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DEVELOPMENT OF AUGMENTED REALITY LEARNING MEDIA TO ENHANCE ELEMENTARY STUDENTS' CONCEPTUAL UNDERSTANDING OF THE HUMAN RESPIRATORY SYSTEM IN SCIENCE LEARNING

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ABSTRACT

This study aimed to develop and evaluate Augmented Reality (AR)-based interactive learning media designed to strengthen fifth-grade students' conceptual understanding of the human respiratory system. The study responds to a research gap in elementary science learning: previous AR studies have mostly emphasized media development, while fewer have integrated AR products with a structured instructional design and multistage classroom testing. This research employed a Research and Development (R&D) design using the ADDIE model. The product was tested through expert validation, a small-scale practicality test involving 10 students and one teacher, an intermediate feasibility trial involving 42 students, and an effectiveness test using a pretest-posttest control group design with 30 students in the control class and 35 students in the experimental class. Instruments consisted of expert validation sheets, teacher and student response questionnaires, observation notes, and conceptual understanding tests. Data were analyzed using Aiken's V, descriptive statistics, paired sample t-tests, effect size, and normalized gain (N-gain). The results showed that the media was highly valid, with Aiken's V values of 0.91 for material, 0.89 for media, and 0.87 for language. The practicality scores were also high, with 93.75% from the teacher and 88.40% from students. In the intermediate trial, students' mean score increased from 67.97 to 77.26, with a significant paired t-test result ($t = -8.072$; $p < .001$) and a large effect size (Cohen's $d = 1.246$). The effectiveness test showed that the experimental class obtained an N-gain of 0.75 (high category), whereas the control class reached only 0.07 (low category). These findings indicate that AR-based interactive media can make abstract respiratory system concepts more visible, interactive, and meaningful for elementary students.

Keywords: *Augmented Reality, Conceptual Understanding, Interactive Media, Respiratory System, Elementary Education.*

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INTRODUCTION

Digital technology has changed the way teachers design learning experiences, particularly in science education where many concepts are difficult to observe directly. At the elementary level, however, classroom practice is still often dominated by verbal explanation and textbook use. Such learning conditions may help students remember facts, but they do not always support the development of conceptual understanding. For this reason, technology is not merely an additional teaching aid; it is part of the pedagogical effort to make learning more concrete, participatory, and meaningful (Permana et al., 2024; Stanic & Spernjak, 2025).

The human respiratory system is one of the science topics that requires appropriate visualization. The process of breathing involves several organs and mechanisms that take place inside the body, including air movement through the nose, trachea, lungs, alveoli, and diaphragm. Because students cannot directly observe these processes, they may form incomplete or inaccurate concepts. Rini et al. (2022) showed that respiratory system material often creates learning difficulties, while Maimuna et al. (2024) emphasized that visual and interactive media can help students build more accurate conceptual understanding.

The initial needs analysis in several elementary schools in Baturetno District, Wonogiri Regency, showed that teachers and fifth-grade students needed learning media that could present the respiratory system more concretely. Teachers reported that conventional media were not sufficient to show the structure and function of respiratory organs, while students expressed greater interest in learning tools that were visual, interactive, and easy to operate. These findings show that the development of learning media needs to be based on the actual characteristics of learners and classroom conditions.

Augmented Reality (AR) offers a relevant solution because it can combine real environments with virtual three-dimensional objects. Through AR, students can observe, rotate, enlarge, and explore respiratory organs from different perspectives. This type of interaction helps students connect visual representations with scientific explanations. Previous studies have shown that AR can improve science learning outcomes and students' engagement (Ratnasari et al., 2025; Varlik, 2025). Fombona-Pascual et al. (2022) also noted that AR supports the transformation of abstract concepts into concrete and manipulable representations.

Although AR has been widely studied in science learning, most previous research has focused on product development or media validation. Fewer studies have combined AR-based media with a structured instructional design, followed by gradual testing from practicality, feasibility, and effectiveness using a control group. This study addresses that gap by developing AR-based learning media through the ADDIE model and testing it in several stages. The novelty of this study lies in the integration of AR visualization, instructional design, staged implementation, and conceptual understanding assessment in elementary science learning.

