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The effectiveness of augmented reality (AR) media on students' concept mastery of the human digestive system in grade VIII at a public junior high school

Ditiyyah Hafidzah*, M. Harja Efendi, Ali Harris
Biology Science Education Study Program, Universitas Islam Mataram, Gajah Mada Street Number 100, Jempong Baru, Sekarbela District, Mataram, West Nusa Tenggara, Indonesia 83116

*Corresponding author: ditiyyah2019@gmail.com

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ABSTRACT

This study was motivated by students' limited understanding of the human digestive system. Based on interviews with science teachers, it was found that students' conceptual mastery of the human digestive system still needs improvement, as some students continue to struggle to understand this material. Interviews with students also revealed that they struggle to understand the functioning of digestive organs and the interrelationships between organ functions in a comprehensive and contextual way. Furthermore, material on the human digestive system is typically presented through two-dimensional media in textbooks. In contrast, the subject matter involves organ structures and processes that cannot be directly observed. Based on these findings, this study utilized a learning medium capable of visualizing concepts more concretely: Augmented Reality (AR). The study aimed to analyze the effectiveness of Augmented Reality (AR) in improving students' conceptual mastery of the human digestive system. The research design employed was a pre-experimental study involving only one group (without a control group). The results of the study show that the significance value of the paired-sample t-test was 0.000, indicating an increase in students' conceptual mastery, with an N-gain of 63.07%, which falls into the "moderately effective" category. Based on the above explanation, it can be concluded that the use of Augmented Reality (AR) media has a positive impact on students' conceptual mastery and can serve as an alternative learning medium.

INTRODUCTION

The development of digital technology has encouraged the use of Augmented Reality (AR) as a learning medium in education. AR can be defined as a technology that combines virtual objects into a real, three-dimensional environment, allowing them to be observed interactively (Aprilinda et al., 2020). This technology can develop students' interest and imagination in learning because it is interactive, allowing users to be directly involved through devices such as smartphones or tablets (Ghofar et al., 2025; Resti et al., 2024). Initial observations and interviews with science teachers indicated that students' understanding of the human digestive system needs further development, as some still find this topic challenging. Interviews with students also showed ongoing difficulties in grasping how the digestive organs function and how these functions interrelate in a comprehensive and contextual manner. Additionally, the learning process predominantly relies on two-dimensional media in textbooks, which limits understanding because many organ structures and processes occur inside the human body and cannot be observed directly (Sari & Widianti, 2026; Siska et al., 2026).

Concept mastery is an important aspect of science learning because it helps students understand concepts as a whole and apply them to solve various problems (Ekasari, 2023). Science learning is often perceived as difficult by students because the topics presented require an understanding of abstract concepts, especially those that are difficult to visualise in real life, such as the human digestive system (Holillah et al., 2024). Therefore, learning media are needed that can visualise abstract concepts to make them clearer and more interesting, for example through Augmented Reality (Mustaqim et al., 2025; Yanita et al., 2025).

Zumbach et al. (2022) reported that Augmented Reality provides interactive and contextual visualizations that facilitate students' understanding of complex biological structures and processes. Through AR, the material is presented not only in theoretical form but also complemented by visualizations of images, animations, videos, and explanations of organ parts, making learning more engaging (Tiana & Rohani, 2025). Real-time visualizations of internal organs can provide a more realistic and meaningful learning experience compared to static images (Karentius & Hardiyantari, 2025).

Several previous studies have shown that Augmented Reality (AR) media effectively improves students' learning outcomes and conceptual understanding. A study by Masruroh et al. (2025) found that Augmented Reality (AR) effectively enhances understanding of science concepts. Another study by Safira et al. (2022) also showed that students' science learning outcomes improved significantly in environmental studies after using Augmented Reality (AR) media. This is because AR can visualize three-dimensional virtual objects within a real-world environment, allowing students to observe objects from various perspectives. Additionally, AR provides more detailed visualizations and animations of objects, which helps concretize abstract science concepts, minimize misconceptions, and support improved mastery of concepts among students. These findings indicate that Augmented Reality (AR) has the potential to be used as an alternative science learning medium because it can visualize three-dimensional objects in the real world, allowing students to observe organ structures and digestive processes more concretely (Salsabila et al., 2022).

