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Augmented Reality in Biology: A Needs Assessment from Senior High School Students' Perspective

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Abstract

In the era of Industry 5.0, education is evolving with automation and immersive technologies like Augmented Reality (AR). This study explores the need for an AR-based e-module in Senior High School biology by assessing students' understanding, interest, confidence, and perceived usefulness of AR in learning. Using a descriptive quantitative approach, data were gathered through a questionnaire covering four key areas: (1) understanding of biology concepts, (2) familiarity with AR, (3) confidence in using AR for learning, and (4) perceived need for AR applications. Results indicate that students are generally satisfied with their biology knowledge and are "somewhat familiar" with AR. A strong interest in AR-based learning was evident, with students favoring its interactive and engaging nature. Results in t-test comparing 11th and 12th graders' interest and confidence in augmented reality (AR) for learning biology showed that while both groups have similar confidence levels, their interest in using AR to understand biology concepts differs. These findings emphasize the potential of AR in enhancing biology education and aligning with innovative teaching practices.

Introduction

In the context of the fifth industrial revolution or Industry 5.0, which is characterized by the implementation of automation technologies like robotics and machine learning alongside the promotion of the use of immersive technologies like virtual and augmented reality in the field of education. Educators must adopt more interactive teaching methods. By incorporating technology into the classroom, teachers can create engaging and effective lesson plans that cater to the learning styles of millennial students (Al-Emran & Al-Sharafi, 2022; Kacprzyk, 2019). Augmented Reality (AR) technology offers a promising avenue for enhancing educational delivery by leveraging visual, auditory, and video components. This approach has the potential to significantly improve learning efficacy, addressing several common student challenges, including a lack of motivation (Ciloglu & Ustun, 2023). AR demonstrated that it can positively impact learning outcomes, foster more favorable student attitudes toward subjects, and heighten both engagement and satisfaction (Santos et al., 2016). According to a systematic literature review by (Permana et al., 2024) the AR theme pertains to educational initiatives aimed at enhancing biology teacher training through the integration of e-learning or mobile learning powered by AR and VR technologies. Its application necessitates the use of augmented reality tools to support biology instruction, thereby linking the teaching process directly to the concept of learning performance.

Background

Augmented Reality

Augmented Reality (AR) was initially introduced in the 1990s as a training tool for airline and air force pilots (Caudell & Mizell, 2003). This technology integrates virtual objects with the real environment, allowing these digital elements to align seamlessly with actual physical surroundings (Azuma et al., 2001). Additionally, (Azuma, 1997) described augmented reality (AR) as defined by three fundamental characteristics: the seamless blending of real and virtual environments, the ability for real-time interaction, and the accurate three- dimensional placement of virtual objects within the real world. By merging virtual and real elements, AR enables interaction at any time and place, presenting three-dimensional objects— one of its most defining features. This capability creates a uniquely immersive learning experience that differs significantly from traditional methods. Other authors cited the benefits of Augmented Reality in education such as: in healthcare specifically in surgery, medical education, enhancement of clinical practices (Ferrari et al., 2019); increased student participation (Wojciechowski and Cellary, 2013); enhance student engagement, improve learning efficiency, and make education more relevant (Saidin et al., 2015). Augmented Reality's capacity to enable real-time engagement with digitally generated content contributes to its efficacy in creating a more immersive and intuitive learning environment.

Augmented Reality in Biology Education

Studies have indicated that AR can be a valuable tool for improving students' learning outcomes, engagement, and confidence in subjects like ecology, anatomy, molecular biology, and botany (Altinpulluk, 2019). An early example of Augmented Reality (AR) technology involved the creation of physical models of complex biological molecules through 3D printing. These physical models were subsequently digitized, either via 3D scanning or computer modeling. The digital representations were then integrated into a specialized computer interface, enabling manipulation, data analysis, and digital editing of the physical models. Ultimately, these augmented models were rematerialized using 3D printing technology (Gillet et al., 2004). Another example of AR in Biology education is an augmented reality application (AR app) designed for a human skeletal anatomy instructional product (HuMAR) was employed in a teaching context. The research suggests that students who engaged with HuMAR demonstrated improved academic achievement and a heightened interest in the field of anatomy (Jamali et al. 2015). Additionally, (Wang et al., 2023) made use of an interactive, AR-based 3D e-book to visualize the human respiratory system. This application presented a 3D model of the respiratory organs and labeled with anatomical terms. A lesson plan was also created to integrate this AR tool with the learning objectives named "Feeling Our Breath". The study revealed that AR significantly enhanced students' flow experiences, learning motivation, and reduced their cognitive load. While the AR did not significantly impact students' self- efficacy or learning achievement, it demonstrated a positive facilitative effect on their overall learning experience.

