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The Impact of Augmented Reality (AR) on Student Engagement and Learning outcomes in Biology Education

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Abstract

It is suggested that Augmented Reality has the potential to be one of the learning processes that effect the impact of increasing student achievement level for secondary school. This study seeks to investigate the effects of using AR on the student interest and achievement in Plant Physiology topic in Biology subject of Form Five. The study was conducted in Temerloh, Pahang and involved only one secondary school. The selected design of this study was quasi experiments and the used approach was quantitative. As stated, two groups were formed and the data collection and analysis processes were conducted.A sample of 50 Form Five students was chosen for the study. This purposive sample was based on predetermined criteria. The samples were divided into control and treatment groups. A set of achievement tests, pre and post-test, and a questionnaire was used to measure the interest and achievement levels of the students on the effectiveness of using Augmented Reality to improve interest and achievement on the topic of Plant Physiology in the Biology subject of For Five. The study showed an improvement in achievement scores in the treatment group compared to the control group.It is therefore evident that the use of teaching and learning materials such as AR can assist to improve achievement. A vast majority of students are interested in learning Plant Physiology with the use of AR or even other themes. In conclusion, this study could enable students and teachers to employ AR in the classroom for learning.

Keywords: Augmented Reality, Achievement, Plant Physiology Theme, Biology, interest

Introduction

IR 4.0 has introduced several alterations in different areas of human existence, such as education (Khairani et al., 2020). The idea of Education 4.0 has led to developments in education that allow for learning at any time and place (Hussin et al., 2021). However, due to their disinterest in conventional educational methods, teaching the Z and Alpha generations has grown more challenging (Ghani et al., 2021). Today's students' primary challenges with academic performance include a deficiency in inventive ideas, motivation, and originality (Ghani et al., 2021). Given that the Z and Alpha generations have grown up with constant

access to the internet and information technology, integrating technology into education is critical to improving the educational experience (Marcus, 2018).

Information technology has quickly advanced in the sphere of education, in line with the Secondary School Standard Curriculum (KSSM) for Biology (Mohd Sufi & Faizah, 2022).
The application of technology in education has been the focus of research. AR stands for augmented reality (Amelia et al., 2020). AR enhances the educational experience by combining digital and physical elements, utilizing 3D technology (Yung et al., 2017). It has been shown that using augmented reality (AR) can streamline and provide flexibility for learning while also improving students' understanding, engagement, and motivation to study. There are still problems in biology teaching, particularly with the use of visual aids and students' understanding of scientific concepts (Muda et al., 2015). This can cause students to lose interest in biology and fail to understand ideas, particularly in physiology (Shaharim et al., 2022). To address these issues, augmented reality (AR) technology is becoming more and more important in biology education (Hsiao et al., 2012; Bressler et al., 2013). Though AR is widely utilized in the medical field, its application in the teaching of KSSM Biology is still limited (Küçük et al., 2016; Çakır et al., 2021; Yap et al., 2021).

This study aims to evaluate the impact of AR on students' learning and performance in Form Five Biology's Flowering Plant Physiology course. The purpose of the study is to assess how well the augmented reality teaching approach increases student achievement and appeal of augmented reality in raising students' interest in the topic (Shaharim et al., 2022). This work is essential to improving students' understanding of difficult biology topics and supporting the development of more efficient mental models of scientific concepts (Shaharim et al., 2022). Because of this, this research has the potential to significantly improve biology education by offering more innovative and effective teaching strategies.