Although various studies have shown that Augmented Reality (AR) media is effective in science education, gaps in the research still require further investigation. A study by Yuliono et al. (2018) demonstrated that AR media effectively improves conceptual mastery of the human digestive system. However, that study was conducted at the elementary school level and therefore cannot yet illustrate its effectiveness among MTs students, who have different characteristics and abilities. Rahmawati et al. (2026) developed an Augmented Reality application for the human digestive system; however, the study primarily focused on students' critical thinking and collaboration skills rather than conceptual mastery. Meanwhile, Masruroh et al. (2025) found that

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AR media effectively improved students' conceptual understanding, though that study was conducted on the topics of vibrations, waves, and sound. These three studies highlight the need for further research to assess how well AR media improves students' understanding of the human digestive system at the MTs level. Consequently, this study was designed to gather empirical evidence on the impact of AR media on the conceptual mastery of eighth-grade students at a public junior high school. The primary goal is to evaluate how effective Augmented Reality (AR) media is in enhancing students' grasp of the human digestive system in eighth-grade classes at a public junior high school.

METHODS

Research Design

This study employed a pre-experimental method using a one-group pre-test-post-test design, which administers a pre-test before the experimental variable is treated (Haryanti & Maknunah, 2025). This design was used to measure students' conceptual mastery before and after instruction using Augmented Reality (AR) media, with assessments in the form of multiple-choice and essay questions.

Population and Samples

The population in this study consisted of all eighth-grade students at a public junior high school during the 2025/2026 academic year, totalling 310 students distributed across eight Grade VIII classes. The sample selected was Class VIII D, consisting of 38 students. The sample analysis consisted of 32 students who completed the entire test series, using a purposive sampling technique based on specific criteria, namely students with varying academic abilities. The selection of this sample aimed to evaluate the effectiveness of Augmented Reality (AR) media on concept mastery among students with varying academic abilities, so that the research results would provide a more representative picture of the application of AR media in learning.

Instruments

This study used a test and a questionnaire as research instruments. The test consisted of 10 multiple-choice and open-ended questions on the human digestive system. It was designed to measure conceptual mastery across the cognitive levels of Bloom's Revised Taxonomy, namely recall (C1), understanding (C2), application (C3), and analysis (C4). These levels were selected to align with the research objective of measuring students' conceptual mastery in stages, from recalling and understanding concepts to applying and analysing them in contexts related to the human digestive system. Thus, the instrument not only measures conceptual understanding but also students' ability to relate concepts to relevant problem contexts. A questionnaire was used to assess students' responses to Augmented Reality (AR) as a learning medium, based on five aspects: the appeal of the learning medium, ease of use, students' attitudes towards the medium, and the medium's benefits in enhancing students' conceptual mastery.

Both instruments were subjected to validity testing to assess the appropriateness of the items or statements, and to reliability testing to assess the stability and consistency of respondents' answers to the items or statements (Prastowo, 2021). The types of validity used in this study include content validity and empirical validity. Content validity was assessed by experts to determine whether the items were consistent with the learning indicators for the human digestive system curriculum and the research objectives (Amos, 2025). The empirical validity test was conducted by pilot-testing the instrument on respondents/students outside the research sample, followed by statistical analysis using the product-moment correlation and item-total correlation (Suryati et al., 2025). The results of the validity test showed that 10 items had a calculated r value greater than the table r value, placing them in the valid category. These results

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indicate that most items are empirically valid and suitable for measuring students' level of conceptual mastery.

A reliability analysis using Cronbach's alpha yielded a calculated r value of 0.734, whereas the table r value was 0.3291. Therefore, the concept mastery test items are reliable, as the calculated r value exceeds the table r value. This indicates that the instrument has good internal consistency and produces stable measurement results, making it reliable for assessing students' concept mastery.

Procedures

This study was conducted in three main stages: pre-test, treatment, and post-test. In the first stage, all students in the research class took a pre-test to measure their initial conceptual understanding of the human digestive system.

