Learning Biology through Virtual Reality Instructional Approach: Effects on Conceptual Understanding, Performance, and Perceived Usefulness

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ABSTRACT

Incorporating virtual reality (VR) tools into the pedagogical instructions has been found to facilitate abstract conceptualization, thereby enhancing learners' understanding of complex concepts. However, the use of VR tools in biology instruction have not been extensively explored, primarily due to its accessibility and the perception that VR devices are perceived as gaming tools rather than learning mediums. This study investigated the effect of VR tools on students' conceptual understanding, performance, and perceived usefulness. To gauge the effect of VRI approach on the students' conceptual understanding, data from pre- and post-diagnostic tests were collected and analyzed using the Wilcoxon signed- rank test in SPSS, the effect size and item analysis was also performed. The effect of the VRI approach on students' performance was evaluated through the summative assessments (SA), and descriptive analysis of the SA scores was conducted using SPSS. Regarding the students' perceived usefulness of VR, selected students were interviewed, and their responses were analyzed using thematic analysis. The findings revealed that VRI approach improved student's conceptual understanding and performance. Additionally, students perceived that VR tools enhance their visualization of concepts and created an immersive experience. However, the complex features of the controllers and their limited availability hindered students' learning. Overall, the study suggests that integrating VR tools into pedagogical instruction fosters an engaging, interactive learning environment and improve students' performance.

Keywords: Virtual Reality Instructional Approach, Virtual Reality, Virtual Simulation, Perception, Conceptual Understanding

INTRODUCTION

The emergence of the digital world paved the way for the development and production of various electronic devices that have spiked interest, enhanced communication, and facilitated worldwide virtual connectivity. The usefulness and effectiveness of technology in facilitating teaching and learning process were recognized when face-to-face classes shifted to online classes due to the global pandemic (Basar et al., 2021). This shift highlighted the significant role of technology in education, making it essential to understand how it influences various aspects of student learning. According to Carsten et al., (2021), the integration of technology in classroom instruction increases students' interest in learning. The various software applications provide more opportunities for students to enhance and engage in their learning at varying levels. Furthermore, technology allows students to be self-sufficient learners beyond the four walls of the classroom. Aside from enhancing the learning and teaching environment, the variety of technology helps

students achieve the best learning outcomes by allowing them to choose and utilize the most appropriate tools for their needs. Berrocoso et al., (2022), found that incorporation of technologies in classroom instructions improves students' academic performance, and Chauhan (2017) argued that technology effectively allows students to use deep learning approaches such as higher-order thinking and reflective learning. Similarly, Mahawan and Celedonio (2023) demonstrated that educational technology in lesson plans can enriches students' understanding of concept and mastery of learning competencies. Banitt et al., (2013) also found that technology- integrated lessons led to a 5% to 10% increase in student engagement. These lessons resulted in enhanced enjoyment and enthusiasm of students compared to conventional education. Furthermore, Hamilton - Hankins (2017) emphasized that integration of technological applications and resources in the planning and implementation of learning materials is a possible strategy that teachers can employ to connect to the needs of diverse learners. Therefore, making the learning experiences of students more meaningful, relevant, and interactive. This highlights the needs for educators to equip students with the technological and informational skills required to thrive in a technology- driven world and succeed in the 21st – century classroom.

While technology has transformed education in various ways, one promising pedagogical tool that may promote active learning, especially in complex subjects like science, is the use of simulation tools such as virtual reality (VR). Simulation involves the process immersing oneself in an actual experience, therefore, learners are actively involved in practical, dynamic, complex, and evaluative context (Cano et al., 2022). Talan (2021) emphasized that simulations enhance learning by increasing visuality and retention through the animation of abstract concepts by engaging students' sensory organs. Contrary to traditional settings, a virtual environment provides users with an immersive experience, enhancing their engagement with the content by allowing objects and scenes to appear in real- time and be explored in 360 degrees. This immersive environment is perceived through the use of a VR headset and helmet, which provide video to each eye, making the visual depth. In addition, VR systems include head and body tracking to enhance the user's interaction with the virtual world they are exploring. However, the use of VR tools in biology education has not been extensively explored, primarily due to challenges related to accessibility and the perception that VR devices are primarily gaming tools rather than educational mediums. While there has been growing interest in the use of VR across various fields, its specific application in biology, particularly for enhancing students' conceptual understanding, academic performance, and perceived usefulness, remains under-researched. This study aims to address this gap by investigating the effects of VR tools on students' learning outcomes in biology, focusing on their effect on conceptual understanding, performance, and perceived usefulness.

REVIEW OF RELATED LITERATURE

Virtual Reality Tool in Education

According to the study of Shim et al., (2014), VR technology can stimulate the multi-sensory organs of students, eliciting student participation and interest in learning activities. VR technology increases students' engagement by allowing them to interact with the scene, objects, or other users. VR technology also allows laboratory experiments to be carried out safely and without expenses. Students are given an opportunity to carry out their learning at their own pace and comfort. Therefore, VR technology can be used to enhance, motivate, and stimulate students' understanding of complex biological concepts, particularly the concepts that have proven inappropriate and difficult by traditional learning methods. This claim was supported by Meredith et al., (2020), stating that VR technology was more interactive and engaging than the traditional way of learning about cells as it improved students' understanding, which may be attributed to their experience using VR. The immersive environment allows the user to engage with the material, with their body, tapping into the concept of embodied learning. Embodied learning is a pedagogical approach that highlight multisensory engagement, allowing deeper learning to occur. The use of VR in education has opened the possibility of representing abstract concepts and virtually manipulating them, providing a suitable platform for understanding concepts and their relationship with the physical world (Campos et al., 2022).

Biology as a Heavy Content Subject

According to the study of Shanah and Abulibdeh (2020), Biology is considered a difficult subject to understand due to its heavy and wide array of concepts which might discourage learners from studying this subject. In line with this, Ramnli et al., (2021) mentioned that genetics, body systems, and evolution are some of the biology topics that are too abstract. Abstract and heavy content subjects exhibit curriculum overload, adversely affecting students as it gives them difficulty grasping the content. These adverse reactions are coupled with frustrations, and feeling overwhelmed when textbooks are designed with high content and complex terminologies (Vgoot et al., 2018). Similarly, the negative perception elicited by curriculum overload inhibits meaningful learning and does not accommodate the needs of diverse learners. As a result, the students and teachers become demotivated and frustrated (Joshua, 2014).

