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INTEGRATING AUGMENTED REALITY IN BIOLOGY EDUCATION: IMPLICATIONS FOR STUDENT ACADEMIC PERFORMANCE

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ABSTRACT

The 21st century has brought a revolutionary change in the field of education, and technology has taken a crucial position in this improvement of teaching and learning. The Department of Education (DepEd) in the Philippines supports the integration of digital tools, particularly in STEM, as a solution to longstanding problems in traditional education. The conventional ways of teaching biology, which involve rote learning and the lecturing method, have been found to lack motivation, interest, and comprehension in students, as the subject is abstract and complex in nature. Augmented Reality (AR), where the real world is enhanced with virtual content, is a promising approach since it can make biological processes more concrete and engaging. This study examines the effect of AR on the academic performance, motivation, engagement, and interest of senior high school students in biology. Using a mixed-methods design, it measured academic outcomes and collected qualitative insights during the fourth quarter of the academic year. Quantitative results showed a marked increase in performance, with a mean grade of 88.75 using AR compared to 83.22 without it. AR was also rated as Highly Acceptable (M = 3.31), with motivation scoring the highest (M = 3.36). However, AR had minimal influence on learner confidence. Thematic analysis revealed that AR acted as a motivational tool, enhanced conceptual learning through 3D visualization, and facilitated self-directed and experiential learning. Students were excited about the increased AR integration despite the technical issues, such as lag on the device. Correlation analysis revealed significant positive correlations between affective factors and academic performance. These results highlight the promise of AR as a low-cost, high-impact educational technology that can promote deeper learning and engagement, even in public-school environments in the Philippine context.

***Keywords**: Augmented reality, academic performance, biology, student engagement, interest, motivation, QR codes.*

I. Introduction:

The 21st century has seen a significant shift in the principal focus of education. Today, technology is a common component of both teaching and learning. In the Philippines, the government has supported incorporating modern technologies in the education system to solve the problems created by the old education system, applauding the use of technology in science education. An example of such technology is augmented reality (AR), which is embraced within different educational contexts worldwide due to its capacity to make learning more engaging by fusing the real world with the imaginary (Ibañez & Delgado-

Kloos, 2018). In AR, students can study complex 3D models and simulations that help make physical structures and processes behind subjects like biology more appealing and exciting for the learners.

The requirement for innovative teaching strategies in biology education is high in the Philippines because numerous classrooms are still lecture- and rote-based, and do not allow students to be engaged (Mutya & Ramas, 2022). Traditional methods often fail to render biology interesting, especially when the content is presented at the cellular or ecological levels. An overall correlation between student motivation and science performance is positive (Sabanal et al., 2024). Other forms of active teaching, such as inquiry-based learning (IBL) and problem-based learning (PBL), have been proven to be effective in greatly enhancing student interest and engagement in science (Sarsale & Langub, 2023).

The Philippines is also making its best efforts to upgrade and enhance its educational system to fit the modern world's standards, which are still in the 21st century. One of the genuine ways to do this is to use technology inside the classrooms, as articulated by the guidelines issued by the Department of Education (DepEd), which incorporates blended learning and technology-enriched education (DepEd, 2022). Appropriate, especially in the Science, Technology, Engineering, and Mathematics (STEM) spheres, there are calls for more engaging, motivational and teaching learning-focused learning strategies. These include many practices; however, augmented reality (AR) has turned out to be very promising in delivering content and experiential learning, particularly in biology. This study investigates the role of AR in student engagement, motivation, interest and academic performance in learning biology within the Philippine educational system.

AR is known as a potential answer to addressing these problems. Using immersive learning experiences, augmented reality (AR) allows students to examine and manipulate many biological entities, including cells, organs, and ecosystems. AR increases student engagement, motivation, and curiosity (Bond et al., 2020)

Even though augmented reality (AR) has drawn the interest of a wide variety of people around the globe, its use in Philippine schools is relatively unexplored, especially in light of such obstacles as monetary limitations, insufficient resources and equipment, and unstable infrastructure (Duldulao, 2024). Although AR has been proven to enhance student engagement, motivation, and learning outcomes across the global academic environment, its specific impact on the learning process in biology classrooms in the Philippines has yet to be evaluated (Berame et al., 2023).

This study aims to concentrate on this area of research and analyze the effect of augmented reality on student engagement, motivation, interest, and performance in biology in the context of the Philippines. This research will be conducted through mixed methods research where numerical data and the content on how AR will enrich students' learning experiences in biology and help raise students' academic results will be presented. The findings of this study will help educators and decision-makers understand the benefits that can be derived from using AR technologies in teaching and learning science, especially in low-resource facilities.

Observations of student difficulties comprehending Biology's abstract concepts, like cell structures and physiological processes, led to this research because these scholastic hurdles create insufficient engagement

and poor academic results. Traditional instructional methods serve as basics but frequently overlook the different ways students learn, thus creating knowledge gaps between what students understand and what they are interested in. By showing students complex material through interactive virtual experiences, Augmented Reality technology showcases noteworthy, definitive solutions to those educational obstacles. The research investigates AR's effects on Biology academic performance as study authors embrace innovative learning methods and aspire to improve educational results.

Today, the Philippines considers its educational system a work in progress, given the shifts of the 21st century. Technology in classrooms is at the core of this, which the Department of Education has supported via its advocacy for blended learning, besides technology-enhanced learning (DepEd, 2022). However, especially in the study of science, technology, engineering and mathematics (STEM), there is a need to address how such subjects can be learned in an interesting, encouraging and effective way. One of these is the development of augmented reality (AR) technology that focuses on improving the educational process by making extreme interactivity and immersion available, most notably in pedagogy and biology. The current study explores the dimensions of student engagement, motivation, interest, and academic performance in biology with the incorporation of AR within the education system in the Philippines.

Statement of the Problem

The main focus of this research is to assess the effect of augmented reality as a tool for boosting academic performance in the study of biology. AR technology has been identified for the potential to alter old systems of learning settings and to provide interactive, immersive, dynamic experiences that may make the otherwise abstract biological concepts graspable by the students. However, similar to most innovations in education, more empirical research is still needed to determine whether it generally affects the learning outcome when used, especially in the Philippine setting. Thus, this study answers the following specific research problems:

1. What is the academic performance of the students in biology?
2. What is the level of acceptance of AR integrated activities in biology in terms of:
    2.1 Motivation;
    2.2 Engagement; and
    2.3 Interest?
3. Is there a significant relationship between the academic performance and above-mentioned variables?
4. How do STEM learners describe their most significant experiences on AR integrated learning activities?
5. Based on the results of the study, what learning module can be proposed to enhance students' academic performance?

Hypothesis

There is no significant relationship between the academic performance and above-mentioned variables.