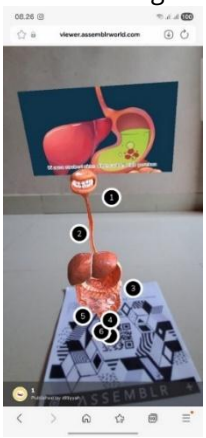
The second stage involved the intervention, which was carried out in a single session on the human digestive system using Assemblr Edu-based Augmented Reality (AR) media. The media was accessed by scanning a QR code using the Google Camera on a smartphone. After scanning the QR code, students were directed to a link displaying a three-dimensional model of the human digestive system, as shown in Figure 1. The AR media presented visualizations of the digestive organs such as the oral cavity, esophagus, stomach, small intestine, large intestine, liver, pancreas, and anus, along with the process of food digestion. The 3D model can be rotated, zoomed in, and zoomed out, allowing students to observe the shape, location, and relationships between organs from various perspectives. This interactive visualization helps make abstract concepts more concrete, making it easier for students to understand the structure, function, and workings of the human digestive system.

During the lesson, students were divided into several groups, with each group using one smartphone. Each group received a Student Worksheet (LKPD) containing instructions for using the AR media, observation steps, questions regarding the structure and function of the digestive organs, an analysis of the relationships between organs in the digestive process, and an assignment to summarize the results of their observations. The LKPD is designed to guide students in conducting systematic exploration so that they not only observe the three-dimensional model but also connect their observations to the concepts they have learned. After conducting observations using AR media, students discuss their answers within their groups and present the results of their discussion to the class under the teacher's guidance. At the end of the lesson, the teacher and students reinforce key concepts regarding the human digestive system.

The final stage is the post-test, which is administered after all learning activities are completed. The post-test uses the same instrument as the pre-test to measure changes in students' conceptual understanding after learning with Augmented Reality (AR) media.

Figure 1

An augmented reality (AR) visualization of the human digestive system using Assemblr Edu.



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The media consists of two main components: (1) an animated video of the digestive process displayed at the top as an introduction to explain the flow of the digestive process, and (2) a three-dimensional model of the digestive system that appears after a marker is scanned with a smartphone. The three-dimensional model can be rotated and zoomed in and out so that students can observe the shape, location, and relationships between organs more clearly.

Data Collection and Analysis

Test data were collected through pre-tests and post-tests. The pre-test was conducted before instruction using Augmented Reality (AR), and the post-test was conducted after completing the AR-based instruction. Initially, the data from both tests were analyzed descriptively to calculate the mean and standard deviation. Subsequently, a paired-sample t-test was performed to assess whether there was a statistically significant difference between pre-test and post-test scores following AR instruction. This analysis was carried out using SPSS version 25, with a significance level set at 0.05. A significance value (Sig., 2-tailed) of less than 0.05 indicates a significant difference between the scores. After confirming a score difference, the improvement in students' conceptual mastery was quantified using the N-Gain formula.

$$\text{N} - \text{Gain} = \frac{\text{Post} - \text{test score} - \text{Pre} - \text{test score}}{\text{Maximum score} - \text{Pre} - \text{test score}}$$

The N-gain values obtained were then interpreted based on the N-gain categories to determine the level of improvement in students' concept mastery. The N-gain categories used in this study are presented in Table 1.

Table 1

N-Gain score categories.

N-gain Score	Category
g > 0.70	High
0.30 ≤ g ≤ 0.70	Medium
g < 0.30	Low

(Universitas Negeri Surabaya, 2024)

To determine the level of effectiveness of using Augmented Reality (AR) media, the N-gain value is converted into a percentage using the following formula:

$$\text{N} - \text{Gain}\ (\%) = \text{g}\ \times 100\%$$

The N-gain percentage obtained was then interpreted based on the effectiveness category to determine the level of effectiveness of Augmented Reality (AR) media use. The effectiveness categories based on the N-gain percentage value are presented in Table 2.

Table 2

N-Gain effectiveness interpretation categories.