Insufficient Learning Instructions

Limited resources in classroom makes students and teachers extremely distress which hinders them to reach their fullest potential (Maffea, 2020). The study of Edessa S. (2017), revealed that access of students to instructional materials, resources and learning facilities were very scarce and limited. This put heavy impacts on the skills and abilities of graduates to succeed in professional careers, which is one of the root cause why students experience difficulties in learning biology (Hadiprayitno et al., 2019). If the teacher's instructional approach is teacher- centered, uninteresting, and unengaging, the delivery of materials may be insufficient, the academic atmosphere may be unsupportive, thereby negatively affecting the student's motivation to learn. Furthermore, biology lessons mostly involve abstract ideas and principles. Therefore, teachers must provide real-life applications of the lessons to help students make meaning to what they are learning and prevent them from losing their motivation, and halt the development of negative attitudes towards learning biology concepts. The study of Hadiprayitno et al., (2019) also noted that there is not enough instructional time to cover all the topics and curriculum within the term. As a result, teachers tend to teach lessons in haste to cover all that needs to be taught for the day, which has a negative impact on how students learn biology. Students may not have opportunity to delve into details, ask questions, or engage in practical work.

Lack of Hands-On Learning and Interaction

Subramaniam (2013) stated that biology should be taught based on the current strategy that promotes meaningful and dynamic learning. This approach significantly influences student engagement in biology class as it helps them visualize what they are learning and make reference points for learning key terms and concepts, preventing them from breezing through a lecture. The study emphasizes that conceptualization of learning takes place when interactive and visual activities, such as the use of biology apparatus and models are incorporated into the instructional materials. Furthermore, biology teachers and content instructors must participate in professional development that upholds the current trends in biology teaching. Similarly, Menon et al., (2020) stated that teacher preparation programs should give opportunities for preservice teachers to experience the use of mobile technologies. Utilizing information and communication technologies will generate students' understanding and retention of lessons that can enhance science achievement (Wardyaningrum & Suyanto, 2019).

Implementation Theory

The virtual reality instructional (VRI) approach is supported by David Kolb's experiential learning theory model, which was published in 1984. This learning theory revolves around the concept of "learning by doing," stating that learning processes occur through experiences. Kolb emphasizes that abstract and complex concepts are applicable in various situations, enabling knowledge to be generated through transformational experience. This learning theory is categorized into two parts, the four-stage cycle and the learning styles. The four-stage cycle consists of stages that allow the learners to convert their experiences into knowledge. Figure 1 includes concrete learning, reflective observation, abstract conceptualization, and active experimentation, a cyclical process where learners can enter at any stage.

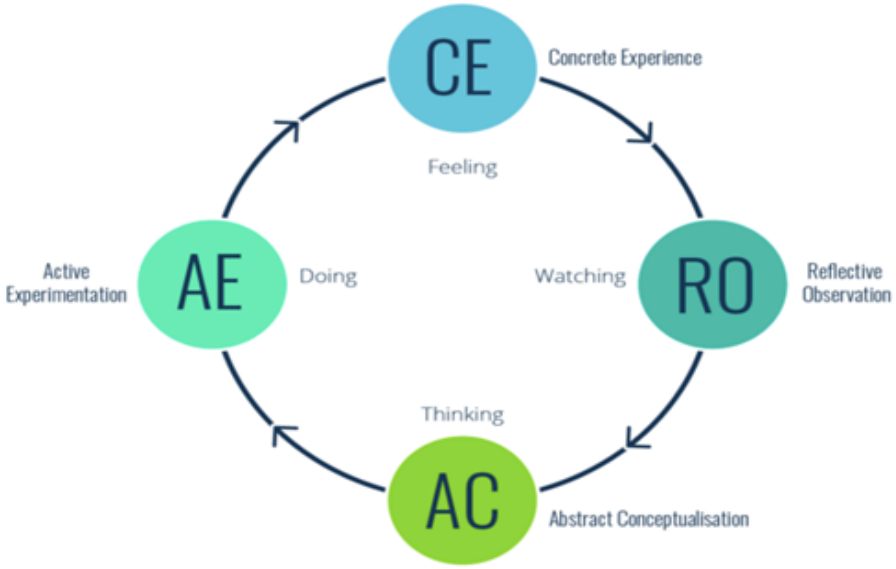

Figure 1. The Four- Stage Cycle of Experiential Theory (Kolb,1984)

Figure 1 shows that concrete experiences lie on the top, which signifies the starting point of the process. At this stage, the learners encounter a new venture or revisit an experience. After the learners engage in an experience, they will proceed to the next stage, the reflective observation. This stage allows the learners to reflect on the experiences they had obtained by asking questions or sharing the learning experiences with other learners. After this, the learners will move on to abstract conceptualization. This phase permits the learners to formulate new ideas or modify their thinking based on what they have experienced and reflected on. The last stage of the cycle is active experimentation, known as the testing stage where the learners apply their newly gain insight with new experiences or real- life situation. This stage is about taking the theories and concepts formed during the learning process and putting them into action, testing them in real-world situations. Then, the process begins again as new concrete experiences are encountered.

The experiential learning cycle is based on the idea that each learner has their own learning style, wherein each learner standout in a particular stage of experiential learning. For example, some learners will excel in concrete learning and reflective observation, while others will excel in abstract conceptualization and active experimentation. The different learning styles introduced by Kolb can be seen in figure 2.

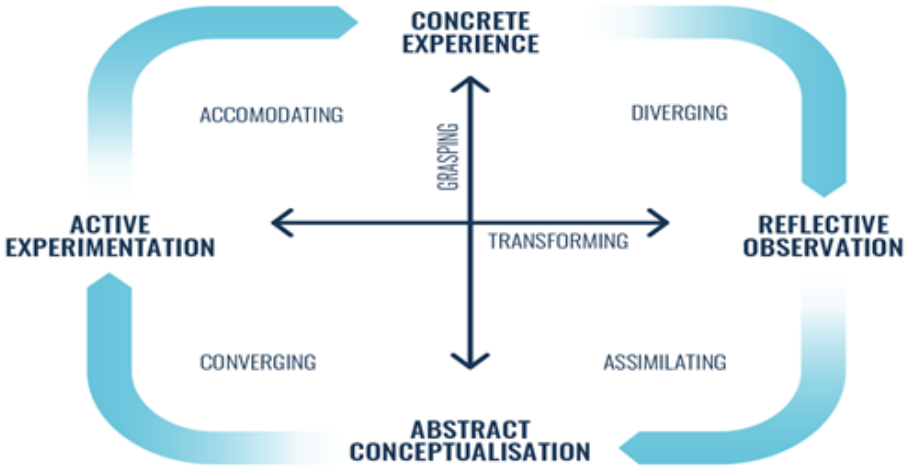

Figure 2. Learning Styles Based on the Experiential Learning Model (Kolb,1984)

Figure 2 shows the different learning styles that are based on the four- stages of the learning cycle. The diverging learning style pertains to learners that prefer watching instead of doing; they also prefer group activities. These types of learners solve problems through imagination and collecting information. Moreover, these learners are dominant in concrete learning and reflective observation. Another learning style highlighted by Kolb is Assimilating. Learning with assimilation as a preferred learning style focuses on abstract conceptualization, reflective observation, and tend to explore ideas using mathematical models. Converging learning styles are problem solvers learners. Learners with converging learning styles apply their learning to real-life situations or issues and prefer technical activities. These learners are gleaned on abstract conceptualization and active experimentation. Experimenting with new ideas is what they love to explore. Lastly, the accommodating learning styles that delves on practicality. Learners exemplifying this learning style are fond of encountering new challenges. Accommodating learners gleaned concrete learning and active experimentation when acquiring knowledge.

