. Of the students, 75% strongly agreed that they like to learn about science subjects through VR, and 70% strongly agreed that using VR to learn about science subjects is fun. In terms of the level of enjoyment felt by the students, 72% achieved level 1, which focuses on activity-specific experiences of enjoyment when discovering a new way of learning by using VR, and 28% level 2, which refers to situation-specific experiences of enjoyment, in which students enjoy and are impressed with the virtual world in the form of a pathology laboratory provided by VR technology.

There is also an increase in the student learning performance of as much as 77% of the entire sample. Meanwhile, 23% of the students achieved maximum scores on the pre- and post-tests, so they did not see an increase in their test results. Overall, using VR in biology learning positively impacts students, with a high sense of enjoyment found in the entire sample. There is also an improvement in their learning. Learning achievement shows an engagement between learning improvement and students’ learning enjoyment. When students enjoy their learning, it improves their learning achievement. There is also a correlation between enjoyment and presence when using VR in learning. This research shows that students accept and feel excited about using new technology (VR) in their learning process. This could be an incentive for lecturers and teachers to start integrating this technology into their classes. It is hoped that these findings can inspire lecturers, researchers, and developers to explore this field more deeply.

**Declarations**

**Competing interests**

No competing interest

**Availability of supporting data**

There is no supporting data

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**Ethics approval statement**

This study has been cleared by the ethics committee
References


**Figures**
Figure 1

The hierarchical model of the experience of enjoyment. There are four levels of experience enjoyment, each with its own factors. Source: Goetz et al. (2006)
Figure 4

Students’ area of study. This figure shows the details of students’ areas of study, which were not from the same field as mentioned before; students who had previous knowledge of cells were also able to join the research.
Figure 7

Students’ level of experiences of enjoyment using VR. From the analysis results in the table above, it was found that of the five themes that had been previously outlined, two levels of experiences of enjoyment matched the students’ learning experiences.