Literature Review

Augmented Reality (AR)

By using mobile devices to interact with AR apps and 3D objects, augmented reality (AR) has the potential to completely transform education (Yen et al., 2013). Benefits of AR in school include better learning outcomes and interaction with abstract concepts and knowledge (Yoon et al., 2020). Additionally, studies show that AR can strengthen users' capacity for learning and help them grasp topics better (Kiryakova et al., 2018). Several academic fields, including chemistry, physics, and mathematics, have adopted AR technology, as reported by Purnama et al. (2019), Fidan et al. (2019), and Demitriadou et al. (2020). Through the use of programs like ATTech and HuMAR, augmented reality has been used in the field of biology to increase learning efficiency (Korenova et al., 2019; Jamali et al., 2015). Moreover, AR is also used to research the digestive tract of humans (Rizqi et al., 2021). Using augmented reality (AR) in the classroom improves student engagement and comprehension while reducing cognitive load (Norafizah & Khalid, 2022; Wei et al., 2015).
Moreover, research by Birt et al. (2018) and Moro et al. (2017) shows that AR is effective in enhancing anatomy and physiology teaching. Passive learning has given way to more dynamic and engaging student participation thanks to AR-based instructional strategies (Stirling & Birt, 2014; Stirling & Moro, 2020). Research has demonstrated that incorporating augmented reality (AR) into the classroom can effectively increase student engagement, comprehension, and enthusiasm (Boyles, 2017; Smith et al., 2022; Ho, 2020; Sattar et al., 2020). AR in

education can make abstract subjects easier to understand using visual aids (Ho, 2020).
AR has the potential to improve concept comprehension, increase motivation, and pique students' interest in biology teaching. Additionally, AR helps students' cognitive load be reduced and increases their inventiveness when working on projects. It is anticipated that AR would be widely employed in Malaysia to improve biology and other topic learning for students.

Augmented Reality (AR) in Education

Studies indicate that the integration of Augmented Reality into the classroom improves students' conceptual understanding and boosts their academic performance (Cai et al., 2013; Lin et al., 2013; Chang et al., 2016). Despite its limited use, augmented reality (AR) has been shown to improve student motivation and performance (Bacca-Acosta et al., 2014). Effective AR interfaces can positively affect learning results, claim Cao and Cerfolio (2019). According to Nincarean et al. (2013), integrating augmented reality (AR) into the classroom helps foster a sense of interest and improve students' understanding of various disciplines.

Augmented Reality (AR) in Biology Learning

Biology is a fascinating subject since it deals with both microscopic and macroscopic parts of the world, but it also demands a deep understanding of concepts and a strong basis in knowledge. Numerous studies have indicated that utilizing augmented reality (AR) Technology can help biology lessons be learned more effectively. The usage of the mobile application ATTech System for learning about subjects including mitosis, meiosis, and respiration was investigated in a study by Korenova et al. (2019) and the results showed improved effectiveness and attractiveness in the learning process. Jamali et al. (2015) reported that the HuMAR AR app, which focuses on the bones in the appendicular skeleton, also showed gains in comprehension, drive, and educational efficiency. Additionally, Rizqi et al. (2021) have developed a smartphone application named

Methodology

In order to compare two classes—one utilizing an AR application to teach Flowering Plant Physiology in Biology and the other using conventional methods—this study used quasi-experimental approaches. Fifty Form Five students participated in the study after being carefully selected based on distinct attributes and objectives as opposed to at random. For four weeks, pre- and post-tests on the subject of flowering plant physiology are administered to both the treatment and control groups. The reliability of the research instrument used to evaluate achievement levels has been tested, but validation testing is still necessary, in accordance with the criteria set by Korkamaz et al. (2017) and Pallant (2001).
Two expert Biology teachers examined the content validity testing, and reliability was evaluated by analyzing Cronbach's Alpha values. SPSS V27 was used for analyzing data to gather descriptive information about the academic performance level in utilizing Augmented Reality in Form Four Biology.

Domain	Item	No. Question
Plant Physiology Theme	5 Tittle related to Plant Physiology	30

The pre-test and post-test in this study follow the Test Specification Table (TST) for biology. Test and monitor achievement scores and mastery levels of themes according to the specified

levels in the TST. The post-test is essential for researchers to evaluate the impact of teaching and learning with Augmented Reality in the Flowering Plant Physiology topic.