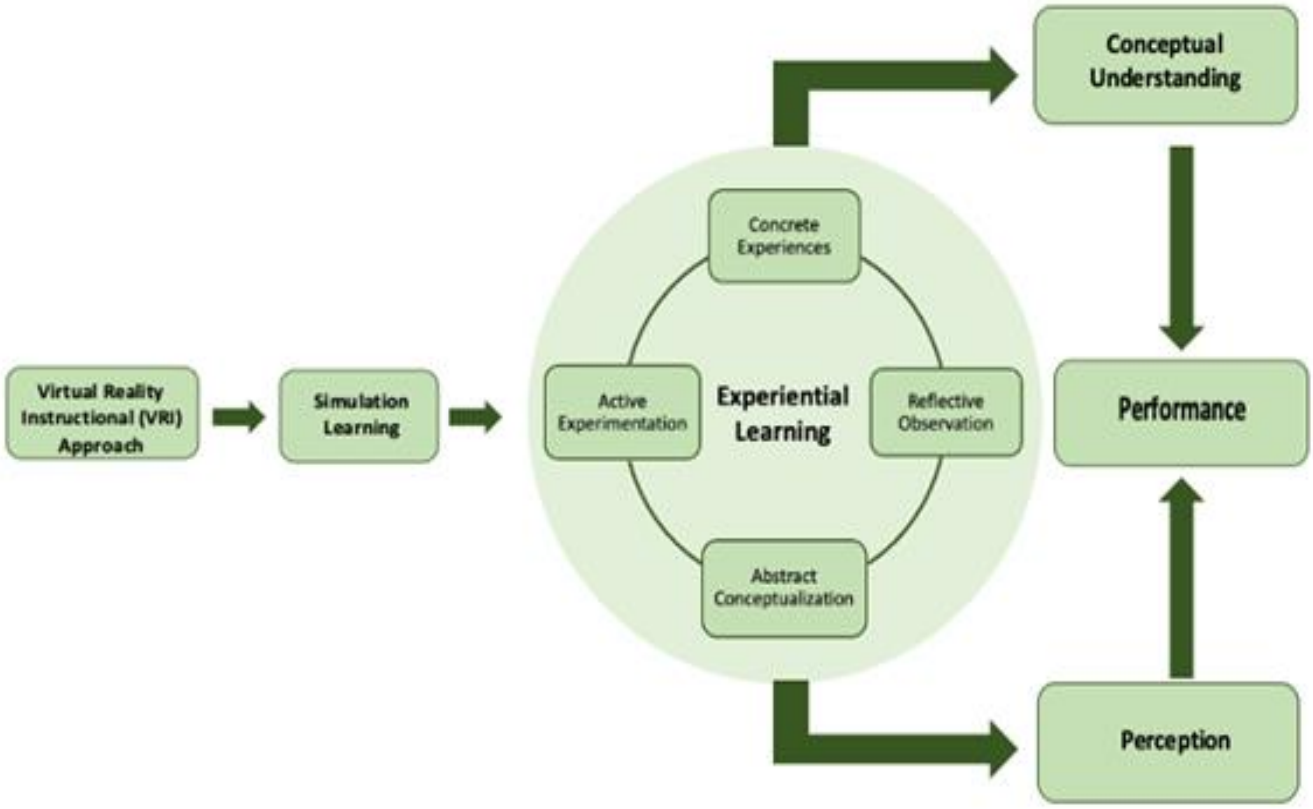

Figure 3: Implementation Theory (Author's Own Interpretation)

The VRI approach implemented in the study follows the implementation theory presented in figure 3. This approach provides simulation activities that engage the student's sensory organs, allowing them to visualize complex concepts with ease. Furthermore, simulation learning facilitates experiential learning, enabling students to undergo concrete experiences, reflective observation, abstract conceptualization, and active experimentation. These stages enhance students' ability to better conceptualize lessons and foster a positive perception of VR as a useful learning tool. As a result, students experience improved performance in assessments due to their deeper engagement and understanding.

Research Question

The main goal of this study is to come up with learning plans that incorporate VRI approach and determine its implications in the pedagogical aspects of learning Biology to improve my teaching practice. Specifically, this research endeavor would like to answer the following questions:

1. What is the level of students' prior conception in Cell Biology?

2. After learning Cell Biology using VRI approach, what are the students'
   2.1. conceptions about Cell Biology?
   2.2. performance in the summative tests?
3. How do the student's perceive the virtual reality as a tool in learning Cell Biology?

METHODOLOGY

This study is an action research that sought to address the challenges faced by the students in learning biology through implementing intervention that would cater the specific needs of the learners and improve their learning environment. This study employed a mixed-method design that requires researchers to collect and analyze quantitative and qualitative data in one study. The participants of this study are an intact of 33 grade 12 senior high school students who have selected STEM as their strand. Additionally, these students have General Biology 1 as their primary subjects in the first trimester.

Pre- Implementation

Designing of VRI Approach Lesson Plans

In designing the lesson plan, we followed the format prescribed by the institution. The lesson plan consists of six components. The fist component is the week number and the title of lesson for that week. This is followed by the learning targets, which consist of the learning objectives for each lesson. The third component is the essential questions and understanding. After this, is the assessment section, which includes a list of assessments that need to be accomplished by the students. The diagnostic tests, CCG worksheets, and SAs are included in this component. The assessment section is followed by the learning experiences, in this section, we described the instructional approach for each class meeting and how the VRI method will be implemented.

Designing of VR Instructional & Assessment Materials

The instructional materials and assessments that were administered during the implementation of VRI approach was the Concept check guide (CCG) worksheet and summative assessment (SA). We designed the CCG worksheet based on Kolb's experiential learning. In addition, the CCG worksheet is organized into four parts that is aligned to the phases of experiential learning. We've named the first part of the CCG worksheet as "Do it" since this is the part where the students will immerse themselves into the virtual environment. In this part the groups are also instructed to label each member as students A to D. Each member of the group will have a specific role or task to accomplish. The second part of the worksheet is the "Recall", we named it that way because the students is prompted to recall their virtual experience and note it on the blank provided. The third part is called "connect the dots", in this part the students will synthesize their experience in exploring the topic using the virtual reality tool. The last part of the CCG worksheet is the "apply it", in this part the students will apply the knowledge they have gain in using the VR tool in learning the topic. On the other hand, the SA was a pen-and-paper test consisting of 10 multiple-choice questions designed to assess the students' learning performance. The SA covers the lessons discussed using the VR tool.

