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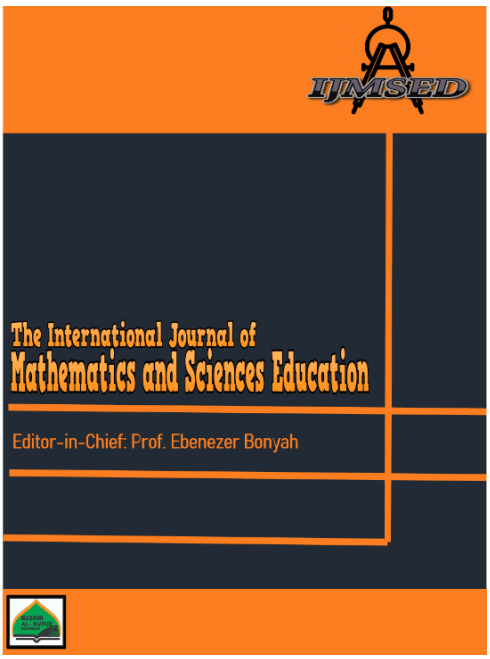

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Abstract
The results of a preliminary study at a junior high school in Indramayu Regency, particularly among seventh-grade students, indicate that there are still students who are less interested in studying biology, especially regarding the topic of plant cell structure. Many students struggle to memorize the various organelles of plant cells and their functions, which impacts their academic performance. Therefore, this research aims to examine the effectiveness of using Augmented Reality (AR)-based poster learning media to improve student learning outcomes in plant cell structure. The research method employed is a descriptive case study, utilizing a purposive sampling technique where the sample is determined based on specific considerations. The sample for this study consisted of 33 students from class VII C, selected because their average learning outcome scores were the lowest compared to other classes. The collected data were analyzed using descriptive methods by calculating the N-Gain Score. The research findings indicate that the N-Gain Score reached 0.7, categorized as a high increase. Additionally, the effectiveness of the learning media was measured by calculating the average score of student learning outcomes after the implementation of the AR-based poster learning media. The average student learning outcome score was 235, with an effectiveness rate of 89.07%, categorized as very effective. This indicates that the use of AR-based poster learning media can significantly enhance student learning outcomes. The implementation of this learning media not only helps students memorize the organelles of plant cells and their functions but also increases their interest and understanding of biological concepts.

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1. Introduction

Plant cells are the basic unit of life in plant organisms (Campbell, 2009). Understanding plant cell structure is an important first step in understanding plant biology as a whole. The structure of plant cells determines the functions and processes of plant life, such as photosynthesis, respiration and transpiration (Kimball, 1992). Knowledge of cell structure helps students understand how plants interact with their environment and what processes occur within them. Many nutrients and medicines come from plants. Understanding plant cell structure helps students understand how plants synthesize important compounds and how to utilize them for health.

In fact, the results of a preliminary study at SMPN 1 Cantigi, especially for class VII students, still show that there are students who are less interested in studying biology, especially in the subject of plant cell structure. This is because students have difficulty memorizing various plant cell organelles

and their functions, resulting in low student learning outcomes on the subject of plant cell structure. Therefore, the method of teaching by rote memorization is no longer appropriate to apply in the current digital age.

Students' comprehension or ability to understand material varies from one individual to another. This is influenced by various factors, including: 1) Each individual has a different level of cognitive ability, including the ability to process information, problem solving, memory, and understanding concepts. 2) Students have different learning styles, such as learning through visual, auditory, kinesthetic, or a combination of the three. Some students may be more effective in understanding material if it is presented in visual form, while others may be better at learning through hearing or direct experience (Ayu, 2009).

Based on these differences, it is important for educators to understand the needs and learning styles of individual students and use diverse, innovative and differential teaching strategies or learning media. This can help maximize students' understanding and achievement in learning. Supporting individual students in overcoming difficulties, capitalizing on their strengths, and providing constructive feedback can also help improve their grasp of course material.

Poster learning media based on Augmented Reality (AR) is the right solution that can overcome this problem. According to Sugianto (2017), poster learning media is a visual tool used to convey information, concepts or messages effectively to the audience. Learning posters usually take the form of pictures or illustrations placed on paper or other printed media, with the aim of clarifying certain concepts or promoting understanding of a topic. Meanwhile, according to Elmqaddem (2019), Augmented Reality (AR) technology in education is a method that combines the real world with virtual or digital elements to improve the learning experience (Fatihah et al., 2023; Sudirman et al., 2023; 2024; Yaniawati et al., 2023). AR poster learning media can be a very effective tool in conveying information and facilitating an interactive and interesting learning process. By utilizing technology as well as visual advantages and the ability to stimulate critical thinking, this learning media can be a valuable addition in efforts to improve student learning outcomes, especially growing cell material.