II. Related Studies

Bridging Abstract Concepts through AR

Augmented reality, by definition, is a technology that incorporates the elements of digital worlds into the real-world environment and makes it possible to interact with virtual objects in real time (Ibáñez & Delgado-Kloos, 2018). The evolution in educational resource development in recent years is centered on Augmented Reality, also known as AR. This wondrous technology permits students to engage with learning resources in a different dimension. Incorporating AR technology in education, which allows virtual projections to be integrated within natural environments, has helped raise student interest in highly abstract subjects, such as biology, including those with challenging and abstract concepts. New research in the educational field emphasizes that student engagement increases when students participate in interactive, immersive, and collaborative educational processes (Godsk & Møller, 2025). This has been exemplified by Augmented Reality (AR), which allows students to work in a physical space with a 3D model of a complex biological system, such as cellular organelles or ecological processes. AR enhances behavioral, emotional, and cognitive immersion by overlaying virtual guidance and simulations on top of real-world experiments, providing a deeper understanding of the complex aspects of biological concepts with an underlying presence and significance (Lampropoulos &Sidiropoulos, 2024; Godsk, M., & Møller, K.L., 2025).The influence of augmented reality on student participation has been explored over the last several years, especially regarding the potential use of AR technology in creating engaging and interactive learning environments. A recent study finds that AR enhances student engagement by offering hands-on interactions that help them internalize biological principles effectively.

Over the past few years, the effect of augmented reality on students' involvement in the learning process has been studied because AR technology holds the unique promise of creating a very fulfilling interactive learning environment. In the same vein, Akçayır and Akçayır (2017) determined that AR improves student behavioral engagement because it provides an interactive platform where the students can look at biological processes in three dimensions. It was found that biology students who adopted AR technology are more active in the classroom, particularly in discussions, because the content is more relevant and accessible. With the help of augmented reality (AR) simulations, it becomes easier for students to picture and understand complex biological processes like cellular respiration and photosynthesis, enabling them to engage more in the learning experience and pose more inquisitive questions. This is in tune with the current study, which aims to assess the extent to which AR can be used to foster the engagement of STEM students in biology lessons, especially in the comprehension of complex and abstract concepts.

Engagement in Learning

Engagement is one of the most important factors affecting students' learning because it demonstrates how involved students are in a given learning process. Different forms of student engagement are behavioral, emotional and cognitive, and all of them are important for academic achievement (Bond et al., 2020). In the Philippine education system, however, student engagement is a problem that is particularly acute in crowded classrooms and limited resources (Bautista Jr. et al., 2021).

Studies show that with the integration of augmented reality as a tool in learning, there are high possibilities of bettering the levels of student engagement (Lin et al., 2022). Regarding biology education, augmented reality allows students to study even the most difficult of systems and interact with systems in three dimensions, which is captivating and helps improve comprehension levels (Ibáñez & Delgado-Kloos, 2018). For instance, AR programs enable users to dissect animals or plants through a screen, animate certain biological activities, or browse different habitats.

Engagement is categorized into interactive engagement, collaborative engagement, and immersive engagement. Such types of engagement are essential for generating effective learning frameworks that enhance student involvement proactively, allowing them to associate with one another and connect with learning materials. The remarkable sustenance of such arsenals of engagement in these elements embodies the excellent possibilities of AR in transitioning from passive to active learning, appealing to learners (Kuncoro et al., 2024). This is a direct contribution to the study's purpose, which is to investigate the capacity of AR to increase interest in biology among students. The study of Putri and Ridwan (2023) helps to add the current evidence, but, on the one hand, it supports the study that augmented reality (AR) significantly increases the level of excitement and emotional engagement in the process of learning, and, on the other hand, the level of identification with practice. In the current study, participants were more enthusiastic and joyful about working with AR-enabled biological materials, specifically the 3D cell models, which made the content more engaging and intellectually stimulating. The two studies suggest that when a student becomes excited and emotionally invested in their learning, it increases their desire to attend classes and achieve more, which highlights the ability of AR to create a more intellectually fulfilling and emotionally stimulating learning experience.

Similar to studies conducted in the area of mathematics education, which display the results of higher degrees of interactivity and immersion, the study at hand can also be expected to yield similar results in the biology context. The application of AR in the biology field enables students to have a visual and tangible experience of understanding complex processes (e.g., fertilization, photosynthesis), which easily beckons to greater levels of engagement due to the curiosity involved in its exploration and the sharing of knowledge among a group of students. Another thing that raises questions about AR is the potential for sustained engagement over more extended periods of use. According to the research conducted by Huang et al.(2021), students' engagement remained high during the whole semester when AR was applied in Biology classes on a regular basis. AR technology did not fade away as there were always new things to do with the technology for the teachers; hence, the use kept the students interested in the lesson. During the research, the students admitted that the use of AR devices made the lessons new and up-to-date every time, making it possible for them to concentrate on the content even after several introductions. This strengthens the importance of the present study, which aims to evaluate the influence of AR on student engagement and motivation at Kasiglahan Village Senior High School over a prolonged period. Thus, it suggests that the technology will sustainably impact learning outcomes.

Interest and Curiosity in Biology

The concept of interest is critical in understanding student participation and even educational achievements, particularly in science education (Renninger & Hidi, 2020). This framework is instrumental in science education, especially for challenging topics such as biology. Biology may seem complex or unfamiliar to many students when they enter school. Nevertheless, educators can enhance intellectual engagement and facilitate future academic achievements by integrating strategies that involve students and address their interests, such as real-life practices, interactive tools (including augmented reality), and student-initiated projects.

Morales and Regio (2023) provide compelling local evidence of the efficacy of augmented reality in enhancing the outcomes of biology teaching for students in Grade 7 in the Philippines. The study was carried out at Guinayangan National High School and established that students who were taught through Augmented Reality-Based Learning Aids (AR-BLA) demonstrated a substantial difference in posttest results compared to students taught through traditional learning methods. Such an observation explains the consistency between AR and learning, as well as preparedness, engagement, and interest in science subjects. The results also align with the theoretical assumption of Renninger and Hidi (2020), who suggest that a person can experience situational interest (most often triggered by interactive technologies, such as AR), which will subsequently lead to increased mental activity and improved academic performance. The study presented by Morales and Regio highlights the importance of incorporating educational technologies, such as AR-BLA, to enhance the learning of biology and make it more interesting, meaningful, and approachable to students. This is because it locates the benefits of AR in a particular learning environment, specifically the Philippine educational system, in their case.

Academic Performance

Besides improving academic outcomes, it has been discovered that augmented reality students' belief in their learning abilities, even in the most challenging subjects, is increased. This positive attitude compliments their performance in class and enhances their grades. Wahyu et. al. (2020) revealed the efficiency of MAR (Mobile Augmented Reality) in supporting STEM-based learning, enhancing the science learning achievement of students compared to the usual instructional approach. The drastic improvement in the mean scores of students under MAR-STEM learning, as indicated by the descriptive analysis and the between-subjects effect, highlights the overall outlook of technology-infused, student-centered, and immersive learning practices on academic learning performance.