Theoretical Framework

Kolb's Experiential Learning Theory

This study is anchored on Kolb's Experiential Learning Theory (KELT). This dynamic perspective posits that

knowledge is constructed through the transformation of experience. Specifically, it involves a cyclical process of grasping and transforming experience (Kolb, 1984). The model delineates two primary modes of grasping experience: concrete experience (CE) and abstract conceptualization (AC). Similarly, it identifies two modes of transforming experience: reflective observation (RO) and active experimentation (AE). As proposed by Kolb, the learning process is a cyclical and interconnected series of stages, each building upon the preceding one. Individuals may enter this cycle at any point and traverse its logical progression. Optimal learning occurs when one cycles through four distinct phases: (1) concrete experience, followed by (2) reflective observation, which then leads to (3) abstract conceptualization, culminating in (4) active experimentation, thereby generating novel experiences. The 4 stages of Kolb's Experiential Learning Theory (ELT) is shown in Figure 1.

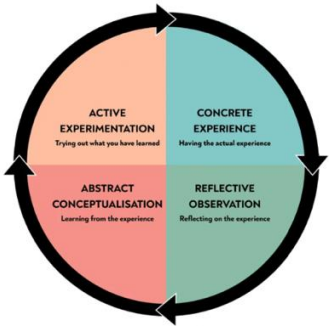

Figure 1. Stages of Kolb's Experiential Learning Theory (ELT)

AR can provide immersive 3D visualizations of complex biology concepts. This allows students to interact directly with otherwise intangible processes and objects, creating a "Concrete Experience." After experiencing the AR module, students can be prompted to reflect on what they observed. Reflecting on their AR experience helps them consolidate their understanding and retain information. AR modules can allow students to experiment by modifying parameters in a simulation. This "Active Experimentation" enables students to test hypotheses and apply their knowledge in simulated experiments, reinforcing learning outcomes.

Statement of the Problem

This study aims to investigate the need for Augmented Reality based e-module by assessing the baseline understanding, interest, confidence, and perceived use of AR applications in enhancing the learning experience in biology of Senior High School students. Specifically, it aims to answer:

a. What is the current level of understanding in Biology concepts of Senior High School Students?

b. How do students perceive the potential of AR to improve their understanding of biology concepts specifically in terms of:

- a. their familiarity and access to AR Technology
- b. their interest and confidence in using AR for learning Biology
- c. their perceived need for Augmented reality based applications

c. Is there a significant difference between Grade 11 and Grade 12 students in their views on the potential of AR to enhance their understanding of biology concepts specifically in terms of:

- a. their familiarity and access to AR Technology

b. their interest and confidence in using AR for learning Biology

c. their perceived need for Augmented reality based applications

Method

This study employs a quantitative survey research design to systematically collect and analyze numerical data from survey questionnaires, thereby addressing the specified research objectives. The following sections detail the methodological approach employed in this study to assess the potential of Augmented Reality (AR)-based modules to enrich the learning experiences of Senior High School students.

Participants

A total of 127 Senior High School students participated in this study. Purposive sampling was employed to deliberately select participants who exhibited the particular characteristics under investigation. The following criteria were applied to the selection of respondents: (1) a senior high school student (either Grade 11 or Grade 12), (2) must be in the STEM strand, (3) Must took or taking General Biology 1 subjects and (4) currently enrolled. In total, 127 students who satisfied the criteria participated in this study.

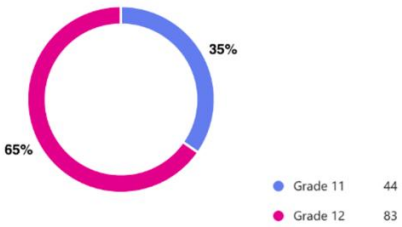

Figure 2. Percentages of the Senior High School Student respondents

Figure 2 presents a visual representation of the distribution of Grade 11 and Grade 12 students who participated in a study. Grade 12 students constitute a significantly larger portion of the participants, accounting for 65% of the total or 83 participants. Grade 11 students make up the remaining 35% or 44 student participants.

Instruments

A researcher-created survey questionnaire was utilized in this study to evaluate the potential benefits of an AR-based module for senior high school biology students. The goal of this module is to improve student engagement and knowledge in biology concepts. The questionnaire was used to assess the baseline understanding, interest, confidence, and perceived use of AR applications for enhancing the learning experience in biology of Senior High School students. The items were divided into 4 categories namely (1) Current Understanding in Biology Concepts, this category is to determine the current level of understanding in Biology concepts of Senior High School Students, (2) Familiarity and Access to AR Technology, this category is to see how familiar students are to AR technology and if they have access in using AR technology, (3) Interest and Confidence in Using AR for Biology learning, this category is to see the students' interests and confidence in using AR in their learning of biology, and

(4) the need for Augmented reality based application, this category is used to establish the need for AR based module for biology.