Securing of VR Videos and Accessories

The Meta Quest 2 virtual reality headset was purchased via online shopping platforms. Metal Quest 2 headset consists of two controllers that enable the movements to be transported into the virtual reality environment. The headset has built-in speakers that provide cinematic 3D positional audio. Moreover, the display that is seen in the headset can be connected to the TV which enables other students to see what is happening in the virtual environment. The Meta Quest 2 headset was chosen because it is easy to set up and operate, it is compatible with a wide array of virtual reality simulations, and it provides an immersive experience to the students. On the other hand, the virtual reality simulation was purchased on the Xready Lab website, which is a 3D and VR learning tool platform that includes simulations and videos in biology.

Figure 4: VR Headset

Figure 5: VR Controller

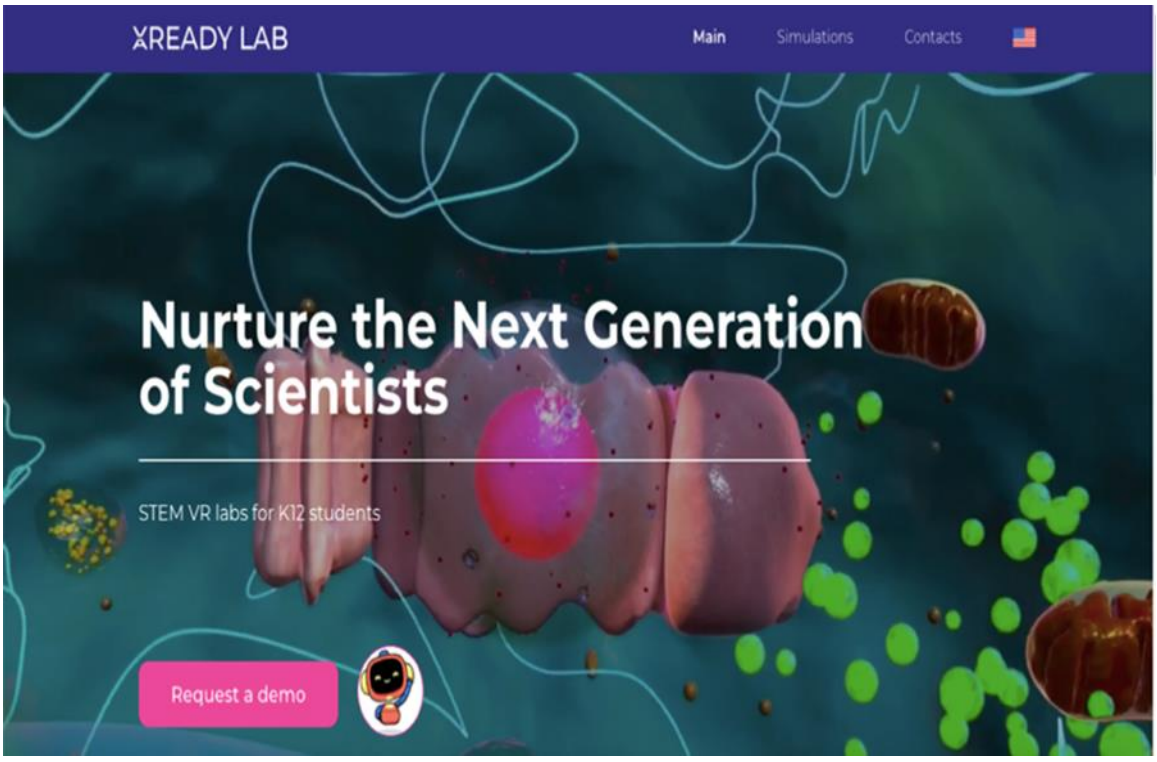

Figure 6: Screenshot of the Xready Lab Website

Orientation

Before the implementation of the study, an orientation was conducted for those students who agreed to participate and whose parents provided consent. The orientation started by discussing the overview of the study, followed by the explanation of the studies objectives, the student's involvement, and the assurances of confidentiality. During the orientation, we assured to the students that the gathered data will remain absolutely confidential and will be used for academic purposes only.

Pre- Diagnostic Test

The study started by examining the students level of conceptual understanding in cell biology topics, particularly the animal cell organelles, plant cell organelles, and cell division. This was done by administering the pre- diagnostic test onsite. The students were given 30 minutes to answer all the questions.

Implementation Proper

The implementation processes occurred during the first trimester of the school year 2023 - 2024. The intervention was implemented from September to the 1st week of October (5 weeks). Moreover, a VR implementation guidelines adapted from the MONASH University was followed to understand and mitigate the risks of the use of immersive technologies. The implementation process started with the usual classroom routine. After that, the VRI approach was introduced by giving an overview and explaining how the students will go about the virtual reality instructions. The topics covered by study was also presented to the students. See table 1 for the topics that was covered per week.

Table 1: Topics Covered for Each Week

Week	Topics
1	Animal Cell Organelles
2	Plant Cell Organelles
3 - 5	Cell Division

The virtual reality instruction began by grouping the class into five groups, each with four members. The members of each group sat together and labeled themselves as student A to D. After that, the concept check guide (CCG) worksheet was distributed. The teacher discussed and walked the students through the different parts of the CCG worksheet. Once this was done, the students were ready to do part 1 of the worksheet.

The first part of the worksheet pertains to the concrete observation phase of the experiential learning model. This part allows the members of each group to go through the virtual reality simulation independently, beginning with student A. All student A will accomplish the directions assigned to them by following the teacher's narration. Once student A completes her part, she will pass the headset and controller to student B. This process will be repeated until Student D. This setup was chosen to make the implementation process more organized, manageable and to have enough space for the students' movement as they go through the virtual reality simulation. Moreover, each students will be given 4 to 5 minutes to accomplish and explore their assigned task.

After completing part 1, the students proceeded to part 2, which pertains to the reflective observation phase of the experiential learning model. This part allowed the students to reflect on their experiences in learning the topic using virtual reality by answering the questions assigned to them in part 2. Once all the members have finished part 2, each member was given 1 minute per question to share their answer, while the other members took note of the important points.

After the students had completed part 2, they proceeded to part 3. Part 3, pertains to the abstract conceptualization phase of the experiential learning model. This part allows the students connect their

experiences to the topic or identify the significance of their experiences by answering the prompts in the worksheet. The students was given 10 minutes to accomplish this part. After accomplishing this part, the students are prompted to share their answers with their groupmates. Following the sharing, the teacher asked volunteers to share in plenum and discussed the key points shared by the students.