This observation closely aligns with the current study on the use of AR-integrated exercises in Biology, which also focuses on how Augmented Reality (AR) can be used to engage more students and help them achieve greater awareness and more successful learning outcomes. These two research articles reflect the area of technology-mediated instruction and demonstrate that, in addition to a positive effect on achievement, such instructional interventions have a positive impact on the development of metacognitive awareness and active engagement in the learning process.

Enhanced comprehension of concepts, which positively influences learning, is a critical advantage of AR as a teaching method in science education. The same study investigated the impact of AR on the understanding of human anatomy and physiology among high school students. It concluded that using this technology-enhanced students' ability to recall intricate biological information. AR's capability to show three-dimensional models of organs and systems helped students engage with the content in ways that were not possible with conventional printed materials composing this content. The study by Abdullah et al. (2022) could be of tremendous use in understanding the efficacy of augmented reality (AR) in enhancing the academic performance of students in science lessons. Based on the instructional program used, the students' academic achievement significantly increased. It was credited to the immersive and interactive nature of AR technology that became a factor leading to the simplification of abstract scientific concepts and enhancing understanding. The results align well with the goals of the current study. The latter study also examines the positive impact of AR integration on students' academic performance. The reviewed research reinforces the notion that measurable academic benefits can be achieved by building upon AR in science, thereby contributing to the theoretical basis of the proposed study and its purpose of assessing the effect of AR in a more specific domain of biology education.

The meta-analysis by Lin and Yu (2023) revealed the positive effect of augmented reality on students' academic performance. Their synthesis of 70 empirical studies helped determine that AR has an impact on general learning effectiveness ($g = 0.717$) and that these changes primarily concern knowledge acquisition, retention, and application, all of which can be recognized as significant markers of academic achievement. Such findings have a close connection to the current study, which explores the significance of AR in learning biological concepts, as they support the claim that AR increases students' subject matter comprehension and provides a deeper learning experience. Moreover, the study's focus on reducing cognitive load and increasing motivation with the help of AR confirms the supposition that implementing AR in biology education can result in enhanced academic performance. The results of the study conducted by Lin and Yu provide a sufficient empirical basis for the current research and justify the assertion that AR can effectively enhance academic performance in areas related to the science field, such as biology.

III. METHODS AND MATERIAL

Research Design

The current study entitled Integrating Augmented Reality in Biology Education: Implications for Student Academic Performance uses both quantitative and qualitative research methods to measure the impact of Augmented Reality (AR) on the general learning process and students' results effectively.

This study employed a sequential explanatory design, which presupposes the collection and analysis of quantitative data, followed by the collection of subsequent qualitative data to clarify the results of the quantitative data. The first stage revealed the impact of Augmented Reality (AR) on students' engagement, motivation, interest, and grades in biology, as measured by Likert-scale questionnaires. Having computed the figures, the researchers conducted interviews and focus group discussions, inquiring about the personal experience and perceptions of students about AR-reception in a classroom. This design was suitable because

it not only measured the effects of AR but also revealed more information about the motivation level of the students and their learning behavior, which might have been difficult to achieve with statistics alone.

Population and Sampling Technique

The study population consists of 67 Grade 11 STEM students enrolled in STEM at Kasiglahan Village Senior High School. These students represent the group from which data were collected to assess the impact of Augmented Reality (AR) on their engagement, motivation, interest, and academic performance.

For the quantitative phase, the study employed total population sampling (also called census sampling), since all 67 students were surveyed using Likert-scale questionnaires. For the qualitative phase, the study employed simple random sampling, where 10 students were randomly selected from a group of 67 to participate in interviews or focus group discussions (FGDs). This allowed for unbiased selection and ensured that the qualitative data helped explain the quantitative results in a representative manner.

Research Instrument

Integrating Augmented Reality in Biology Education: Implications for Student Academic Performance employed the following research instruments to gather both quantitative and qualitative data:

Engagement, Motivation, and Interest Questionnaires

Likert scale was utilized to assess the levels of engagement, motivation, and interest in biology in utilizing AR-integrated activities. Three different questionnaires based on a four-point scale from 1 (not acceptable) to 4 (highly acceptable) was applied to find out the student's self-reported level of engagement, motivation, and interest in Biology. These questionnaires consist of 10 statements each and administered to the grade 11 STEM students. Students' curiosity and desire to acquire more information about biology issues were explored through the questionnaires and their interest in biology as a subject.

Semi-Structured Interviews (Qualitative Instrument)

The purpose of the semi-structured interviews was to understand students' experiences with using augmented reality in learning Biology. Ten students were selected to take part in the interviews. The questions had no right or wrong answers and were designed to explore how students felt about AR—whether they found it meaningful, helpful, effective, or enriching to their learning.

Data Gathering Procedure

The approach used in this study's data-gathering process was structured. It encompassed obtaining necessary permissions, formulating and applying research instruments, and collecting and analyzing data.

Securing Permissions

The first one is designed to get permission to conduct the research from the authorities. A formal letter of permission was sent to the DepEd Rizal Superintendent for approval of the study, which was conducted in Kasiglahan Village Senior High School. A request letter was sent to the school head of Kasiglahan Village SHS to request permission to conduct the research with the students of the STEM strand.

Moreover, a parental consent letter was provided to the parents or guardians of the participating students, written in simple language about the purpose and objectives of the study and the extent of activities their children will be involved in. In the current letter, emphasis was placed on the participation being voluntary,

and the students can leave the program at any time they wish to do so. Since the study employed technology, the letter also indicated that the research strictly observes data privacy and child protection laws.

A letter of permission to use school facilities, including tables and the Internet, was written and addressed to the school authority. This letter requested approval to allow students who did not own individual cell phones or lacked internet connections at home to use the school's resources during their studies. This ensured that all participants in the research process were given equal status and opportunity to engage in the study.

This phase was preceded by an orientation session for the students, in which they would be briefly told about the rationale for the study, their role in collecting data via the designed AR tools, and the general expectations. This session also helped in responding to any questions or issues that students have regarding the subject.

Statistical Treatment of Data

This study employed a combination of quantitative and qualitative statistical approaches to analyze the research data. Descriptive statistics, including mean and standard deviation, were used to summarize students' academic performance and responses related to motivation, engagement, and interest after the implementation of AR-integrated learning activities. Pearson r was employed to illustrate the level of correlation between the academic performance of students and their motivation, engagement, and interests in the school. Also, qualitative data that was collected as a result of open-ended responses or interviews were analyzed using thematic analysis to determine any common trend, theme, and insight into the experience of students using the AR tool. This mixed-methods approach provided a comprehensive understanding of both the numerical trends and the deeper contextual meanings behind students' learning outcomes and perceptions.