The researcher-developed survey questionnaire was subjected to content validation by three experts in the fields of biology, Augmented Reality and education. The instrument developed by Duad (2016) was employed as a validation tool for a researcher-designed survey questionnaire, which aimed to assess the needs for an Augmented Reality (AR)–based module to enhance the learning experiences of senior high school students in biology. As the primary purpose of this questionnaire is to analyze the specific needs for an AR-based module rather than broader assessment objectives, establishing the instrument's reliability and conducting pilot testing were considered unnecessary. Therefore, content validation was prioritized as the principal method to affirm the instrument's validity, ensuring it was effective and relevant for data collection in this context. The questionnaire received a high satisfactory rating of 3.86, suggesting that its structure, layout, and overall presentation are clear, easy to understand, and appropriate for the target audience. With a score of 3.93, the language and style used in the questionnaire are deemed highly satisfactory. The questions are phrased clearly, concisely, and in a way that is easily understandable by senior high school students. The content of the questionnaire achieved an outstanding rating of 4.00. This indicates that the questions are relevant, comprehensive, and adequately cover the range of needs related to the development of an AR-based biology module. The overall validity score of 3.93, classified as "Highly Satisfactory," confirms that the survey questionnaire is a reliable tool for assessing the need of AR module in biology of senior high school students. The high scores across all descriptors provide confidence in the validity of the data collected using this instrument and all were shown in Table 1.

Table 1. Results of Content Validation of the Survey Questionnaire used for the Needs Analysis

Descriptors	Expert 1	Expert 2	Expert 3	Validity per Descriptor	Description
Format and Design	4	4	3.6	3.86	*Highly Satisfactory*
Language and Style	4	4	3.8	3.93	*Highly Satisfactory*
Content	4	4	4	4.00	*Outstanding*
Overall Validity			3.93 (*Highly Satisfactory*)		

Data Collection

Prior to the commencement of the survey, formal approval to conduct the research study was secured from the designated research coordinator of the intended research site. This process involved a detailed discussion of the study's context, ethical considerations, and specific protocols to ensure adherence to ethical guidelines. Subsequently, upon obtaining necessary permissions, informed consent forms were provided to all prospective student participants. These forms outlined the study's objectives, the potential benefits and risks associated with participation, and the measures implemented to safeguard the privacy and confidentiality of all collected data. The survey instrument was administered online via Microsoft Forms. The online platform facilitated the efficient collection of data, while also providing a clear and concise explanation of the study's purpose. Participants were required to electronically indicate their informed consent by ticking the provided consent button prior to

commencing the questionnaire.

Data Analysis

The responses of Senior High School students to a needs assessment questionnaire were analyzed using descriptive statistics (mean and standard deviation) to establish a baseline understanding of their interest, confidence, and perceived utility of Augmented Reality (AR) applications in enhancing biology education. Independent t-test was used to compare the means of two independent groups, in this case the two independent groups are Grade 11 and Grade 12 students. The t-test compares the means of the two groups to determine if the difference between them is statistically significant.

Results

Current Understanding of Biology Concepts

Table 2 represents the students' response in terms of 'How satisfied are you with the current understanding of Biology concepts. It was found out that the weighted mean is 2.953 showing that the students are satisfied with their understanding of Biology concepts.

Table 2. Students' Current Understanding of Biology Concepts

	n	*M*	SD
1. How satisfied are you with your current understanding of biology concepts?	127	2.95	0.775

1.0-1.49: Not Satisfied; 1.50-2.49: Somewhat Satisfied; 2.50-3.49: Satisfied; 3.50-4.00: Very Satisfied

Table 3 shows the students' response in terms of how difficult the concepts are. It was found out that in terms of the concept of learning the cell, it was perceived as difficult with a mean of 2.819 while in terms of biological molecules and energy transformation, it were deemed somewhat difficult with a mean of 2.433 and 2.488 respectively.

Table 3. Students' Perceived Difficulty of Biology Concepts

	n	*M*	SD
2.a. The Cell	127	2.81	0.771
2.b. Biological Molecules	127	2.43	0.685
2.c. Energy Transformation	127	2.48	0.689

1.0-1.49: Not difficult; 1.50-2.49: Somewhat difficult; 2.50-3.49: difficult; 3.50-4.00: Very difficult

Table 4 shows the respondents' reason for difficulty in terms of the cell concept. It was found out that majority of the reason is 'There was too much memorization' with a frequency of 46 and a percentage of 49.462%. Indeed according to the study of (Veres et al., 2023) to have an understanding of the different cellular processes it requires significant amount of memorization, but it is also important to focus more on understanding concepts over rote

memorization. Next reason is ‘It was hard to picture the concepts in my mind’ with as frequency of 27 and a percentage of 49.462%. Then the reason of ‘The terms were too hard to understand’ with a frequency of 11 and a percentage of 11.828% and lastly, ‘I need a different approach to learning the material’ with a frequency of 9 and a percentage of 9.677%.