N-Gain Percentage (%)	Interpretation
<40	Ineffective
40-55	Less Effective
56-75	Quite Effective
>76	Effective

(Ismiati, 2023)

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In addition to the effectiveness of the learning media, this study also analyzes student responses to the use of AR media. Student response analysis was conducted using questionnaire data administered after the learning process. Scores for each assessment aspect were then converted to percentages using the following formula.

$$\text{Percentage} = \frac{\text{Mean score across all assessed aspects}}{\text{Maximum possible score}} \times 100$$

The percentage results will then be converted into statements to determine students' responses to the use of Augmented Reality (AR) media for the human digestive system. The assessment criteria are shown in Table 3.

Table 3
Criteria for student response results to AR media.

No.	Percentage (%)	Assessment criteria
1.	0%-25%	Very Bad
2.	26%-50%	Not good
3.	51%-75%	Good
4.	76%-100%	Very good

(Arikunto, 2013)

RESULTS AND DISCUSSION

Students' conceptual mastery was measured through pre- and post-learning tests using Augmented Reality (AR) media. Augmented Reality (AR) media was implemented to determine its effectiveness on students' conceptual mastery of the human digestive system. Measurements were conducted through a pre-test and post-test to determine the increase in students' understanding after using AR media. The results of the analysis of students' conceptual mastery are presented in Table 4.

Table 4
Descriptive statistics of pre-test and post-test results.

Test Types	N	Mean	Standard Deviation
Pre-test	32	61.13	18.41
Post-test	32	84.00	12.44

As shown in Table 4, the average scores of the 32 students increased from the pre-test to the post-test. The students' pre-test average score was 61.13 with a standard deviation of 18.41, while the post-test average score was 84.00 with a standard deviation of 12.44. This increase indicates that learning using Augmented Reality (AR) media has the potential to improve students' conceptual mastery of the human digestive system. This improvement is believed to have occurred because AR media can visualize abstract concepts more concretely through interactive three-dimensional models, thereby making it easier for students to understand organ structure, functions, and the human digestive process. These findings align with a study by Yuliono et al. (2018), which stated that students' average scores after being taught using Augmented Reality (AR) media were higher than their average scores before being taught using such media, indicating a significant improvement in students' mastery of the human digestive system following instruction with Augmented Reality (AR) learning media. Masruroh et al. (2025) also state that the use of Augmented Reality (AR) has a positive impact because it makes it easier for students to understand

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the material, as the material is presented alongside 2D and 3D images, animations, and videos that help convey it effectively to students.

Thus, based on Table 4, there appears to be an increase in students' average conceptual mastery scores from the pre-test to the post-test following instruction using Augmented Reality (AR) media. However, descriptive statistics alone cannot determine whether this increase is statistically significant. Therefore, a paired-sample t-test was conducted to determine the difference between the mean pre-test and post-test scores. The results of the test are presented in Table 5.

Table 5
Paired sample t-test results.

Comparison	t	df	Sig. (2-tailed)
Pre-test– Post-test	-11,247	31	0.000

Table 5 shows that the t-value of -11.247, with a significance level (Sig., 2-tailed) of 0.000, is less than the significance level of 0.05 (0.000 < 0.05), indicating a significant difference between students' pre-test and post-test scores. This finding indicates that the use of Augmented Reality (AR) media has an impact on changes in students' learning outcomes regarding the digestive system, as students' conceptual mastery improved after using Augmented Reality (AR) media. This is consistent with the results of a study conducted by Sylvia et al. (2020), which stated that the significant difference between pre-test and post-test scores is attributable to the fact that during the learning process, students received instruction using Augmented Reality (AR) media, which they operated directly via their own smartphones, thereby facilitating their understanding of the presented material.

Another study by Mardiyah et al. (2020) found that learning with Augmented Reality (AR) applications can facilitate students' conceptual mastery. The results showed a significant difference in test scores for conceptual mastery between the control and experimental classes, indicating that Augmented Reality (AR) applications can facilitate students' conceptual mastery. Thus, the use of Augmented Reality (AR) media has a positive effect on improving student learning outcomes. However, to determine the extent of improvement in students' conceptual mastery following instruction using Augmented Reality (AR) media, an N-gain analysis was conducted. The results of the N-gain calculations are presented in Table 6.

Table 6
N-gain test results.