Ethical Consideration

All research participants received due attention relating to their rights together with their welfare throughout this research. All participants received parents' consent with their parents' or guardians' signatures for minor participants to get informed consent before the study begins. All personal information received secure handling through pseudonyms and coded reporting procedures while ensuring complete confidentiality. All voluntary aspects associated with this study offer students the freedom to pull out of the research at any instance without facing adverse effects. AR tool testing processes will verify non-maleficence through user safety and usage-based measurements to safeguard participants from discomfort, stress, or harm during the testing period. The study protected participant anonymity through the removal of identifying information in results while providing equal access to the AR tools to all students in order to prevent unfavorable treatment. AR tools deployed in the study maintained ethical compliance to protect both personal data privacy and safeguard users against hazardous digital content. All stakeholders received complete information about research purposes through clear communication as research findings are presented in an understandable format. Last but not least, the study maintained an ethical process through

the complete absence of coercion to protect participant freedom and their ability to join the study voluntarily.

IV. RESULTS AND DISCUSSION

This chapter presents, analyses, and interprets the data gathered to determine the effects of the AR-Integrated Activities on student engagement, motivation, and academic performance. The results are aligned with the research questions and are discussed through both quantitative and qualitative lenses.

Problem 1. What is the academic performance of the students in biology?

Table 1. Academic Performance of Students in Biology

Students' Academic Performance in Biology	N	Minimum	Maximum	Mean	Std. Deviation
First Quarter	67	75.00	95.00	85.4328	5.27494
Second Quarter	67	73.00	94.00	86.2239	5.43786
Third Quarter	67	70.00	96.00	83.2239	6.53620
Fourth Quarter	67	75.00	98.00	88.7463	5.67382
Average	67	75.00	95.75	85.9067	5.27929

Table 1 presents the academic performance in Biology of 67 students across four academic quarters. The data reveal that the highest mean score was recorded during the fourth quarter with the mean of 88.75 and standard deviation of 5.67, indicating improved academic performance toward the end of the school year. On the contrary, the lowest mean score was recorded in the third quarter mean of 83.22 and standard deviation 6.54, which showed the most significant standard deviation. This would indicate difficulties that the students had in that period, perhaps because of the nature of the topics covered, or lack of involvement, judging by the spread in grades. The overall average academic performance across all quarters was 85.91, reflecting a generally high level of achievement in Biology among the students.

Notably, the fourth quarter is also when augmented reality (AR) is to be integrated into the teaching-learning process. The substantial growth in the mean performance in this period corroborates existing literature on the advantages of AR in boosting educational outcomes. For instance, Weng et al. (2019) found that AR-based learning environments significantly improved students' understanding of complex biological concepts and increased their motivation to learn. Likewise, Amores-Valencia et al. (2023) concluded that AR significantly improves academic performance. To be more precise, students who were the subject of AR-based instructions demonstrated substantially higher post-test scores compared to their peers, who were taught the same material with the help of traditional pedagogy, despite having equally matched baseline proficiencies. This helps substantiate the findings of the current study that AR is effectively used in enhancing understanding and learning effectiveness in biology, including plant and animal organ systems.

In addition, the use of AR has the potential to support diverse learning inclinations, which is ideal to make lessons interactive and student-centered. This could account for the decrease in the performance variability from the third to the fourth quarter, where all the students of varying abilities were more or less occupied. Such results highlight the prospects of AR as a successful pedagogical instrument in the biology discipline and reinforce its further application to improve performance and equality of the outcomes. The

results also demonstrate the significance of prompt intervention and the development of instructional strategies to meet students' problems and maintain their achievement level.

Problem 2. What is the level of acceptance of AR integrated activities in biology in terms of:

2.1 Motivation;

2.2 Engagement; and

2.3 Interest?

Table 2 presents the respondents' assessment of the level of acceptance of AR-integrated activities in Biology in terms of motivation. Results show that all ten indicators received verbal interpretations of Highly Acceptable, except for one which was rated Acceptable. The most highly rated item was Augmented reality makes Biology lessons more enjoyable and motivating with mean of 3.63, meaning AR was a highly engaging tool which made biology more engaging This was followed closely by items that reflect increased willingness to learn, such as, I am encouraged to learn Biology because of the interactive elements of augmented reality with mean of 3.52, and I am more willing to put in extra effort when augmented reality is used in class with mean of 3.40. The lowest-rated item was Augmented reality boosts my confidence in my ability to learn Biology concepts with mean of 3.10, which, while still acceptable, suggests that confidence building may require additional scaffolding beyond AR alone.

The composite means of 3.36 interpreted as Highly Acceptable denotes students' motivation to AR-based learning in Biology. This finding is similar to the work of Weng et al. (2020), who reported that students felt more enjoyment and motivation in utilizing AR tools in science learning. On the same lines, AR can potentially alter passive learning into an interactive and immersive one, exponentially improving learners' motivation by arousing curiosity and increasing their attention span (Çetin & Türkan, 2022).

Table 2. Respondents' Assessment on the Level of Acceptance of AR Integrated Activities in Biology in Terms of Motivation

Indicators	Mean	VI
1. Augmented reality makes Biology lessons more enjoyable and motivating.	3.63	HA
2. I am encouraged to learn Biology because of the interactive elements of augmented reality.	3.52	HA
3. Using augmented reality in Biology lessons makes me look forward to the class.	3.33	HA
4. Augmented reality increases my motivation to study and review Biology topics independently.	3.28	HA
5. Augmented reality makes learning Biology feel more achievable.	3.34	HA
6. I am more willing to put in extra effort when augmented reality is used in class.	3.40	HA
7. Augmented reality boosts my confidence in my ability to learn Biology concepts.	3.10	A
8. I am more motivated to improve my performance in Biology through AR.	3.39	HA
9. Augmented reality inspires me to explore Biology topics outside of class.	3.36	HA
10. My motivation to participate in Biology activities has increased with augmented reality.	3.27	HA
Composite Mean	3.36	**HA**

****Legend: 3.26-4.00-Highly Acceptable; 2.51-3.25- Acceptable; 1.76-2.50 –Slightly Acceptable 1.00-1.75 – Not Acceptable*

Table 3 shows the respondents' evaluation of the level of acceptance of AR-integrated activities in Biology regarding engagement. The overall mean score of 3.26 falls in the range for Highly Acceptable, showing a generally positive perception of AR as a tool for increasing students' engagement in Biology classes.