Table 4. Reason for Difficulty in terms of the Cell Concept

The Cell	Frequency	Percent	Cumulative Percent
The terms were too hard to understand.	11	11.828	11.828
It was hard to picture the concepts in my mind.	27	29.032	40.860
There was too much memorization.	46	49.462	90.323
I need a different approach to learning the material.	9	9.677	100.000

Table 5 shows the respondents’ reason for difficulty in terms of the concept of biological molecules. It was found out that majority of the reason is ‘It was too hard to picture the concepts in my mind’ with a frequency of 37 and a percentage of 37%. According to the study of (Bennett & Schwenk, 1974) saying that indeed understanding biological molecules can be challenging, as chemical formulas are often depicted in two dimensions, which complicates the visualization of their three-dimensional structures. With this difficulty AR can help because, Augmented reality (AR) is a technology with the potential to aid students in comprehending abstract scientific concepts. AR enhances and alters a user's perception of reality (Swensen, 2016). Next reason is the ‘There was too much memorization’ with a frequency of 30 and a percentage of 30%. Then the reason of ‘The terms were too hard to understand’ with a frequency of 21 and a percentage of 21%. Lastly, the reason is ‘I need a different approach to learning the material’ with a frequency of 12 and a percentage of 12%.

Table 5. Reason for Difficulty in terms of Biological Molecules

Biological Molecules	Frequency	Percent	Cumulative Percent
The terms were too hard to understand.	21	21.000	21.000
It was hard to picture the concepts in my mind.	37	37.000	58.000
There was too much memorization.	30	30.000	88.000
I need a different approach to learning the material.	12	12.000	100.000

Table 6 shows the respondents’ reason for difficulty in terms of Energy transformation concept. It was found out that majority of the reason is ‘It was too hard to picture the concepts in my mind’ with a frequency of 34 and a percentage of 35.417%. Understanding energy transformation can be challenging due to its abstract nature. However, various instructional strategies can enhance comprehension by making these concepts more tangible.

Employing diverse representations, including diagrams, simulations, and real-world examples, effectively elucidates complex concepts such as energy transfer, transformation, and conservation. This strategy has been demonstrated to enhance students' conceptual comprehension of energy (Yap & Lau, 2023). Augmented reality offers a potential solution to the challenge of visualizing abstract concepts. This technology can be employed to render models of systems and processes, illuminate details of complex objects, and visualize abstract entities. (Kravtsov and Pulinets, 2020) Next reason is 'There was too much memorization' with the frequency of 32 and a percentage of 33.333%. Then the reason of 'I need a different approach to learning the material' with a frequency of 17 and a percentage of 17.708. Lastly, the reason 'The terms were too hard to understand' with a frequency of 13 and a percentage of 13.542%.

Table 6. Reason for Difficulty in terms of Energy Transformation

Energy Transformation	Frequency	Percent	Cumulative Percent
The terms were too hard to understand.	13	13.542	13.542
It was hard to picture the concepts in my mind.	34	35.417	48.958
There was too much memorization.	32	33.333	82.292
I need a different approach to learning the material.	17	17.708	100.000

Table 7 presents the students' responses regarding their familiarity with and access to Augmented Reality (AR) technology. The data indicates that Question 3 yielded a mean score of 2.063, which is interpreted as "somewhat familiar," suggesting that students have a moderate level of familiarity with the concept of AR. For Question 4, the mean score was 2.024, interpreted as "seldom," indicating that teachers rarely incorporate AR into their teaching practices. Meanwhile, Question 6 recorded a mean score of 3.409, interpreted as "often," signifying that students frequently have access to devices that enable the use of AR applications, either through personal ownership or provisions made by the school.

Table 7. Students' Responses in terms of Familiarity and Access to AR Technology

	M	SD
3. How familiar are you with Augmented Reality?	2.06	0.932
4. My teachers use Augmented Reality tools in Biology lessons.	2.02	0.913
6. Whenever needed, there are AR devices I can use (either your own or provided by the school)	3.40	0.494

1.0-1.49: Not familiar at all/Never; 1.50-2.49: Somewhat familiar/Seldom; 2.50-3.49: familiar/Often; 3.50-4.00: Very familiar/Always

Table 8 above shows the students' responses in terms of interest and confidence in using AR for Biology Learning. Based on the table, it was found out that the mean of question 5 is 3.087 interpreted as Interested suggesting that

students are interested in using Augmented Reality to improve their understanding in various biology concepts. Question 7 has a mean of 3.008 interpreted as Confident suggesting that students are confident that when they used interactive modules it can support their learning in biology concepts and question 6 has a mean of 3.000 interpreted as Confident suggesting that students are confident in using Augmented Reality to improve their learning in Biology concepts. Students exhibit a growing interest in utilizing Augmented Reality (AR) in biology education, as it enhances engagement and understanding of complex concepts. AR technology effectively bridges the gap between abstract biological ideas and tangible learning experiences, fostering motivation and collaboration among students. The study of (Stojšić & Ostojić, 2022) shows that students view AR applications as useful and easy to use, and are eager to use them in their studies. When it comes to confidence in using Augmented Reality to improve their learning, the study of (Guo & Kim, 2022) highlights that the use of AR technology in educational settings has the potential to increase confidence in their learning decisions.