After the students had finished this part, they proceeded to part 4 of the worksheet. Part 4 is the last segment, pertaining to the active experimentation phase of the experiential learning model. This part allows the students to apply their learnings by answering the given questions in the worksheet. Furthermore, the students were given 15 minutes to answer all the questions. Once the students were able to answer all the questions, the teacher collected the worksheets and discussed the answers for each question. The same learning instructions and procedures was implemented in topic 2: plant cell organelles and topic 3: cell division.

Administration of Summative Assessment (SA)

The written SA's were administered by the teacher after every topic to assess the students' learning performance. Therefore, two SA were administered onsite. The students were given one hour to answer the SA.

Administration of Post- Diagnostic Test

A post-diagnostic test was administered onsite to determine the effect of the VRI approach on students' conceptual understanding in selected cell biology topics. The students were given 30 minutes to answer all the questions.

To gather the essential information for the pre- diagnostic test, the students' answers were checked, and the scores were recorded in a spreadsheet for data analysis. The data garnered from the pre- diagnostic test were used to determine the students' level of conceptual understanding in cell biology. On the other hand, the data from the post- diagnostic test was collected by also checking the students' answers and recording the scores in the spreadsheet. The data collected from the post- diagnostic test will shed light to the effect of virtual reality on the students' conceptual understanding.

To collect data about the effect of the VRI approach on the students' performance in biology, a SA was administered after every topic. The first SA covers animal and plant cell organelles, while the second focuses on cell division. The SAs were first validated by two experts in the field of biology to ensure that the questions were relevant and clear in covering the concept of interest. The answers of the students in the SAs were checked, and the scores were recorded in a spreadsheet as well.

An interview was conducted with selected STEM students to gather data about their perception of using virtual reality as a learning tool. The data collection process began by obtaining consent from the participants. The students who agreed to participate were interviewed onsite. While conducting the interview, the responses were noted using my laptop.

Post- Implementation

After the implementation of the post-diagnostic test, one- on- one interviews were conducted with selected STEM students. The selection process was done by analyzing the students' performance in the assessments. The top 5 performers and the bottom 5 performers were chosen to be interviewed. The students were provided with a consent form to confirm their willingness to participate in the interview. Before conducting the interviews with those who agreed to participate, we made sure to establish a rapport with the participants to encourage an open and honest responses. After this, we explained the process of the interview, then asked the prepared questions designed to assess their perception of using VR as a learning tool. The responses of the students from the interviews were thematically analyzed to uncover the main topics and themes that emerged in the participants' responses.

To determine the level of students' conceptual understanding in biology, the mean score in the pre-diagnostic test was calculated and analyzed using the levels of conceptual understanding interpretation found in Table 2.

Table 2: Level of Conceptual Understanding; The Author's own interpretation

Category	Mean Score Range	Level of Understanding
5	12.1 – 15.0	Excellent
4	9.1 – 12.0	Average
3	6.1 – 9.0	Below Average
2	3.1 – 6.0	Poor
1	0 – 3.0	Very Poor

The data presented in Table 2 shows the mean score range and its equivalent level of understanding remark. A mean score range of 0 to 3.0 is remarked as "very poor", this indicates that students do not have a deep comprehension of biology concepts. A mean range of 3.1 to 6.0 shows a "poor" understanding of biology concepts. This exemplifies that students find it challenging to comprehend biology concepts. A mean range of 6.1 to 9.0 is remarked as "below average". This signifies that individuals with below average conceptual understanding struggles to grasp biology concepts and principles. Their comprehension is superficial and incomplete that leads to gaps in their understanding of subject matter. On the other hand, a mean score range of 9.1 to 12.0 is remarked as "average". This shows that individuals demonstrate good understanding of relevant biology concepts. Lastly, a mean score range of 12.1 to 15.0 indicates an "excellent" level of conceptual understanding. This refers to individuals with great extent of understanding, proficiency, and mastery of biology concepts.

To gauge the effect of VRI approach on students' conceptual understanding, the results of the pre- and post-diagnostic tests were analyzed using a non- parametric test, specifically the Wilcoxon signed- rank test, which was conducted in SPSS. Additionally, the effect size of the pre- and post-diagnostic tests were determined. To further justify the data garnered from the Wilcoxon- signed rank test and effect size, an item analysis was performed. Finally, the data collected from the SAs were examined by calculating the average percentage and standard deviation of the scores.

RESULTS AND DISCUSSIONS

Level of Students' Conceptions in Cell Biology?

To examine the student's level of conceptual understanding in cell biology, particularly in the topics animal cell organelles, plant cell organelles, and cell division the result of the pre- diagnostic test were analyzed by calculating the mean score. The mean was analyzed by assessing the level of conceptual understanding. The interpretation table is seen in Table 3.

Table 3: Descriptive Statistics of the Diagnostic Tests and Summative Assessments

	No. of Items	Mean	Std. Deviation
Pre- Diagnostic Test	10	5.01	2.27
Post- Diagnostic Test	10	11.95	2.58
Summative Assessment 1	10	7.61	1.34
Summative Assessment 2	10	7.24	2.11

The data presented in Table 3 reveals that the mean score of the pre- diagnostic test of STEM students is 5.01, exemplifying a "poor level" of conceptual understanding. This signifies that students do not have an in-

depth understanding of the selected topics in cell biology. These results are supported by several studies that assessed the causes of students' low conceptual understanding in biology (Vgoot et al., 2018; Shanah & Abulibdeh, 2020; Ramnli et al., 2021).

The mean score garnered from the pre- diagnostic test was further supported by examining the percentage of students who answered each item in the pre- diagnostic test correctly. The item analysis is seen in Table 4.

Table 4. Percentage of Students who Answered the Items in Pre and Post- Diagnostic Test Correctly

Topic	Item	Percentage of Students	
		Pre- Diagnostic Test	Post- Diagnostic Test
Animal and Plant cell	1	79	100
	2	33	100
	3	61	91
	4	61	73
	10	45	52
	11	24	76
	12	30	70
	14	3	79
	15	15	30
Cell Division	5	18	67
	6	12	58
	7	27	67
	8	3	91
	9	24	79
	13	12	64

The data presented in Table 4 of pre- diagnostic test shows that majority of the students incorrectly answered the items related to cell organelles and cell division. Items 11, 14, and 15 related to animal and plant cells garnered the highest incorrect answer. 76 % of students find difficult to answer item 11 which requires students to identify the organelle in the given illustration. In item 14, 97% of students failed to answer it correctly. This item pertains to the functions of chloroplast a plant cell organelle. The last item related to animal and plant cell that garnered the most incorrect answer is item 15, consisting 85% of students who incorrectly answered. This item also pertains to the structure and function of the chloroplast.