Out of the indicators, Augmented reality makes me feel more engaged and active during Biology activities with mean of 3.42 and using augmented reality in Biology classes has made me more involved in learning with mean of 3.40 had the highest mean scores that were rated as Highly Acceptable. This finding indicates that students view AR as a good medium to enhance their active engagement and involvement in learning activities. This correlates with the study by Jaballudin and Khalid (2024) that determined that AR applications hugely improved student engagement and learning in Biology studies.

Other statement like I pay more attention to Biology lessons when augmented reality is used with mean of 3.22, I participate more in class when augmented reality tools are incorporated with mean of 3.15, came up with the mean scores in the Acceptable range. These relatively lower scores are still good, but there could be some areas where AR integration could be further improved to ensure optimal student attention and participation. Weng et. al (2020) identified that, though AR can improve learning gaps, it depends on reasonable integration in the curriculum and conformity to the object lessons.

The statement Augmented reality helps me better understand complex Biology concepts got a mean of 3.39 which verbally interpreted as Highly acceptable suggests the potential of AR in helping understand complex aspects. This has been supported by Chang and Yu (2018), whereby AR technologies in science laboratories enhanced students' understanding and participation by creating interactive and immersion learning experiences.

From an overall perspective, the data would suggest that the AR integration into the biology education showed a positive effect, especially on engagement and learning of the complex concepts among the learners. With this in mind, the educators should prepare to strategize in including the AR tools in the lesson plans such that they reflect and uphold the learning objectives.

Table 3. Respondents' Assessment on the Level of Acceptance of AR Integrated Activities in Biology in Terms of Engagement

Indicators	**Mean**	**VI**
1. Using augmented reality in biology classes has made me more involved in learning.	3.40	HA
2. I pay more attention to Biology lessons when augmented reality is used.	3.22	A
3. Augmented reality makes me feel more engaged and active during Biology activities.	3.42	HA
4. I participate more in class when augmented reality tools are incorporated.	3.15	A
5. Augmented reality helps me better understand complex Biology concepts.	3.39	HA
6. I am more focused during Biology lessons with augmented reality than in traditional lessons.	3.06	A
7. Augmented reality helps me stay focused on the topic for extended periods.	3.13	A
8. I feel more connected to the subject material when augmented reality is used.	3.39	HA
9. Augmented reality encourages me to discuss the lessons more with classmates.	3.18	A
10. I feel more confident about my understanding of Biology when I use augmented reality tools.	3.22	A
Composite Mean	3.26	**HA**

****Legend: 3.26-4.00-Highly Acceptable; 2.51-3.25- Acceptable; 1.76-2.50 –Slightly Acceptable 1.00-1.75 – Not Acceptable*

Table 4 contains the respondents' opinions on the appeal of AR-supported activities in Biology to students. Since the average mean score is in the Highly Acceptable range, AR has significantly boosted interest in Biology classes.

The highest mean score on the indicators was I am more interested in exploring biology through augmented reality, indicating that AR encourages students to learn more about Biology. Both responses containing augmented reality scored 3.42 each, confirming once more that AR elements can stimulate students' curiosity about Biology. It agrees with the study by Weng et al. (2020), which revealed that using AR technology can help students learn biology more effectively and have a better attitude toward it. Moreover, research by Jaballudin and Khalid (2024) pointed to an increase in student interest and understanding in the activity after applying AR.

In comparison, the statements Augmented reality made Biology my favorite subject with mean of 3.06 and My impression of Biology has been greatly affected by Augmented reality with mean of 3.13 received scores that were slightly lower and were sorted into Acceptable indicators. It means that AR boosts interest temporarily, but encouraging students to keep this interest may depend on its regular use and various supporting activities. Generally, AR inclusion in Biology lessons encourages students and makes learning more engaging. Educators can make the most of AR by carefully integrating the technology into teaching materials to ensure it helps students achieve the desired learning results

Table 4. Respondents' Assessment on the Level of Acceptance of AR Integrated Activities in Biology in Terms of Interest

Indicators	Mean	VI
1. I am more interested in Biology lessons when they include augmented reality elements.	3.42	HA
2. Augmented reality makes me curious to learn more about Biology topics.	3.42	HA
3. I am more interested in exploring Biology concepts with the help of augmented reality.	3.45	HA
4. The use of augmented reality increases my desire to participate in Biology-related activities.	3.31	HA
5. Augmented reality has made Biology one of my favorite subjects.	3.06	A
6. Biology is more exciting when I use augmented reality tools in class.	3.42	HA
7. Augmented reality has sparked a lasting interest in Biology for me.	3.13	A
8. I feel more enthusiastic about Biology because of the use of augmented reality.	3.16	A
9. Augmented reality makes me eager to learn more about science and technology.	3.42	HA
10. My interest in studying Biology has grown since augmented reality was introduced.	3.31	HA
Composite Mean	3.31	**HA**

****Legend: 3.26-4.00-Highly Acceptable; 2.51-3.25- Acceptable; 1.76-2.50 –Slightly Acceptable 1.00-1.75 – Not Acceptable*

Table 5 gives an overview of the respondents' assessment on how well using Augmented Reality (AR) aligns with motivation, involvement, and interest in Biology. The overall response regarding using AR in Biology is positive and rated as Highly Acceptable (HA). The composite mean score of **3.31**,

interpreted as *Highly Acceptable (HA)*, reflects a positive overall perception among students regarding using AR in the Biology classroom.

The dimension that was rated highest at 3.31 was the one related to sparking students' interest in Biology through AR technology. This supports the findings of Weng et al. (2020), who emphasized that AR enriches the learning environment by allowing students to visualize complex biological structures and processes, increasing their willingness to explore the subject further.

Table 5 . Summary of the Respondents' Assessment on the Level of Acceptance of AR Integrated Activities

Indicators	Mean	VI
Motivation	3.26	HA
Engagement	3.26	HA
Interest	3.31	HA
Composite Mean	**3.28**	**HA**

****Legend: 3.26-4.00-Highly Acceptable; 2.51-3.25- Acceptable; 1.76-2.50 –Slightly Acceptable 1.00-1.75 – Not Acceptable*

Motivation and engagement received mean scores of 3.26**,** which also fall within the *Highly Acceptable* range. According to the results, AR encourages both enjoyment during lessons and students' active involvement. Based on Jaballudin and Khalid (2024), students taught with augmented reality lessons felt motivated to learn and took part in class discussions, as the interactive features of AR made the lessons more engaging.

The research revealed average scores in the areas of motivation, engagement, and interest Highly acceptable. These results support the discussion by Dhaas (2024), who states that augmented reality may reconsider learning as a practical and valuable practice. Instead, immersing students in an experiential, interactive world will foster the enhancement of engagement and interest levels, thereby strengthening the positive attitudes of the sample regarding the technology. Overall, the summary table confirms that AR technology is well-received by students and holds promise for enhancing motivation, engagement, and interest—three critical affective factors that influence academic achievement and positive learning attitudes.