Table 8. Students' Responses in terms of Interest and Confidence in using AR for Biology Learning

	M	SD
5. How interested are you in using Augmented Reality to improve your understanding of biology concepts?	3. 08	0.817
7. How confident are you that interactive modules (accessible on Android devices or school computers) can support your leaning of biology concepts?	3.00	0.761
10. How confident are you in using Augmented Reality technology to learn biology?	3.00	0.701

1.0-1.49: Not Interested/confident at all; 1.50-2.49: Somewhat Interested/confident; 2.50-3.49: Interested/confident; 3.50-4.00: Very Interested/confident.

Table 9 shows the students' responses in terms of the need for Augmented Reality based applications for their biology learning. Based on the table, it was found out that the mean of question 8 has a mean of 3.394 and interpreted as Agree suggesting that the students believe that using AR will make their biology learning will be more interesting and engaging suggesting the need for it. Specifically, according to the study of (Sathyapriya et al., 2024) AR revolutionizes traditional pedagogy by offering interactive, multisensory experiences that captivate and motivate learners. And question 9 has a mean of 3.299 interpreted as agree suggesting that students believe that they can improve their understanding of biology with the help of Augmented Reality.

Table 9. Students' Responses in terms of the Need for Augmented Reality Based Applications

	M	SD
8. I believe that using AR technology to learn biology will be more interesting and engaging.	3.39	0.506
9. I believe that I can improve my understanding of biology with the help of AR.	3.29	0.509

1.0-1.49: Strongly Disagree; 1.50-2.49: Disagree; 2.50-3.49: Agree; 3.50-4.00: Strongly Agree

The following results shows the result of the independent samples t-test showing if there's a significant difference between grade 11 and grade 12 in their views on the potential of AR to enhance their understanding of biology concepts specifically their familiarity, access, interest, confidence and perceived needs.

Table 10 shows the significant difference between grade 11 and 12 students in their views on the potential of AR to enhance their understanding of biology concepts in terms of their familiarity and access to AR Technology. The null hypothesis is 'Grade 11 and Grade 12 students are not significantly different in terms of their familiarity and access to AR Technology'. Moreover, the alternative hypothesis is 'Grade 11 and Grade 12 students are significantly different in terms of their familiarity and access to AR Technology'. The null hypothesis will be rejected if the p-value is less than the level of significance (0.05). Based on the table, it was found out that the p-values of question 3, 4, and 6 are greater than 0.05, hence null hypothesis will not be rejected. Thus, there is enough evidence to say that Grade 11 and Grade 12 students are not significantly different in terms of their familiarity and access to AR Technology. This suggests that Grade 11 and Grade 12 students are equally familiar with and have similar access to AR technology.

Table 10. Independent Samples T-Test Result of Grade 11 and Grade 12 Students in terms of Their Familiarity and Access to AR Technology

	t	df	p
3. How familiar are you with Augmented Reality?	0.954	125	0.342
4. My teachers use Augmented Reality tools in Biology lessons.	-1.220	125	0.225
6. Whenever needed, there are AR devices I can use (either your own or provided by the school)	0.382	125	0.703

Note. Student's t-test

Table 12 shows the significant difference between grade 11 and 12 students in their views on the potential of AR to enhance their understanding of biology concepts in terms of their interest and confidence in using AR for Biology. The null hypothesis is 'Grade 11 and Grade 12 students are not significantly different in terms of their interest and confidence in using AR for Biology'. Moreover, the alternative hypothesis is 'Grade 11 and Grade 12 students are significantly different in terms of their interest and confidence in using AR for Biology'. The null hypothesis will be rejected if the p-value is less than the level of significance (0.05). Based on the table, it was found out that the p-values of question 7, and 10 are greater than 0.05, hence H_0 (null hypothesis) will not be rejected. However, the p-value for question 5 is less than α=0.05, thus, the H_0 will be rejected for this question. Therefore, there is enough evidence to say that only the interest of grade 11 and grade 12 students in using Augmented Reality to improve their understanding of Biology concept is statistically different. This implies that while both grades share similar confidence levels, their interest in using AR technology to understand biology concepts differs. Consistent with these findings, Alviar et al. (2021) investigated the impact of augmented reality (AR) as a supplementary learning tool on the interest and confidence levels of Grade 12 students in cell biology. Their study demonstrated that the use of AR applications effectively engaged students, stimulating their curiosity. Moreover, the research indicated a positive correlation between AR utilization and increased student confidence

in comprehending cell biology concepts.