Achievement Scores	Grade	Scale
90-100	A+	A
70-79	A-	
65-69	B+	B
60-64	B	
55-59	C+	C
50-54	C	
45-49	D	F
40-44	E	
0-39	G	

Source: The Evaluation and Certification Unit of MARA Higher Education Division

Descriptive statistics, such as minimum values and standard deviations, were used to analyze data from the study on the academic performance of Form Four students.

Percentage (%)	Level
80-100	Very High
70-79	High
55-69	Moderate
40-54	Low
0-39	Very Low

This study uses a survey method to measure the level of interest and acceptance of using AR in learning. The questionnaire is divided into two parts, Part A for demographic information of respondents and Part B to assess students' interest in the effectiveness of using Augmented Reality in the Flowering Plant Physiology theme. The questionnaire is given to the treatment group only, which participates in teaching and learning sessions using Augmented Reality (AR). The research instrument utilizes a five-point Likert scale (1- Strongly Disagree (SD), 2- Disagree (D), 3- Neutral (N), 4- Agree (A), 5- Strongly Agree (SA)) because the clarity of its statements can be well measured. The validity and reliability of items are tested using Cronbach's alpha coefficient.

The ADDIE model is used in the study design because it involves both quantitative and qualitative data with the TUP Bednarik Model. Data collection processes are conducted through pre- and post-tests. The ADDIE model is chosen because it is more flexible and encompasses all the study's requirements. This model is used by educators to analyze and develop software and teaching materials based on needs. The ADDIE model serves as the foundation for many other instructional design models and requires adjustments before use. Its purpose is to produce more effective and efficient teaching and learning plans.

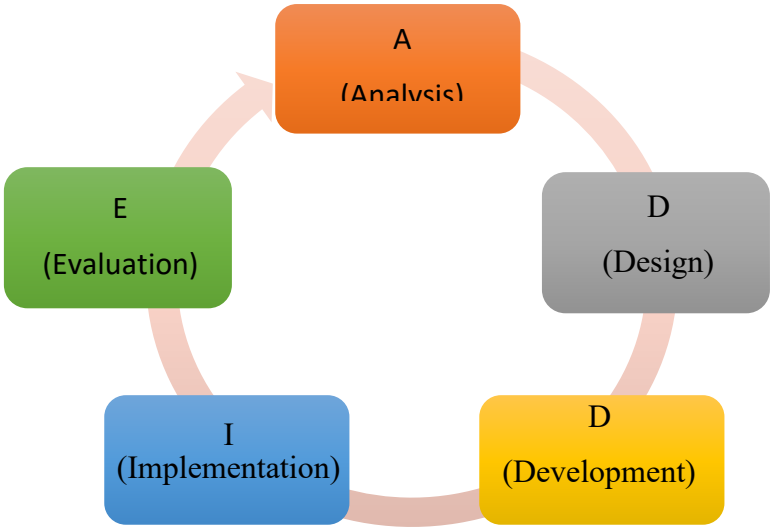

Figure 2: Workflow Based on ADDIE Model

Phase 1: Analysis
During this phase, problem analysis is conducted by examining the weaknesses of Form Five students in mastering the topic of Flowering Plant Physiology in the Biology subject. This analysis is based on thorough and open observation and assessment.

Phase 2: Module Design
During this phase, the six fundamental elements of the ADDIE Model are emphasized to address the previously identified problems. Storyboards and narrative boards are created to visually outline each sequence of content, while interface designs are developed based on the completed storyboard. These steps are taken to ensure the continuity of the storyline and to organize a structured procedural flow.

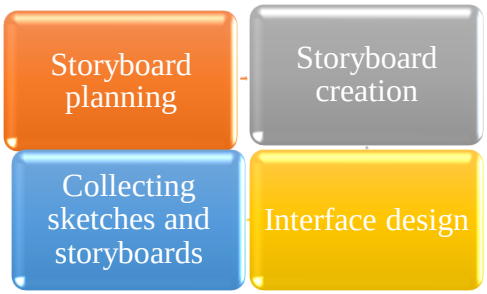

Figure 3: Workflow in Phase 2

Phase 3: Module Development
During this phase, the designs from the previous phase are transformed into a system or program that will become the application to solve the problem. Several key software is utilized, including the Unity Real-Time Development Platform, Blippar, PlantAR, Canva, and 3Ds Max to complete the development of the Flowering Plant Physiology AR application.