Previous research by Aprilinda et al. (2020) shows that the implementation of AR technology in learning the human excretory system can make it easier for students to learn and understand the material, as well as make learning more interesting and less boring. In line with that, Susilo et al. (2021) found that the use of mobile AR in the learning process can change learning and teaching methods to be innovative through visualization techniques, thereby changing students from passive learners to active learners. Soflianti et al. (2021) also reported that students experienced an increase in language intelligence in knowing and recognizing new vocabulary through educational flashcard game tools based on augmented reality technology.

However, a gap in previous research is the lack of focus on the use of AR in studying plant cell structure. Previous studies mostly discussed the use of AR in other topics such as the human excretory system or in the context of educational games. Apart from that, there is not much research examining the effectiveness of AR-based learning media in the context of biology learning at the junior high school level. Based on the explanation above, the author is very interested in using AR-based learning media on the subject of plant cell structure. Therefore, the author will carry out research with the title "Implementation of Augmented Reality-Based Plant Cell Structure Learning Media to Improve Student Learning Outcomes".

2. Method

Research Design

This study employs a descriptive case study design aimed at exploring and understanding the effectiveness of Augmented Reality (AR)-based learning media in enhancing students' learning outcomes specifically related to plant cell structures. The descriptive case study design is suitable for this research as it allows for an in-depth examination of the educational phenomenon within a real-life context. The research focuses on gathering qualitative and quantitative data to assess how AR-based learning media can address existing challenges in biology education.

The study is structured to incorporate both pre-test and post-test assessments, enabling a comparison of students' knowledge before and after the intervention. This approach facilitates a comprehensive understanding of the impact of AR-based learning media on student engagement,

retention of information, and overall academic performance. By focusing on the integration of innovative technology in teaching, the study aims to provide actionable insights and recommendations for educators and curriculum developers.

Research Participants

The participants in this study comprised 33 seventh-grade students from class VII C at a junior high school in Indramayu Regency. The selection of this specific group was done using a purposive sampling technique, which allows researchers to select individuals who meet particular criteria relevant to the research focus. In this case, the criterion for selection was based on the students' average learning outcome scores, which were found to be the lowest compared to other classes within the same grade level. This deliberate selection process aimed to identify students who would most benefit from the intervention, thereby maximizing the potential for observable improvements in their learning outcomes. The demographic characteristics of the participants, including their prior knowledge of biology and interest levels in the subject, were also considered during the selection process to ensure a diverse representation of students who face similar challenges in biology education.

Data Collection

Data collection in this study was conducted through a combination of quantitative and qualitative methods to provide a comprehensive understanding of the student's learning outcomes. The primary method involved administering both pre-tests and post-tests designed to assess students' knowledge and understanding of plant cell structures.

1. **Pre-Tests**: These tests were administered prior to the implementation of the AR-based poster learning media. They aimed to establish a baseline measurement of students' existing knowledge and understanding of the topic.
2. **Post-Tests**: Following the implementation of the AR-based learning media, post-tests were administered to evaluate the student's learning gains and retention of information regarding plant cell structures.

Additionally, classroom observations were conducted throughout the learning process. These observations aimed to gather qualitative insights into student engagement, motivation, and overall interest during the lessons. The use of observation checklists allowed researchers to systematically record student behaviors and interactions with the AR learning media, providing further context to the quantitative findings.

Data Analysis

The collected data were analyzed using descriptive quantitative methods to assess improvements in student learning outcomes. The analysis was carried out in several steps:

1. **N-Gain Score Calculation**: The N-Gain Score was calculated to measure the effectiveness of the AR-based learning media in enhancing student knowledge. This score indicates the degree of improvement in students' understanding from the pre-test to the post-test.
2. **Average Score Calculation**: To further evaluate the effectiveness of the learning media, the average score of student learning outcomes after the implementation of the AR-based poster learning media was calculated. The average post-test score was found to be 235.
3. **Effectiveness Rate Calculation**: The effectiveness of the learning media was assessed by determining the effectiveness rate, which was calculated to be 89.07%. This high effectiveness rate places the intervention in the "very effective" category, indicating a significant improvement in students' learning outcomes.