Table 12. Independent Samples T-Test Result of Grade 11 and Grade 12 Students in terms of Their Interest and Confidence in Using AR Technology for Biology

	t	df	p
5. How interested are you in using Augmented Reality to improve your understanding of biology concepts?	-2.613	125	0.010
7. How confident are you that interactive modules (accessible on Android devices or school computers) can support your leaning of biology concepts?	0.085	125	0.933
10. How confident are you in using Augmented Reality technology to learn biology?	-1.064	125	0.289

Note. Student's t-test

The table above shows the significant difference between grade 11 students in their views on the potential of AR to enhance their understanding of biology concepts in terms of their perceived need for Augmented Reality based applications. The null hypothesis is 'Grade 11 and Grade 12 students are not significantly different in terms of their perceived need for Augmented Reality based applications'. Moreover, the alternative hypothesis is 'Grade 11 and Grade 12 students are significantly different in terms of their perceived need for Augmented Reality based applications'. The null hypothesis will be rejected if the p-value is less than the level of significance (0.05). Based on the table, it was found out that the p-values of question 8, and 9 are greater than 0.05, hence null hypothesis will not be rejected. Thus, there is enough evidence to say that Grade 11 and Grade 12 students are not significantly different in terms of their perceived need for Augmented Reality based applications. Both groups perceive the need for AR applications similarly. In accordance with this result, the study of (Alviar et al., 2021) examines the influence of AR on the academic achievement of Grade 12 students in cell biology. The findings indicate that the AR group, which incorporated AR into their learning process, experienced a substantial 22.11% enhancement in average scores. Conversely, the control group, which did not utilize AR, achieved a more limited 5.84% improvement. With this, it can be said that AR can enhance students' scores while using Augmented Reality applications.

Table 13. Independent Samples T-Test Result of Grade 11 and Grade 12 Students in terms of Their Perceived Need for AR Based Applications

	t	df	p
8. I believe that using AR technology to learn biology will be more interesting and engaging.	0.616	125	0.539
9. I believe that I can improve my understanding of biology with the help of AR.	0.060	125	0.952

Note. Student's t-test

Discussion and Conclusion

This study aims to investigate students' access to and familiarity with augmented reality (AR) technology. According to the study of (Kozov & Ivanova, 2023) familiarity in Augmented Reality (AR) enriches students' educational experiences by fostering greater engagement, enhancing problem-solving skills, promoting collaboration, and stimulating creativity. Another facet of this study is to investigate students' interest and confidence with using Augmented Reality. Students exhibit a growing interest in utilizing Augmented Reality (AR) in biology education, as it enhances engagement and understanding of complex concepts. AR technology effectively bridges the gap between abstract biological ideas and tangible learning experiences, fostering motivation and collaboration among students. The study of (Stojšić & Ostojić, 2022) shows that students view AR applications as useful and easy to use and are eager to use them in their studies. When it comes to confidence in using Augmented Reality to improve their learning, the study of (Guo & Kim, 2022) highlights that the use of AR technology in educational settings has the potential to increase confidence in their learning decisions. Additionally, this study also aims to investigate students' perceived need for Augmented Reality in learning Biology. Students believes that with the help of Augmented reality, it can improve their level of understanding in biology, this is in line with the study of (Subran & Mahmud, 2024)(Tamam & Corebima, 2023) stating that studies indicate that augmented reality (AR) significantly improves knowledge retention, with students exhibiting a better recall of biological concepts compared to those using traditional learning methods.

The statistical evidence suggests a significant difference in interest in using Augmented Reality (AR) to enhance understanding of Biology concepts between Grade 11 and Grade 12 students. While their confidence levels appear similar, their interest in AR technology for learning biology diverges. This observation aligns with the findings of Alviar et al. (2021), who explored the effects of AR as a supplementary learning tool on Grade 12 students' interest and confidence in cell biology. Their research indicated that AR applications effectively fostered student engagement and curiosity, and further revealed a positive relationship between AR use and increased confidence in comprehending cell biology concepts.

This study aims to investigate the need for Augmented Reality based e-module by assessing the baseline understanding, interest, confidence, and perceived use of AR applications in enhancing the learning experience in biology of Senior High School students. The paper follows a descriptive quantitative research design using a researcher made questionnaire divided into 4 categories namely (1) Current Understanding in Biology Concepts, (2) Familiarity and Access to AR Technology, (3) Interest and Confidence in Using AR for Biology learning, and (4) the Need for Augmented reality-based application. Analysis was done using descriptive statistics.

Results shows that student respondents expressed satisfaction with their current comprehension of biological concepts. However, they identified cell biology as a particularly challenging topic, while classifying biological molecules and energy transformation as moderately difficult. Specifically, students attributed the difficulty of cell biology to its heavy reliance on memorization. For biological molecules and energy transformation, the primary challenge was the abstract nature of the concepts, making them difficult to visualize. Augmented Reality (AR)

can help address these challenges by providing interactive, three-dimensional visualizations of cellular structures, biological molecules, and energy transformation processes. This immersive approach enables students to explore complex systems in a hands-on manner, making abstract concepts more tangible and enhancing memory retention through engaging, visual learning experiences.