Problem 3. Is there a significant relationship between the academic performance and above-mentioned variables?

Table 6. Relationship Between the Academic Performance and Above-Mentioned Variables(Motivation, Engagement, and Interest)

	Indicators	Pearson r	Sig	Ho	VI
Academic Performance	Motivation	.200	.104	Failed to Reject	Not Significant
	Engagement	.256	.037	Rejected	Significant
	Interest	.239	.051	Failed to Reject	Not Significant
	Overall	.245	.045	Reject	Significant

***Legend: FR-Failed to Reject; R-Rejected; NS-Not Significant; S-Significant

Table 6 presents the correlation results between students' academic performance in Biology and their motivation, engagement, and interest toward Augmented Reality (AR)-integrated activities. The Pearson *r*

values indicate the strength and direction of the linear relationship, while the significance values (*Sig*) determine whether these relationships are statistically meaningful at the 0.05 significance level.

The analysis shows that **student engagement** has a **significant positive correlation** with academic performance (*r = 0.256, p = 0.037*), leading to the **rejection of the null hypothesis**. This suggests that students more engaged in AR-based Biology activities tend to perform better academically. overall composite variable, it was observed that this variable is positively associated with students' grades (r = 0.245, p = 0.045). This supports the findings of Jaballudin and Khalid (2024)**,** who noted that AR tools enhance interactivity and contribute to better content retention and academic success in science education.

On the other hand, both motivation (r = 0.200, p = 0.104) and interest (r = 0.239, p = 0.051) did not reach statistical significance, although they exhibited positive trends. Although the relationship between these variables and academic performance was not very strong, their not-so-high Pearson r values may indicate that they might influence students' learning, which could be explained by factors such as engagement. Zhou et al. (2020) agree with this finding, showing that motivation and interest influence academic performance only by leading to actions that enrich their learning. Overall, the results highlight student engagement as the most robust predictor among the three variables about academic performance, reinforcing the value of interactive technologies like AR in fostering meaningful and compelling learning experiences in Biology.

Problem 4. Learners' description on their experiences on utilizing augmented reality integrated activities

The study involved ten student participants selected through random sampling from three different sections. The distribution included three participants from each of the two sections and four from the third. They were interviewed to provide insights based on their experiences with the use of augmented reality in Biology learning.

The feedback provided by students demonstrates the ground-breaking impact of Augmented Reality (AR) on their motivation and learning strategies. Participant 1 claimed that AR use grew them excited to learn because it is exciting and new which means that AR can induce excitement, a sense of freshness, and engagement by a student to a given course, the theme consistent with the sub-theme Technology as a Motivational tool. As another student wrote, they were more inclined to study on their own with this approach, so AR does favor independence and individual learning, in addition to supporting the sub-theme of Increased Likelihood of Independent Study. Furthermore, statement by participant 7 on using technology reveals how AR can be appreciated as a tool for effective learning. This observation aligns with the sub-theme *Appreciation of Technology in Education.* Participant 5 added that AR promotes realistic, detailed visuals aid learning. Collectively, these insights emphasize how AR not only motivates students but also supports personalized, enjoyable, and self-directed learning experiences.

Table 7. AR Facilitated Motivation and Independent Learning

Significant Statements	Formulated Meaning	Sub-theme
"It makes me excited to study because it is something new that is educational and fun at the same time." -Participant 1	AR fosters novelty and interactivity, which boosts student excitement.	Technology as a motivational tool
"More likely to study alone using this."- Participant 8	AR tools encourage independent learning.	Increased Likelihood of Independent Study
. "Aside from realistic structure of an organism, it also provides each detail of that structure for the students to have an easy understanding about that structure."- Participant 5	AR promotes Realistic, detailed visuals aid learning	Support for Visual Experiential Learning
" I use phones and technology, which makes it more exciting" -Participant 7	AR promotes appreciation of technology	Appreciation of Technology in Education

The participants expressed how augmented reality (AR) significantly enhanced their learning experience by stimulating curiosity, supporting comprehension, and sustaining focus. One of the participants claimed that the lesson was more enjoyable and entertaining, and that the use of AR aroused emotional appeal and intellectual interest, as covered in the sub-theme of Curiosity and Enjoyment Boost. Participant 8 noted that AR creates a lasting impression due to its immersive experience. Participant 4 sees how 3D objects of AR enhances understanding by providing a concrete visual model of abstract concepts. This is also in line with the sub-theme of Visual Learning Comprehension, which depicts the role of AR in learning based on its ease of understanding due to its interactive and visual presentations.

Table 8. Augmented Reality as a catalyst for Engagement and Learning

Significant Statements	Formulated Meaning	Sub-theme
". I felt more curious while using AR to see 3D models of different organs/cells, at my own pace, completely captivated my attention. The realistic visualization and interactive nature of the experience contributed significantly to enjoy Biology- Participant 2	AR increases student curiosity and enjoyment, making lessons more appealing.	Curiosity and Enjoyment Boost
"Seeing how things work in 3D helped me understand better than just reading the text." -Participant 4	AR enhances understanding by providing a concrete visual model of abstract concepts.	Visual Learning Comprehension
"I stayed focused because it was something new and different from usual lessons." Participant 5	The novelty of AR captures and maintains students' attention during lessons.	Sustained Attention Through Novelty
"I still remember my first time using AR—it was so different and unforgettable."- Participant 8	Initial exposure to AR creates a lasting impression due to its immersive experience.	Memorable First Encounter

Furthermore, engagement through immersion in AR was reported to have maintained attention as highlighted in the response of participant 5 novelty of AR captures and maintains students' attention during lessons. This fact gives rise to the sub-theme of Sustained Attention Through Novelty, which demonstrates how the uniqueness of AR tools can help learners stay on track. Additionally, Participant 7's Initial exposure

to AR creates a lasting impression due to its immersive experience. However, they did not describe the feeling of using AR for the first time, which underpins the emotional and cognitive effects of interacting with AR for the first time. This is associated with the subtheme of the Memorable First Encounter, as it means that AR produces an impression that can be utilized to improve learning. Research suggests that AR does not make science more accessible, but rather makes the learning environment more dynamic, student-centered, and meaningful.