Through this comprehensive analysis, the research provides evidence supporting the positive impact of AR-based learning media on enhancing students' understanding of plant cell structures, ultimately leading to improved academic performance.

3. Results and Discussion

Results

The pretest and *posttest* score data obtained is first converted into grades. Next, the values obtained were analyzed to find the average increase in student learning outcomes after implementing *Augmented Reality* -based plant cell structure poster learning media using the N-gain and N-gain tests which can be seen in Table 1.

Table 1
Improvement in Student Learning Outcomes

	Pretest	Posttest	Gains	N-gain
Max	50	90	0.87	Tall
Min	9	66	0.35	Currently
Average	32.97	80.21	0.70	Tall

The findings in this study show that the average pretest score on student learning outcomes before *the Augmented reality-based* plant cell structure poster learning media was implemented was 32.97. There was an increase in the posttest average score after the *Augmented reality-based* plant cell structure poster learning media was implemented. *Reality* is 80.21. Furthermore, the N-Gain Score is 0.7 with a high qualifying score, this shows an increase in student learning outcomes after the implementation of *Augmented Reality* -based plant cell structure poster learning media.

The results of this research can be strengthened by the research conducted Aprilinda *et al* (2020) , the results of their research show that the implementation of AR technology in learning the human excretory system can make it easier for students to learn and understand the material, making learning more interesting and not boring. Supported by research by Susilo *et al* (2021) , the results of the research show that the use of mobile AR in the learning process can change learning and teaching methods to be innovative through visualization techniques, thereby changing students from passive learners to active students.

In contrast to Soflianti *et al* (2021) , research results show that students experience an increase in language intelligence in knowing and recognizing new vocabulary, namely the names of fruits, through an educational flashcard game based on augmented reality technology.

Table 2
Augmented Reality -based plant cell structure poster learning media for each group

Group	Score	Effectiveness (%)	Criteria
A	236	84.29	Very effective
B	249	88.93	Very effective
C	244	87.14	Very effective
D	224	93.33	Very effective
E	220	91.67	Very effective
Average	***235***	***89.07***	***Very effective***

The following findings (Table 2) are based on observation results. Group A shows excellent effectiveness with a score of 236 and a percentage effectiveness of 84.29%, indicating that the implementation of this learning media has been very successful in enhancing their understanding of plant cell structure. Group B achieved the highest score of 249 with an effectiveness of 88.93%, demonstrating that the Augmented Reality-based poster learning media is very effective for them and provides highly satisfying results in the learning process. With a score of 244 and effectiveness of 87.14%, Group C also showed excellent results, indicating that they were able to understand the material very well through this learning media. Group D demonstrated the highest effectiveness at 93.33%, although their score was lower at 224. This suggests that the learning media is very effective for them and may even exceed initial expectations. Group E scored 220 with an effectiveness of 91.67%. Although the score is slightly lower compared to other groups, the high level of effectiveness shows that the learning media is very useful for them.

Discussion

Overall, the average score is 235 with an effectiveness of 89.07%, placing it in the very effective category. This indicates that, generally, the implementation of the Augmented Reality-based plant cell structure learning media is very effective in improving student learning outcomes. This finding is supported by research from Booyoesen (2023), which demonstrates that the implementation of

Augmented Reality in science education significantly enhances conceptual understanding and student engagement. This technology allows for better visualization of complex concepts, contributing to higher learning outcomes.

Additionally, research by Magi et al. (2023) found that the use of Augmented Reality in education provides a more interactive and engaging learning experience, which can boost student motivation and participation. Morales et al. (2022) also show that AR can help students understand challenging material in a more intuitive and visual manner, which traditional methods cannot achieve. A study by Du & Dewitt (2024) concluded that AR not only aids in material comprehension but also improves students' collaborative skills through interactive group learning activities. Finally, research by Taylor et al. (2022) highlights that the use of AR in science education offers opportunities for students to actively engage with the material, which enhances long-term retention of knowledge and understanding.

To further support the effectiveness of the Augmented Reality-based plant cell structure poster learning media, each indicator was analyzed. These indicators include the availability and condition of AR posters, accuracy of information content, relevance of content to target students, interactivity and user experience, as well as the alignment of AR technology with learning objectives.