N	N-Gain Minimum	Maximum N-Gain	Average N-Gain Score	Average N-Gain (%)	Category
32	14.29	100.00	0.6307	63.07%	Quite effective

Table 6 shows that the average N-gain value of 63.07% falls into the "moderately effective" category. This indicates that Augmented Reality (AR) media can improve student learning outcomes, although the improvement has not yet reached the "highly effective" category. This finding aligns with a study by Afaf et al. (2025), which attributes the "moderately effective" N-gain to several limitations, including the implementation of AR media for only one session, differences in student characteristics, varying levels of students' technological skills, and the observation of learning conditions in only one group (without a control group). Safira et al. (2022) also noted that the effectiveness of using Augmented Reality (AR) media can be observed through improvements in students' learning outcomes as measured by evaluation tests. A similar study by Masruroh et al. (2025) demonstrated that the use of Augmented Reality (AR)-based learning media is effective

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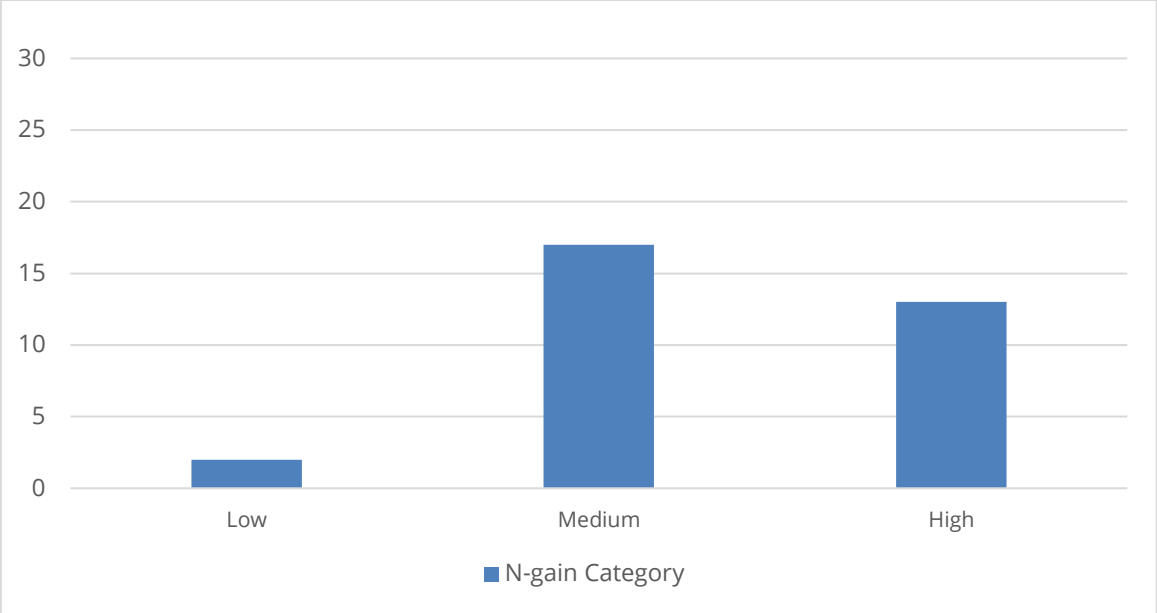
in significantly enhancing students' conceptual understanding. Previous studies have shown that Augmented Reality enhances conceptual understanding by providing interactive three-dimensional visualisations that support meaningful learning and knowledge acquisition (Nurhasanah et al., 2019; Zumbach et al., 2022). It can be concluded that the effectiveness of using Augmented Reality (AR) media for digestive system material falls into the "fairly effective" (moderate) category, with an effectiveness score of 63.07%. The results of the N-gain test can be seen from the number of students in each category, as shown in Figure 2.

Figure 2
N-gain category result diagram.



The diagram shows that most students are in the medium N-gain category, followed by the high category, and only a few students are in the low category. This indicates that the majority of students experienced a fairly good increase in learning outcomes after the learning was given. The number of students in the high category is also quite significant, indicating that some students experienced very good improvement. Meanwhile, the small number of students in the low category indicates that only a small number of students experienced improvement that was still less than optimal. Thus, overall, it can be concluded that the use of learning media is effective in improving student learning outcomes, with a dominant increase in the medium category. In addition to improving learning outcomes, student responses to the use of Augmented Reality (AR) media were also analyse to determine the level of student acceptance of the media used. Student responses were measured through a questionnaire covering several aspects, such as attractiveness, use, concept mastery, benefits, and student attitudes towards AR media. The results of the student response analysis are presented in Table 7.