Table 9. Augmented Reality improves Biology Learning and Interest

Significant Statement	Formulated Meaning	Sub-theme
"I understood the lesson better when I saw how the cell works in 3D."Participant 9	AR helps make abstract biology concepts more concrete and easier to understand through visualization.	Improved Conceptual Understanding
"I usually get bored in Biology, but with AR, I was focused and excited to learn." Participant 10	AR enhances student engagement and motivation by making the lesson more interactive and enjoyable.	Increased Engagement and Motivation
"Using AR made me realize I want to take a science-related course in college." Participant 6	AR encourages students to pursue science by boosting their confidence and interest in the subject.	Support for Career Interest and Confidence

The use of Augmented Reality (AR) in the Biology curriculum has enormous benefits for both the curriculum and students, as it improves their learning by enhancing conceptual understanding, increasing their interest and participation, and aiding their career reflection. A learner posted that after observing how the cell operates in 3D, I learned the lesson better, suggesting that AR allows for visualizing abstract biological processes and making them more accessible and easier to understand. This is echoed by another student, who expressed that he used to get lost during classes in Biology, but with AR, he was hooked and became interested in learning. This shows that the interactive component of AR enhances a student's interest and engagement, making them more attentive in the classroom. Moreover, Participant 6 responded that with AR, she wants to take science related course in college. These insights affirm that AR is not only a tool for academic support but also a catalyst for long-term motivation and educational direction in science.

Table 10. Augmented Reality enhances Visualization and Learner-centered Education

Significant Statement	Formulated Meaning	Sub-Theme
"I understood how the circulatory system works better when I saw it in 3D."Participant 2	AR helped clarify complex biological processes through interactive visuals.	Clarity Through Visualization
"I learn better by seeing than reading — AR really helped me and my classmates." Participant 4	AR supports various learning styles, especially for visual and kinesthetic learners.	Support for Diverse Learning Styles
"My scores improved after using AR apps for our Biology lessons." Participant 7	AR use is linked to better academic performance due to improved understanding.	Positive Impact on Academic Performance
"When I saw the 3D plant cell, I finally understood what each part does." Participant 8	Visualization with AR improved conceptual learning and memory retention.	AR Enhances Visualization and Conceptual Learning
"I liked it, but some classmates still prefer books or videos." Participant 9	Reactions to AR vary based on student preferences and comfort with technology.	Mixed Views Based on Preferences

The participants' answers reflect the role of augmented reality (AR) in enhancing accessibility in learning and visualization. Testimonials such as the fact that certain revelations in the anatomy of the circulatory system were more apparent to me upon viewing it in 3D serve to reinforce the point that AR allows the learner to get a clearer picture of larger concepts in biological processes because they can see it moving in a way that a book cannot deliver. This confirms the sub-theme *Clarity Through Visualization.* Additionally, AR caters to various learning preferences, especially for those who benefit from visual or experiential modes of instruction, supporting the sub-theme *Support for Diverse Learning Styles.* The remark, I learn better by seeing than reading — AR helped me and my classmates, affirms this. It is also unmistakable that technology affects academic performance results, as some students reported positive academic performance scores following the utilization of AR tools, which aligns with the sub-theme Positive Impact on Academic Performance.

Table 11. Optimizing AR for Students

Significant Statement	Formulated Meaning	Sub-theme
"I had a hard time using AR at home because the internet was too slow." Participant 8	AR requires stable internet to function effectively, limiting usage in low-access areas.	Internet Dependency
"The app lagged a lot and sometimes crashed on my phone." Participant 7	Technical glitches and app instability affect the learning experience.	Technical Limitations
"We didn't have enough time to explore the AR features during class." Participant 4	Time constraints limit the full use of AR tools in the classroom.	Time and Accessibility Constraints
"It would be amazing if it doesn't need internet connection as well as it has bigger visualization, but all in all it was cool."Participant 2	Students seek more interactive and multimedia-rich features in AR content.	Enhance Visual and Interactive Features
"Some features didn't load properly or froze halfway through the activity." Participant 5	Improving reliability is essential to avoid disruption in AR-based learning.	Improve Technical Reliability

The interviewees demonstrated a corresponding level of excitement about using AR and expressed reservations concerning its drawbacks and issues, which should be addressed to make it efficient in classrooms. Internet dependency was one of the key problems expressed, as a number of students reported that their learning experience was hindered by poor or fluctuating signals. This is corroborated by the fact that, most of the time, the effective implementation of AR depends on having effective internet connectivity, which not all students can access and enjoy. The same issues apply to technical settings. Reasons such as freezing of some AR applications, veiling, and unresponsiveness of older devices were common among students, who cited them as obstacles to the learning process. These issues directly relate to the sub-theme *Improve Technical Reliability*. Another challenge was time and accessibility constraints. As an illustration, some learners stated that they had access to the AR tools only when they were in the classroom, whereas others indicated that it took instructional time to navigate the interface. The following are the obstacles that constrain the use of AR in self-directed or distance learning. More positively, the students liked the graphic quality of AR and its interactive nature. Nevertheless, they suggested that they should be improved further to

help them maintain longer contact and acquire more profound knowledge, in parallel with the sub-theme of Enhancing Visual and Interactive Features. In the feedback given by FGD it was also seen that AR environments needed to be made more hyperactive and receptive to academic contents All these insights demonstrate that the potential of AR can be tremendous; however, to become a tool that supports equitable and effective science learning for all learners, optimization (in terms of accessibility, reliability, and redesigned interactivity) is necessary.

Problem 5. Based on the results of the study, what learning module can be proposed to enhance students' academic performance?

Proposed Learning Module

The capability to bridge the knowledge gap between classroom-based lessons and immersive technology education is noted. A learning module with AR is an essential movement in the direction of integrating instruction and learning traditions, and a product of the environment. The module design not only facilitated the acquisition of knowledge but also promoted student engagement and motivation, as well as the integration of knowledge with real-life scenarios. Statistically, based on the input and outputs demonstrated by the students during the implementation of the AR-integrated module, there is a close association between greater student engagement and higher academic performance. The organization and the content of the module give clues as to the reasons why such integration was practical and had educational significance.

The AR-Integrated Learning Module would follow a systematic instructional method that allows students to have a gradual learning experience. During the introduction to a module, learners will be engaged with aspects such as 'Let Me Know' and 'Let Me Remember,' which are intended to support the process of activating prior knowledge and developing a specific learning target. The latter are Letter Me Update and Letter Me Discover, which provide the main content and interactive AR-based tasks. The reflection, application, and post-assessment are included in the sections labeled "Let Me Explore," "Let Me Share," "Let Me Apply," and "Let Me Check." This step-by-step process will facilitate the constructivist theory of learning, which implies that new knowledge should be based on previous learning through experience and reflection. The research conducted by Hashim et al. (2022) demonstrates the efficacy of a well-structured, experience-based paradigm of AR-based learning, as it shows that the involvement of multimodal inputs (speech, emotion, and visual markers, etc.) can optimize engagement, learning performance, and cognitive processing. This approach is consistent with the phased nature of the AR-Integrated Learning Module, which utilizes the experiential learning model proposed by Kolb to facilitate the development of reflective and interactive experiences that foster knowledge construction. In this module, Blender was utilized—a free and accessible 3D modelling software known for its advanced capabilities in designing three-dimensional digital objects. The platform automatically generates the code for each 3D

model, although users retain the option to modify the code within the application. After creating the 3D model, it was exported in GLB file format, which is widely supported by Web-based Augmented Reality (AR) platform.