Phase 4: Implementation
This phase aims to ensure that the developed application functions properly before it is published. The usability of the application is also evaluated in this phase to ensure that it can

achieve the set objectives.

Phase 5: Test

The Alpha testing method is used to identify any errors or mistakes that occur within the application. Feedback is also obtained from project supervisors and external respondents to ensure a satisfactory final outcome.

Result and Discussion

Demographic

This research included a grand total of 50 students in Form Five. In this group, 52% of the students were female (26 students), and the remaining 48% were male (24 students). The results show that there are more female students than male students in the study group, with a discrepancy of two people. This demographic study offers valuable information about the makeup of participants and can help in creating more precise conclusions about the impact of utilizing Augmented Reality technology in studying Flowering Plant Physiology. Additionally, understanding the differences in performance and interest between male and female students can help assess how technology affects biology teaching.

Group	Sex	Frequency(n)	Percentage (%)
Experimental Group	Male	8	16
	Female	17	36
Control Group	Male	16	32
	Female	9	16
	Total	50	100

*Students' achievement level resulting from the use of Augmented Reality (AR**).***

The information in the table presents the outcome of students' performance in Flowering Plant Physiology when taught with Augmented Reality (AR) versus traditional methods. RQ 1 focuses on how effective the AR teaching method is in improving student performance in that specific subject.

The pre-test findings show that without the use of teaching aids, the treatment group using AR had greater understanding in the Flowering Plant Physiology theme (average=65.96, standard deviation=13.34) than the control group (average=62.50, standard deviation=6.43). Yet, the post-test findings indicate a rise in minimum scores for both sets, with a more notable increase for the control group (mean=71.67, SD=11.67) in comparison to the treatment group (mean=89.04, SD=8.95). The analysis indicates a notable disparity between the two groups, as the treatment group demonstrated a higher rise in minimum scores (23.03) in comparison to the control group (9.17).

These findings validate that employing AR educational tasks enhances students' academic performance in Biology, especially in the topic of Flowering Plant Physiology. Hence, AR offers notable benefits over traditional teaching methods, affirming the claim that AR is superior in aiding comprehension and learning in this particular situation. Furthermore, this examination also confirms the efficiency of AR in improving students' academic performance, leading to the creation of new and efficient teaching methods in the education field.

		Pre-Test		Post-Test	
Experimental Group N=25	*Grade*	*No. Student*	*Percentage (%)*	*No. Student*	*Percentage (%)*
	A	6	23.1	21	84.6
	B	10	38.5	4	15.4
	C	7	26.9	-	-
	F	2	11.5	-	-
Control Group N=25	A	-		5	20.8
	B	6	25.0	11	45.8
	C	17	75.0	6	29.2
	F	-		1	4.2

	Control Group, N=25		Experimental Group, N=25	
Test	*Min Score*	*Std*	*Min Score*	*Std*
Pre	62.50	6.43	65.96	13.34
Post	71.67	11.67	89.04	8.95

Identifying the effectiveness of using Augmented Reality (AR) on students' interest in the Flowering Plant Physiology topic

The data in the table indicates a significantly high average in the effectiveness of utilizing Augmented Reality (AR) to engage students in the Flowering Plant Physiology subject. The average score is 4.17, indicating that most participants think using AR has a good effect on their interest in the subject. Upon closely inspecting every item, the majority of Respondents had positive things to say about using AR. Statements like "Using AR Applications enhances understanding of Flowering Plant Physiology in Biology" and "AR increases knowledge more than textbooks" received high ratings from respondents, who agreed with them to a satisfactory degree.