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Table 7
Results of student responses to the use of AR media.

No	Rated aspect	Score Obtained	Average Score	Presentation	Category
1	The Attraction of Augmented Reality (AR) Media	387	3.02	75.59%	Good
2	Use of Augmented Reality (AR)	358	2.80	69.92%	Good
3	Concept Mastery Through Augmented Reality (AR)	413	3.23	80.66%	Very good
4	Benefits of Augmented Reality (AR) in Learning	388	3.03	75.78%	Good
5	Students' Attitudes Towards Augmented Reality (AR) Media	388	3.03	75.78%	Good
	Total	1546	11.69	75.55%	Good

Table 7 shows the results of student responses to the use of Augmented Reality (AR) media; it was found that student responses were generally in the good category with an average percentage of 73.24%. This shows that Augmented Reality (AR)-based learning media received a positive response from students. Based on the table, the attractiveness aspect of Augmented Reality (AR) media obtained a percentage of 75.59% in the good category, indicating that students consider Augmented Reality (AR) media interesting. The aspect of using Augmented Reality (AR) media obtained 69.92% in the good category, indicating that the media is quite easy for students to use.

The aspect of conceptual mastery through Augmented Reality (AR) media achieved 80.66% in the “very good” category, indicating that Augmented Reality (AR) media can help students understand and master the learning concepts related to the digestive system. The aspect of benefits and students’ attitudes toward Augmented Reality (AR) media in learning achieved a percentage of 75.78% in the “good” category, meaning that this medium is beneficial in supporting the learning process and indicating that students have a positive attitude toward the use of Augmented Reality (AR) media in learning. Overall, based on a total score of 1,546, a percentage of 75.55% was achieved in the “good” category. These positive responses are also consistent with the findings of a previous study, namely the research by Kristanti and Suryanti (2025), which examined students’ responses to Augmented Reality (AR)-based flipbooks and found that students’ responses to AR media were very positive, with a response rate exceeding 96%. This indicates that AR media was well-received and engaging for students in science lessons on the digestive system. Furthermore, these positive results are consistent with the findings of another study by Laia et al. (2025), which showed that integrating Augmented Reality (AR) into learning can create a more engaging and interactive learning experience, thereby improving students’ conceptual understanding and engagement in the learning process.

The fact that student responses fell into the “good” category may be due to variations in assessment across each aspect. Based on the survey results, the aspect of Augmented Reality (AR) media usage received a score of 69.92%, which was the lowest compared to the other aspects. This indicates that there are still obstacles in the use of Augmented Reality (AR) media, such as students who are not yet accustomed to using this technology or who experience difficulties in operating it.

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Zilaturrohmah and Fathi (2025) stated that although Augmented Reality (AR) enhances students' understanding, there are still several challenges in its use, including limited user skills, particularly among students who are not yet accustomed to using AR technology, and the time required to adapt to operating it. Furthermore, not all students have the same level of experience with technology-based devices, which affects the ease of using this technology in the learning process. Findings from the study by Akçayır and Akçayır (2017) report that, although Augmented Reality enhances learning outcomes, its implementation remains hindered by usability and technical issues, as well as the need for students to adapt to the interface before they can effectively use the technology. Thus, although AR media offers benefits for learning, a process of adaptation and guidance is still required for students to utilize it optimally. Usage challenges and varying levels of technological experience among students can influence the ease of using AR media in the learning process.

CONCLUSION

Based on the research findings, the use of Augmented Reality (AR) media in teaching the human digestive system effectively improved the conceptual understanding of eighth-grade students at a public junior high school. Interactive three-dimensional visualizations help students understand the structure, function, and processes of human digestion more concretely, thereby supporting improved conceptual understanding. In addition, students responded positively to the use of AR media because it made learning more engaging, interactive, and easier to understand. Therefore, Augmented Reality (AR) media can be considered as an alternative technology-based learning tool to support science education, particularly for abstract topics.

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