On the other hand, items in the pre- diagnostic test that are related to cell division that consisted of highest incorrect answers are 6, 8, and 13. In item 6, 88% of students incorrectly answered it. This item focuses on the events that happen in a particular stage of mitotic cell division. While item 8, 97% failed to answer it correctly. In this item, the students are asked to identify the stage of mitosis exemplified by the given illustration. In item 13, 88% of students answered it incorrectly. This item also pertains on the events that happens in a particular stage of mitosis.

Upon further analyzation, the items that garnered the highest incorrect answers are related to the processes, functions, and structure of the said topics. The result shows that majority of the students has limited knowledge or low conceptual understanding about cells and cell division. Moreover, students have difficulty in answering items that requires them to analyze illustrations.

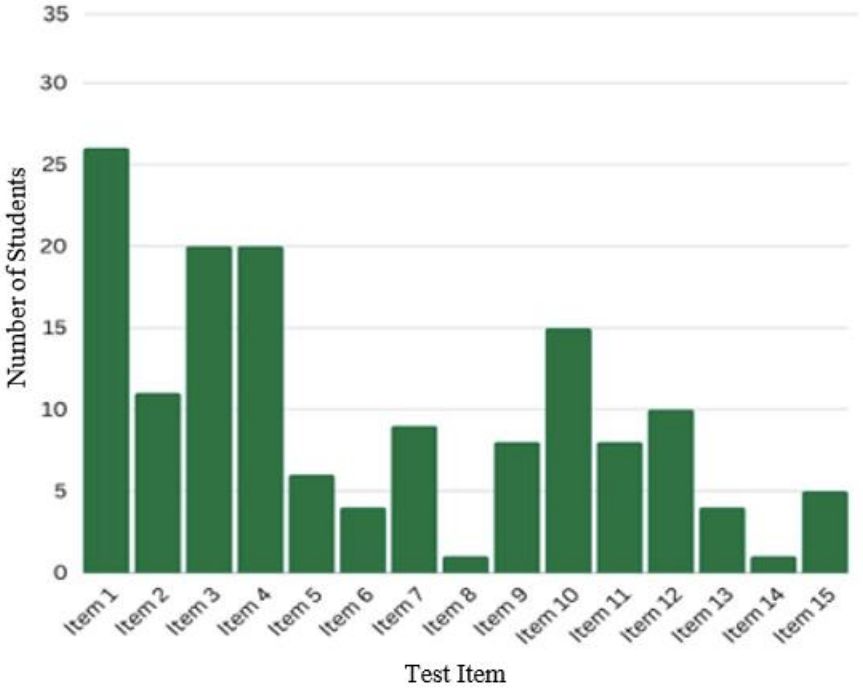

Figure 7: The Number of Students who Correctly Answered Each Item in the Pre- Diagnostic Test

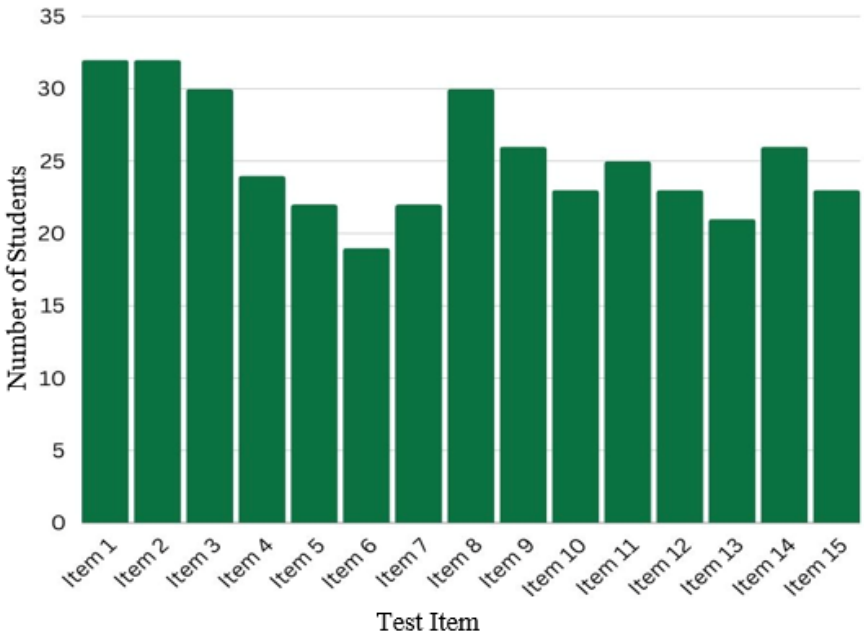

Figure 8: Number of Student who Correctly Answered Each Item in the Post- Diagnostic Test

After learning Cell Biology using VRI approach, what are the students' performance in the summative tests?

To gauge the effect of VRI approach on the students' performance the result of the summative assessment were analyzed by calculating the mean and standard deviation of the scores and using descriptive statistics in SPSS.

Table 3 shows that SA 1 garnered a mean score of 7.61 and 7.24 in SA 2. This suggest that the students performed reasonably well on the their SA 1 and SA 2. In terms of the std. deviation, SA 1 has a value of 1.34, indicating that the students' scores are relatively close to the mean. On the other hand, SA 2 signifies a

standard deviation of 2.11 suggesting that the scores exhibit a moderate level of dispersion. These findings indicate that majority of the students' scores are consistent within the mean average. See figure 9 and 10 for the distribution of score in SA 1 and SA 2.

The analysis presented in Table 4 revealed that the implementation of VRI approach positively affects students' performance in cell biology. This was supported by the study of (Berrocoso et al., 2022; Chauhan, 2017) expressing that incorporation of technologies in classroom instructions improve students' academic performance as it allow them to use deep learning approaches such as higher-order thinking, reflective learning, and integrative learning during their learnings. As stated in the study of Chernikova et al., (2020), simulation can significantly improve the students' cognitive skills, since it offers opportunities for the students to experience activity first- hand activities, leading to better understanding of the concept.