Observation results show that the availability and condition of AR posters have been largely achieved (71.21% rated as very well), while a smaller proportion (28.79%) was sufficiently achieved. This is because the AR posters about plant cell structure are readily available and accessible, and are in good condition without damage. The accuracy of information content was achieved at 62.12%, while 36.36% was sufficiently achieved, and only 1.52% was nearly achieved. This is due to the fact that the information presented in the AR posters is accurate, comprehensive, and clear.

Most of the content is appropriate for the target students (68.18%), while 30.30% was sufficiently achieved, and only 1.52% was nearly achieved. This is because the content in the AR posters aligns with the understanding and needs of the target students, including age level, educational level, and language and style of information delivery. Indicators of interactivity and user experience were achieved at 46.97%, while 42.42% were sufficiently achieved. About 9.09% was nearly achieved, and 1.52% did not achieve the desired outcome. This is due to the interactive nature of the AR posters, which allows users to explore plant cell structures and provides a sense of involvement and interest. Indicators of AR technology suitability for learning objectives were achieved at 45.45%, while 53.03% were sufficiently achieved, and 1.52% was nearly achieved. This is because the AR technology used supports the learning objectives of plant cell structure and enhances understanding through its features.

Overall, the implementation of the Augmented Reality-based plant cell structure poster learning media is considered very effective based on various indicators. Most aspects, such as availability and condition of posters, accuracy of information, relevance of content to target students, and suitability of AR technology to learning objectives, have been achieved or sufficiently achieved. However, there are areas, such as interactivity and user experience, that could be improved, as these indicators were only sufficiently achieved or nearly achieved.

4. Conclusion

The research results indicate that the N-Gain Score value obtained is 0.7, which is categorized as a high enhancement. This N-Gain Score signifies a significant improvement in student learning outcomes after the implementation of the Augmented Reality (AR)-based plant cell structure poster learning media. This enhancement not only shows that students have a better understanding of the material but also demonstrates that this learning method effectively helps students overcome difficulties in memorizing and understanding the various organelles of plant cells and their functions.

Overall, the average score for student learning outcomes is 235, with an effectiveness level of 89.07%, placing it in the very effective category. This high level of effectiveness shows that the use of AR-based poster learning media not only improves students' understanding of the material but also significantly enhances their learning results. This improvement can be attributed to several factors related to the use of AR technology in learning. First, AR-based learning media offers a more interactive and engaging learning experience compared to traditional methods. By using AR, students can view a clearer and more detailed visual representation of the plant cell structure. This visualization helps students better understand how cell organelles function and interact with each other. When students can

see and interact with 3D models of cell structures, they find it easier to remember and understand the information presented.

Second, AR technology enables students to study in a more active and participatory manner. Students are not just passive recipients of information but are actively involved in the learning process. Interaction with virtual elements in AR allows students to explore lesson material in a more in-depth and personal way. This activity can increase students' interest and motivation in learning biology, which, in turn, improves their learning outcomes. Furthermore, the use of AR in learning supports various student learning styles. Some students benefit more from visual representations and animations, while others may prefer kinesthetic interactions with 3D models. Therefore, AR-based learning media can provide a more inclusive learning experience tailored to individual student needs. The effectiveness of AR-based poster learning media is also supported by observational results showing increased student involvement and participation during learning. Students appear more enthusiastic and actively engaged in class discussions and are more frequently asking questions related to the material. In conclusion, the implementation of the Augmented Reality-based plant cell structure poster learning media has proven to be highly effective in improving student learning outcomes. The high N-Gain Score and effectiveness level demonstrate that this method not only helps students understand the material better but also enhances their engagement and motivation in learning. These findings provide strong evidence that AR technology in education can be a very valuable tool for enhancing learning quality, especially in biology lessons.

Limitations

The limitations of this study include its focus on the specific content of plant cell structure and organelles, making the findings potentially inapplicable to other biology topics or subjects. Additionally, the population and sample used in this research may have unique characteristics, such as prior knowledge or interest in AR technology, limiting the generalizability of the results to broader populations. The short duration of the AR-based intervention may also influence the observed improvements in learning outcomes, requiring further research to determine its long-term effectiveness. Lastly, the study focused mainly on learning outcomes and student engagement, leaving other variables such as critical thinking skills or collaboration unexplored.

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Author Contribution

Diana Eka Maharani: Conceptualization, Writing - Original Draft
Sugianto: Review & Editing
Nur Subkhi: Methodology, Formal Analysis, Validation and Supervision.

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Conflict of Interest

The authors declare no conflict of interest.

Additional Information:

Additional information is available for this paper.

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