This study also examined students' familiarity with and access to Augmented Reality (AR). The findings revealed that students are "somewhat familiar" with AR and frequently use it as a tool in learning biology. Additionally, they have access to devices that support AR applications, enabling its use in educational settings. The t-test result for grade 11 and grade 12's familiarity and access to AR reveals theres no statistically significant difference between the two groups. This suggests that Grade 11 and Grade 12 students are equally familiar with and have similar access to AR technology. The need for an AR module is evident, as it provides an innovative and interactive approach to addressing challenges in traditional biology instruction, such as abstract or complex topics. By offering immersive and engaging experiences, an AR module can bridge the gap between theoretical knowledge and practical understanding, making biology concepts more accessible and relatable for students.

When it comes to interest and confidence in using AR in biology learning, student responses indicate a strong interest in utilizing augmented reality (AR) as a tool to enhance their comprehension of various biology concepts. Most students believe that interactive modules incorporating AR can significantly improve their learning experience. Regarding interest, students expressed interest for utilizing AR to enhance their understanding of biological concepts and demonstrated confidence that incorporating AR would significantly improve their learning outcomes. This finding underscores the potential of AR to provide an engaging and effective learning environment, regardless of the students' academic level. The t-test result of grade 11 and grade 12 students when it comes to their interest and confidence in AR reveals that while both grades share similar confidence levels, their interest in using AR technology to understand biology concepts differs, with a statistically significant difference. The integration of AR in interactive educational modules is particularly vital in subjects like biology, where complex structures, processes, and systems often challenge traditional teaching methods. By fostering both engagement and confidence, AR-based interactive modules can transform the learning landscape and better prepare students for advanced scientific studies.

To establish the need for Augmented Reality based applications in classroom, responses from students highlight a strong preference for incorporating Augmented Reality (AR) applications in biology education, emphasizing their belief that AR can make learning more interesting, engaging, and effective. The result of the t-test between Grade 11 and 12 in terms of their perceived need for AR based module reveals that there's no significant difference. Both groups perceive the need for AR applications similarly. This feedback underscores the need for an interactive module that integrates AR-based applications, as it could transform traditional learning methods, increase student engagement, and foster a deeper comprehension of biology.

Recommendations

Based on the findings of this study, it is recommended that educational institutions integrate Augmented Reality

(AR) modules into the biology curriculum to enhance student engagement, comprehension, and retention of complex biological concepts. Given that students expressed strong interest and confidence in using AR for learning, educators should leverage this technology to create interactive and immersive experiences that facilitate understanding. The results also indicate that while students are somewhat familiar with AR, their access and exposure to its applications in the classroom remain limited. Schools should consider investing in AR-compatible devices and training teachers to effectively incorporate AR-based lessons into their instruction.

Future research should explore the long-term impact of AR in biology education, as well as its effectiveness across different learning styles and academic levels. Ultimately, integrating AR in biology education aligns with the advancements of Industry 5.0, fostering an innovative and interactive learning environment that supports student success.

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References

Al-Emran, M., & Al-Sharafi, M. A. (2022). *Revolutionizing education with industry 5.0: challenges and future research agendas*. IJITLS, 6(3), 1-5.

Alice, S., Bennett., Karl, Schwenk. (1974). 1. *3-D Structure of Molecules of Biological Significance*. American Biology Teacher, doi: 10.2307/4444988

Altinpulluk, H. (2019). *Determining the trends of using augmented reality in education between 2006-2016. Education and Information Technologies*, 24(2), 1089–1114. https://doi.org/10.1007/s10639-018-9806-3

Alviar, A. M. R., Fernandez, A. J. V., Parcia, J. R., Recato Dy, J. K. L., & Villarba, J. D. B. (2021). *Exploring the Viability of Augmented Reality as a Supplementary Material for Learning Cell Biology and Photosynthesis for Grade 12 Students.*

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). *Recent advances in augmented Reality. IEEE Computer Graphics and Applications*. https://doi.org/10.1109/38.963459

Badrud, Tamam., Aloysius, Duran, Corebima. (2023). 5. *Implementing augmented reality to improve students' biology learning outcomes: Gender-based effect*. International Journal of Evaluation and Research in Education, doi: 10.11591/ijere.v12i4.25645

Boon, Chien, Yap., Donavan, Lau. (2023). 4. *Using Multiple Representations to Teach Energy– An Alternative Conceptual Approach.* doi: 10.22492/issn.2189-1036.2023.17

Caudell, T. P., & Mizell, D. W. (2003). *Augmented Reality: an application of heads-up display technology to manual manufacturing processes.* https://doi.org/10.1109/hicss.1992.183317

Ciloglu, T., & Ustun, A. B. (2023). *The effects of mobile ar-based biology learning experience on students' motivation, self-efficacy, and attitudes in online learning.* Journal of Science Education And Technology,

32(3), 309–337.https://doi.org/10.1007/s10956-023-10030-7

Duad, C.B. (2016). *Development of a Strategic Intervention Material (SIM) for Grade 10 Science: Chemical Equations and Reactions.* Manuscript submitted for publication.