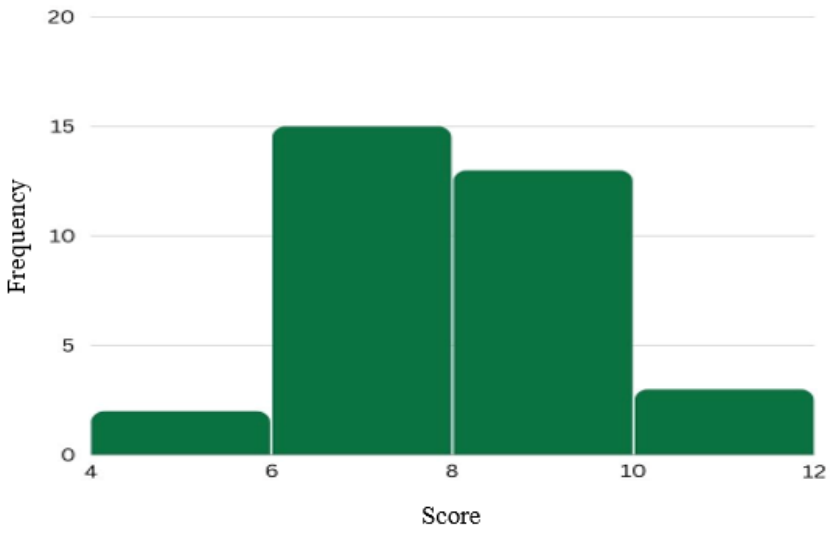

Figure 9: Score Distribution in SA 1

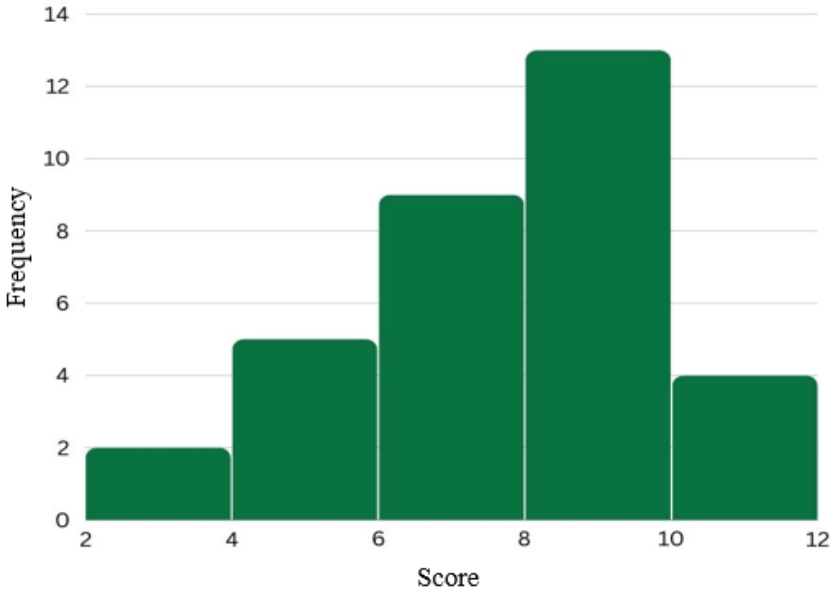

Figure 10: Score Distribution in SA 2

After learning Cell Biology using VRI approach, what are the students' level of conceptions?

To determine the effect of VRI approach on students conceptual understanding, the results of the diagnostic tests were statistically analyzed using Wilcoxon Signed Rank Test in SPSS. Moreover, the effect size was also determine by calculating the Cohen's d.

Table 5: Results of Wilcoxon Signed Rank Test and Effect Size of Pre and Post- Diagnostic Test.

	Total N	Test Statistics	Standard Error	Standardized Test Statistics	Asymptotic Sig.	Cohen's d
Test Summary	33	558.5	55.9	4.98	<.001	2.77

The data tabulated in Table 5 shows that the Asymptotic Sig. is <.001, which reject the null hypothesis. The result implies that there is a significant difference between the pre and post -diagnostic tests, indicating an improvement recorded in the pre- diagnostic test and post- diagnostic test. This finding was supported by the result of the Cohen's d as seen in Table 5. The Cohen's d signify a large effect size, which suggest that the difference between the pre- diagnostic and post- diagnostic test is highly substantial. The result of the Cohen's d also convey a strong practical significance that incorporation of VRI approach increases students conceptual understanding.

Moreover, the item analysis of the pre and post- diagnostic test seen in Table 4 shows that all the items in the post- diagnostic test garnered a higher percentage of correct answer compared to the pre- diagnostic test. Items 1, 2, and 3 under animal and plant cells garnered the highest correct answer. 100 % of students answered item 1 and 2 correctly, while 91% of students answered item 3 correctly. These items requires the students to identify the structure and function of certain cell organelles. In terms of the topic in cell division, items 5, 6, 8 and 9 garnered the highest score. Item 5 and 6 consists of 67 % of students with correct answers. These items focuses on the events that occurs in each stages of cell division. In Item 8, 91% of students answered it correctly. This item requires the students to identify the phase of cell division exemplified by the illustration. In item 9, 79% of students answered it correctly. This item also requires the students to identify the phase of cell division exemplified by the illustration.

Upon further analyzation, the items that garnered the highest correct answers required students to visualize the cell organelles and the stages of cell division. The result shows that majority of the students has high conceptual understanding about the said topics, which implies that the use of VRI approach increases students visualization and understanding of the concepts. Moreover, this reflects that the part of the VR activity that greatly helps students to visualize and understand the concepts is the "do it" part where the students are given the opportunity to immerse themselves into the VR environment.

These findings were supported by several studies, mentioning that VR technology can stimulate students understanding of complex biological concepts since it has the ability to virtually manipulate abstract concepts, leading to better understanding of the topic (Shim et al., 2014; Campos et al., 2022). Another study also revealed that simulation facilitate learning by increasing visuality and retention through animation of abstract and complex concepts (Talan, 2021).

How do the student's perceive the virtual reality as a tool in learning Cell Biology?

To assess students' perception of using VR as a learning tool in biology, one- on- one interviews were conducted with 10 students. Five high- performing and five low performing students were selected. The participants' responses were thematically analyzed to identify common themes. The following sections discusses the themes that emerged from the students' responses.

Enhanced Visualization

One of the primary themes that arises from the responses of the students is the effectiveness of VR tool in helping students visualize the lesson. This, in turn, has improved their understanding of the lesson and enhanced their retention. One the student remark that " *the VR is a useful way to absorb the lesson because it provides a visual depiction of what we were learning*". Another student share the same comment stating that " *the parts of the cell are easier to comprehend because I can visualize them easier and this is a great help for me especially that I'm a visual learner*". Additional remarks from the students are seen below.

"I was able to see how cells work as if I was inside that cell and not just an observe"

"Virtual Reality tool would be especially helpful in science related subjects especially for subjects that require a lot of visual imagery such as biology, chemistry, physics and more"

"I think that VR devices can be implemented in other subjects since it is really helpful in giving a visual representation for what is being taught"

"The VR is useful when it came to visualizing the cell organelles and cell division processes"

Several studies that incorporate VR tool into their teaching instructions revealed the same outcomes (Shim et al., 2014; Talan, 2021; Campos et al., 2022).

Immersive Experience

One of the features of VR devices is their ability to provide an immersive experience by creating a virtual environment that engages the students physically and emotional. This allows students to actively participate, make choices, and respond to what they are seeing by translating their movements into the virtual environment. Moreover, as the students immerse themselves in the virtual cell environment, many of them express amazement by saying "wow" or "this is so cool". Some of the students remarks are seen below.