SUMMARY OF FINDINGS

The findings of the research exhaustively define how the involvement of Augmented Reality (AR) in teaching biology would influence the academic performance of the students, their motivation, engagement, and the level of interest. The quantitative work showed how the academic results improved measurably after the introduction of the AR. At the same time, the qualitative conclusions highlighted the life-altering experiences and beliefs of students regarding AR as a motivator and a better understanding of complex biological concepts.

Academic Performance

Augmented reality in the teaching of Biology has also contributed significantly to the improvement of students' academic performance. With the introduction of AR, there was an upward trend in student achievement; the figure shows that students performed better. Overall, the level of performance was relatively high during the quarters, indicating that AR could be an effective supplementary tool to traditional teaching.

Level of Acceptance of AR integrated Learning Activities

Students generally accepted the utilization of augmented reality in Biology. It was an enjoyable experience for many, and it was described as participatory. Although AR contributed to increased motivation and interest, it had a limited impact on student confidence. The results on the levels of engagement were generally positive, but the aspects such as sustained attention and active participation should be improved. Overall, students were aware of the use of AR as an educational tool.

Correlation Between Motivation, Interest, Engagement and Academic Performance

Student engagement was found to have a positive correlation with academic performance. There was a significant relationship between motivation, engagement/ interest and improved academic performance when they were taken together. Although motivation and interest alone did not show strong individual connections to performance, their combined effect highlighted the value of interactive and student-centered learning experiences.

Student's Learning Experiences on AR integrated Learning Activities

Students found Augmented Reality (AR) to be one of the effective learning technologies that supported their motivation, engagement, and conceptual way of learning biology. AR was a more engaging interactive replacement for conventional lectures, promoting independent work and learner autonomy. It even contributed significantly to the level of attention and curiosity of students, as most of them reported their initial experience with AR to be memorable and emotionally captivating. The 3D simulations also allowed learners to have a better understanding of the complicated biological mechanisms, making them more transparent and fostering a desire to become professionals in STEM. AR was personal and visual and

compatible with the different types of learners and was associated with better academic outcomes. Notwithstanding these advantages, students reported such disadvantages as internet dependency, technical problems, and lack of access to the equipment, alongside their interest in more immersive elements and systems of more successful integration into the classroom setting.

AR Integrated Learning Activities

The research found that the AR-Integrated Learning Activities proved competent in linking the conventional teacher-centered instruction with the emerging immersive technology of Biology learning. It helped improve students' academic performance and interest with a goal-oriented, constructivist approach, thus enabling the knowledge base to be gradually acquired with the help of the interactive AR functionality. The learners had profound learning experiences when participating in 3D simulations of biological processes, which led to better comprehension, motivation, and independence. Conceptual understanding and critical thinking were further enhanced through collaborative learning, differentiated assessments, and practical applications. AR has enhanced positive impacts on attention, curiosity, and reflective thinking, despite slight barriers to technology experiences. Quantitative data supported the assumption that there was an exceptionally high positive correlation between student involvement and achievement, approving AR not only as a digital addition but also as a pedagogical tool of the new millennium, ideally put in teaching STEM.

CONCLUSION

The statistical analysis of the data collected on academic performance, specifically in terms of educational achievements, indicated a significant improvement in Biology following the implementation of augmented reality (AR). There was a definite positive trend, demonstrating that students performed better with AR than they did in the preceding non-AR quarter. Despite the variance in individual performance, there was a relatively high overall academic average in all quarters. This implies that AR was successful in augmenting conventional instructional practices and adding value to student results.

About motivation, augmented reality (AR) was met positively, and most of the students stated that augmented reality (AR) makes learning Biology more entertaining and inspires active engagement. Yet, it had little effect on increasing the confidence of students. In terms of engagement and interest, the student feedback expressed a positive attitude towards AR, with areas for improvement including consistent attention and participation in the classroom. Altogether, the degree of acceptability implies that AR has been regarded as a valuable and practical educational asset.

The results of the statistical analysis indicate that the relationship between student engagement and academic performance was significant and positive. After taking into account affective factors like motivation, engagement and interest together, they were found to be substantially related to academic success. The fact that the individual effects of motivation and interest were not significant proved to be inessential because the interaction effect with engagement was overwhelming and indicated the importance of a student-centered and interactive learning environment in improving academic outcomes.

Students considered augmented Reality (AR) to be an exceptionally efficient and enjoyable tool, increasing their motivation, level of engagement, and knowledge of intriguing biological aspects. Its dynamic and visual nature favored most learning styles and helped to develop curiosity and interest in the STEM subjects. Nevertheless, some students also cited the need to overcome internet addiction, technical difficulties, and a lack of devices as issues that complicate their integration into the classroom.

The research demonstrated that AR-integrated learning was a successful configuration for bridging the gap between traditional teaching methods and immersive technology, which increased students' academic performance, interests, and knowledge in the discipline of Biology. The use of interactive 3D simulations and group work helped learners develop a deeper understanding, motivation, and critical thinking. AR succeeded as an educational tool because it encourages student participation and success in modern STEM education despite some minor technological issues.

RECOMMENDATIONS

According to the results of the study, it may be suggested that the following recommendations should be used to contribute to the further use of Augmented Reality (AR) in teaching Biology and increase students' learning achievement:

Since the academic development was much better with the use of AR, schools ought to institutionalize AR-based actions in Biology and other STEM topics and make sure that they provide supplements to the current instructional procedures. The educators will have the opportunity to create lessons that can combine conventional methods with AR simulations to ensure that the performance levels remain high.

It is also recommended that teacher training and assistance programs should be regular. Such programs are to discuss not only the technical aspects of AR but also the ideas meant to bring the use of AR into line with learning goals, encourage students to engage in AR-based activities in the classroom, and foster confidence in students working on AR-based tasks. This kind of training will inform teachers of the skills required to handle technology-enhanced learning.

The solutions to the issues of accessibility and technical constraints are to equip the schools with long-lasting internet connections, offline-compatible AR technologies, and classroom-ready devices. It should also encourage developers and ICT professionals to create AR applications that consume less bandwidth and are compatible with various devices commonly used in schools.

It is also suggested that educators emphasize student focus and participation by designing interactive and collaborative AR lessons. Gamified AR experiences, scenario-based simulations, and embedded formative assessments are recommended to foster active student involvement and sustained attention during lessons.

To ensure equitable access to AR-based instruction, it is strongly suggested that schools and policymakers establish measures to support students from underserved communities. It may be possible to get local government units (LGUs), DepEd, and privately-owned stakeholders to partner, so that all the

learners are not left out of the opportunities of gaining the benefits of AR-enabled learning through devices and the internet.

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