Ferrari, V., Klinker, G., & Cutolo, F. (2019). *Augmented Reality in Healthcare*. Journal of healthcare engineering, 2019, 9321535. https://doi.org/10.1155/2019/9321535

Gillet, A., Sanner, M., Stoffler, D., Goodsell, D., & Olson,A. (2004, October). *Augmented reality with tangible auto-fabricated models for molecular biology applications.* In IEEE Visualization 2004 (pp. 235-241). IEEE.

J., Sathyapriya., K., Vedavalli., Swathi, Sree, M.. (2024). *Enhancing Engagement and Understanding in Education using Augmented Reality.* Journal of Information Technology and Digital World, doi: 10.36548/jitdw.2024.3.005

Jamali, S. S., Shiratuddin, M. F., Wong, K. W., & Oskam, C. L. (2015). *Utilizing mobile-augmented reality for learning human anatomy*. Procedia - Social and Behavioral Sciences, 197, 659–668. https://doi.org/10.1016/j.sbspro.2015.07.054

Kacprzyk J (2019). *Industry 4.0: Industrial Revolution of the 21st Century Studies in Systems, Decision and Control* vol 169 ed E G Popkova, Y V Ragulina and A V Bogoviz (Switzerland: Springer)

Kravtsov, Hennadiy; Pulinet, Anastasia. (2020). *Interactive Augmented Reality Technologies for Model Visualization in the School Textbook.* EasyChair Preprint Kherson State University, Ukraine,4536.

Permana, T. I., Husamah, H., Nurhamdani, M. I., Zaskia, A., Savitri, A., & Salsabila, D. A. (2024). *Augmented reality in biology education: A systematic literature review.* Research and Development in Education (RaDEn), 4(1), 630-652.

Santos, M.E.C., Lübke, A.i., Taketomi, T. et al. (2016). *Augmented reality as multimedia: the case for situated vocabulary learning.* RPTEL 11, 4 (2016). https://doi.org/10.1186/s41039-016-0028-2

Stojšić, I., Ostojić, N., & Stanisavljević, J. (2022). *Students' Acceptance of Mobile Augmented Reality Applications in Primary and Secondary Biology Education.* International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE), 10(3), 129–138. https://doi.org/10.23947/2334-8496-2022-10-3-129-138

Suhaida, Subran., Siti, Nur, Diyana, Mahmud. (2024). 2. *Augmented Reality (AR) Technology in Biology and Life Science Education: A Systematic Literature Review (SLR).* International Journal of Academic Research in Progressive Education and Development, doi: 10.6007/ijarped/v13-i1/20455

Swensen H. (2016). *Potential of augmented reality in sciences education. A literature review..* In: Gómez Chova L, López Martínez A, Candel Torres I. ICERI2016 Proceedings. 9th International Conference of Education, Research and Innovation, 2016. Associated University Presses p. 2540-2547

Tamas, Veres., Márk, Kerestély., Borbala, M., Kovacs., David, Keresztes., K., Schulc., Erik, Seitz., Zsolt, Vassy., Daniel, V., Veres., Peter, Csermely. (2023). *Cellular forgetting, desensitisation, stress and ageing in signalling networks. When do cells refuse to learn more?.* doi: 10.1007/s00018-024-05112-7

Wenbin, Guo., Jung, Hyup, Kim. (2022). 3. *Investigating Academic Performance Using an AR-based Learning Environment with Retrospective Confidence Judgments.* Proceedings of the Human Factors and Ergonomics Society ... Annual Meeting, doi: 10.1177/1071181322661333

Wojciechowski, R., & Cellary, W. (2013). *Evaluation of learners' attitude toward learning in ARIES augmented*

reality environments. Computers and Education. https://doi.org/10.1016/j.compedu.2013.02.014

Xiao-Ming Wang, Qing-Nan Hu, Gwo-Jen Hwang & Xiao-Han Yu (2023) *Learning with digital technology-facilitated empathy: an augmented reality approach to enhancing students' flow experience, motivation, and achievement in a biology program*, Interactive Learning Environments, 31:10, 6988-7004, DOI: 10.1080/10494820.2022.2057549Armstrong, D. (2019). Malory and character. In M. G. Leitch & C. J. Rushton (Eds.), *A new companion to Malory* (pp. 144-163). D. S. Brewer.

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