"*The VR allowed me to immerse myself completely in the experience"*

" It allows me to interact and really indulge in the event"

"VR devices can be implemented in other subjects because they enable us to immerse ourselves more deeply"

"It's cool how I'm able to do something both productive by learning about the subject matter and engaging too as I get to personally interact with whatever contents it has"

Difficult to Operate

The primary difficulty experienced by the students was the proper way of maneuvering the controllers. A student stated that " *A disadvantage I experienced was controlling how I interacted with the elements since I have never used a VR, so it took a while to get used to".* Another students remarked that *"As someone that is still new to using VR, we still might need some assistance to effectively use such tool.* Further comments are seen below.

"All I need is just to have more opportunities or assistance to familiarize myself with the VR tool especially with its functions or how to maneuver such"

"I recommend to have a briefing before using the VR so that we can maximize its functions"

"I would recommend that the students are given a test run for the VR before the actual lesson to help them warm up to the device and so that any potential problems can be solved"

During the orientation, I discussed how each button in the controllers work. However, I should have let the students try it before the implementation to ensure that they really understood how the controllers operate .

Lack of VR Tool

The students also mentioned that the availability of VR devices minimizes their opportunity to immerse in their learning. Only one device was used during the implementation due to the limited budget. One participant remarked that " I suggest that more VR devices are given so that more people can try it at once

and the session moves faster". Another student mentioned that "*since there is only 1 VR, it sometimes slows down the session, and not everyone gets to maximize it".* In line with this, the lack of VR device also consumes a lot of instructional time, therefore, limiting the students experience in using the tool. As stated by one student "*one of the disadvantages of the virtual reality tool is the time it takes to set it up. Additionally, these take up time especially when multiple people are assigned to use the virtual reality tool*". Another comment states that *"I would also suggest that more VR devices are given so that more people can try it at once and the session moves faster".*

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

This action research was designed to identify the effect of VRI approach to the conceptual understanding and performance of STEM students in learning cell biology, particularly focusing on the topics of animal and plant cell organelles and cell division. Additionally, the study assesses the students' perception of using virtual reality as a learning tool in cell biology.

The pre- implementation process started by obtaining necessary permits from the institution's administration to allow the implementation of the study. This was followed by the formulation of VRI approach lesson plans and VRI materials aligned with Kolb's learning theory model. The purchasing of VR headset, videos, and accessories was also completed during this stage, with all the materials acquired through online platforms. The VR videos were purchased from Xready Lab, an educational VR/ 3D games platform. The final step in the pre- implementation process is the administration of pre- diagnostic test that would determine the participants' level of conceptual understanding in animal and plant cell organelles and cell division.

After administering the pre- diagnostic test, the VRI approach was implemented. During the implementation process, the CCG worksheet was provided to guide the students while going through the VR simulation. Upon completing and consolidating the students' answers in the CCG worksheet, an SA was administered to assess their performance in learning cell biology using the VRI approach. Following the implementation of VRI approach, the post- diagnostic test was conducted to gauge the effect of VRI approach on students' conceptual understanding. In terms of the post- implementation, the process occurred when the one- on- one interviews were facilitated. The responses of the participants shed light regarding their perception in using virtual reality as a learning tool in cell biology.

The data collected from the research instruments were recorded in a spreadsheet and analyzed using appropriate statistical tools. The data from the pre- diagnostic test were analyzed by calculating the mean scores and interpreting it to assess the level of conceptual understanding. For the data in the SAs, we examined it by computing the mean and standard deviation of the scores. In terms of the data in the pre - and post- diagnostic tests, we used the Wilcoxon Signed Rank test to assess whether there is a statistically significant difference between the pre- and post- diagnostic test. The effect size between the pre and post - diagnostic tests were also determined to identify the practical significance of the results. Finally, the data from the interviews were evaluated using thematic analysis.

The findings in the pre- diagnostic test indicate that the students' level of conceptual understanding in the topics of animal and plant cell organelles and cell division is "poor". The results of the SA suggests that VRI approach increases the students' learning performance in these topics. While the findings in the interview show that the implementation of the VRI approach has improved the students' conceptual understanding in cell biology. Furthermore, the interview results indicate that VR devices enable the visualization of abstract concepts, making the lessons more understandable and allows retention of the lessons discussed. It was also gleaned that VR provides an interactive environment that make learning engaging. However, the use of VR also imposes setbacks such as the difficulty in using the controllers, and the availability of the device as it is very costly.

The incorporation of the VRI approach into the teacher's pedagogical instruction imposes several relevance for the educators and students. The use of VR tools in teaching enhances the digital competency of teachers, as it enables them to learn how to set up and operate VR hardware and software, troubleshoot technical issues, and manage VR content. It also provides professional development opportunities for educators, as many institutions offer training and workshops related to VR and other digital technologies. In addition to enhancing the teachers' digital competency and providing opportunities for professional development, the incorporation of VRI fosters innovative and creative approaches to teaching. It encourages teachers to think creatively about how to deliver their pedagogy and which teaching strategies and assessments would best take advantage of VR's immersive capabilities. Moreover, the study's findings indicate that the majority of participants are visual learners, which provides teachers with insights into what strategies to use and how to design their learning materials to better suit the needs of the learners (Hussein & Natterdal, 2015; Hu- Au & Lee, 2017; Adelana et al., 2023; Tandale & Nrip, 2023).

In terms of the relevance of the study to students, the use of the VRI approach in learning biology concepts can help students perform better in assessments. This is because it engages the students' sensory organs, allowing them to better visualize and understand abstract and complex concepts in biology. Furthermore, integrating VRI in students' learning creates a fun, engaging, and interactive learning environment. This, in turn, fosters a positive attitude towards the subject, which can lead to an increased motivation to learn and explore (Shim et al., 2014; Talan, 2021; Campos et al., 2022; Chauhan, 2017; Berrocoso et al., 2022; Tandale & Nrip, 2023).

In the interest of providing a comprehensive and balanced assessment of the research findings, several limitations were observed in the implementation process. Primarily, the lack of VR headsets due to their expensive cost. Only one VR headset was used in the implementation process, leading to the consumption of a considerable amount of instructional time, as each students in each group had a particular roles to accomplish while using the VR headset. In line with this, we had a difficult time managing the class since some groups are doing the VR simulations while the other groups that are done are instructed to proceed to the CCG worksheet to maximize the instructional time. Moreover, due to time constraint, the VR videos were not maximized in the implementation of the study. Other cell biology topics, such as photosynthesis and biological macromolecules were not included in the study's implementation process. In addition, the students lack of knowledge on how to use the VR controllers imposes difficulties in conducting the study.

To address these limitations, we plan to request a VR budget to the STEM department to provide more VR headsets to the students. This will also help alleviate the time constraints and difficulties in managing the class, as all the students will be engage in the activity simultaneously. Additionally, to address the limitation regarding the use of VR controllers, we plan to conduct an extensive orientation. This will ensure that all the students understand the purpose of each button on the controller, thereby reducing repetitive questions and re- teaching of the controller's functions.

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