Respondents had positive things to say about using AR. Statements like "Using AR Applications enhances understanding of Flowering Plant Physiology in Biology" and "AR increases knowledge more than textbooks" received high ratings from respondents, who agreed with them to a satisfactory degree.

These findings are consistent with earlier studies that support the use of augmented reality (AR) in the classroom. For example, studies by Cai et al. (2020) and Marcon et al. (2022) have demonstrated that using augmented reality (AR) can increase students' understanding and involvement during the learning process procedure. These results lend more credence to the notion that AR can be a useful teaching aid for biology, particularly for the study of flowering plant physiology. As a result, the study's findings offer insightful information about how using augmented reality (AR) might improve learning by raising student effectiveness and engagement. This opens up opportunities for further research into augmented reality technology in educational settings, with an emphasis on developing creative and captivating learning resources for students.

Item	Response					Min
	1	*2*	*3*	*4*	*5*	
C1. I find online AR applications enjoyable due to their interesting nature.	-	-	4	13	8	4.16
C2. Using AR apps improves my understanding of Plant Physiology in Biology class.	-	-	6	14	5	3.96
C3. AR is appropriate for use in studying new subjects within the Plant Physiology topic in my Biology course.	-	-	2	10	13	4.44
C4. I enjoy using AR apps as they enhance the engagement of learning sessions.	-	-	1	12	12	4.44
C5. AR can aid in my retention of plant physiology information.	-	-	3	8	14	4.44
C6. Utilizing AR can enhance my understanding more than relying on traditional textbooks.	-	-	1	5	19	4.72
C7. I am capable of imparting information on using AR apps to my friends.	-	-	7	9	9	4.08
C8. I have the ability to find information through the use of AR applications.	-	-	7	9	9	4.08
C9. I am experienced in scanning QR codes for login and utilizing AR apps.	-	-	7	9	9	4.08
C10. I like the way AR applications present explanations and visuals.	1	6	9	3	6	3.28
	Total					**4.17**

Conclusion

The study's findings demonstrate that students in the treatment group outperformed those in the control group academically when they studied plant physiology using augmented reality (AR) apps. Previous research has shown that AR applications can simplify complex topic explanations and represent abstract structures in three dimensions (Yuen et al., 2011; Bujak et al., 2013; Wu et al., 2018). Applications for augmented reality (AR) are acknowledged for their capacity to enhance the effectiveness and allure of the learning process, providing additional advantages to traditional textbooks (Lee, 2012; Albrecht et al., 2019; Iván et al., 2016).

The findings are consistent with other research (Chien et al., 2010; Andujar et al., 2011; von Jan et al., 2018; Chytas et al., 2020) that suggests augmented reality (AR) can enhance academic achievement and student participation in education. Students' happiness with learning can be increased and their ability to organize their knowledge properly can be aided by engaging in real-world activities (Yeh et al., 2019). Students can learn anywhere, at any time, thanks to the advantages of mobile learning (Dijkstra et al., 2023). Depending on each person's learning style and pace, this facilitates learning (Bujak et al., 2018). As a result, the potential for enhancing academic achievement through AR applications may be associated with the flexibility of mobile learning.

Moreover, the findings of the study suggest that students demonstrated significant enthusiasm and expertise in the field of Plant Physiology within the realm of Biology when utilizing AR applications. Utilizing AR applications has boosted their drive and enthusiasm for learning, ultimately enhancing their comprehension. Additional research also backs up this discovery, showing that utilizing AR for learning can benefit students' comprehension and

success (Hanid et al., 2023; Mohd Fadzil & Mohd Nihra, 2019).

In conclusion, AR apps for studying Plant Physiology could improve students' academic performance and spark their interest in Biology topics. Using this technology enhances learning by allowing for increased interactivity and enjoyment, while also accommodating individual learning styles and paces. There is optimism that the advancement of AR technology in education will progress and bring about a beneficial change in enhancing the quality of education for students.

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