Based on this background, the research questions are: (1) How is AR-based interactive learning media for the human respiratory system developed through the ADDIE model? (2) What is the validity, practicality, and feasibility level of the

developed media? (3) How effective is the AR-based media in improving fifth-grade students' conceptual understanding compared with conventional learning? Accordingly, this study aims to develop and evaluate AR-based interactive learning media that can support students' conceptual understanding of the human respiratory system.

RESEARCH METHOD

This study used a Research and Development (R&D) approach with the ADDIE development model, consisting of analysis, design, development, implementation, and evaluation. The model was selected because it provides a systematic framework for designing, producing, revising, and testing instructional media. In this study, ADDIE was not treated only as a product development sequence, but also as a pedagogical framework to ensure that the AR media was aligned with learning objectives, student characteristics, and assessment indicators (Alifah et al., 2025; Rahayu & Wulandari, 2024).

The research was conducted in elementary schools in Baturetno District, Wonogiri Regency. The subjects were fifth-grade students selected through cluster random sampling at the class level. The implementation consisted of three testing stages: a small-scale practicality test with 10 students and one teacher, an intermediate feasibility trial with 42 students using a pretest-posttest design, and an effectiveness test with two intact classes. The effectiveness stage involved 30 students in the control class and 35 students in the experimental class. Because school learning was organized in existing classes, class-level cluster assignment was used while maintaining similar learning objectives, time allocation, topic coverage, and test instruments in both groups.

The analysis stage included classroom observation, teacher interviews, and a review of science learning needs. The focus of this stage was to identify students' difficulties in understanding the respiratory system, the availability of learning media, and the teacher's need for interactive visualization. The design stage involved preparing learning objectives, organizing respiratory system material, constructing a storyboard, designing AR interaction flow, and preparing assessment instruments. The media was designed to include learning materials, AR visualizations, instructional videos, and evaluation quizzes.

In the development stage, the AR application was produced using Unity for AR object creation. CorelDRAW X7 was used for graphic design, while Camtasia 2022 was used to edit supporting videos. The product was then validated by three experts: a subject matter expert, a media expert, and a language expert. The material validation assessed content accuracy, curriculum alignment, concept depth, and suitability for elementary students. Media validation examined interface design, navigation, visual clarity, and interactivity. Language validation focused on readability, clarity, sentence structure, and appropriateness for fifth-grade learners.

The instruments used in this study consisted of expert validation sheets, teacher and student response questionnaires, observation notes, and conceptual understanding tests. The validation and response questionnaires used a four-point Likert scale. Content validity was analyzed using Aiken's V, with values above 0.80 interpreted as highly valid. The conceptual understanding test was developed based on learning indicators related to organ identification, organ function, breathing mechanism, and the relationship between structure and function. Before use, the test items and questionnaires were reviewed by

experts to ensure content relevance and clarity. Reliability checking was directed at the internal consistency of the questionnaire and test instruments, with a reliability coefficient of 0.70 or higher used as the minimum acceptable criterion.

The implementation stage was carried out gradually. First, the small-scale trial was conducted to obtain user responses regarding the attractiveness, ease of use, and clarity of media instructions. Revisions were made based on teacher and student feedback. Second, the intermediate trial was conducted with 42 students to examine whether the media performed consistently in a broader classroom setting. Third, the effectiveness test compared the experimental class using AR-based media with the control class using conventional learning materials. The same topic, learning duration, and evaluation indicators were applied to reduce instructional bias.

Data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to present mean scores, standard deviations, percentages, and score distributions. The Shapiro-Wilk test was used to check normality. A paired sample t-test was used to examine the difference between pretest and posttest scores in the intermediate trial. The effect size was interpreted using Cohen's d. Normalized gain (N-gain) was used to determine the level of learning improvement in the control and experimental classes. Qualitative data from observations and comments were used to explain how students interacted with the media during learning.

RESULTS AND DISCUSSION

The results of this study focus on the development and evaluation of an Augmented Reality (AR)-based interactive learning media designed to enhance fifth-grade elementary students' conceptual understanding of the human respiratory system. This development was motivated by the limitations of conventional learning approaches, which often fail to effectively present abstract scientific concepts. Elementary school students frequently experience difficulties in understanding the structure and function of the respiratory system due to its internal and complex nature (Siburian et al., 2024). In addition, conventional teacher-centered instructional methods tend to limit student engagement and participation, which ultimately affects their conceptual mastery (Nadela et al., 2022; Carolina, 2022).

To address these challenges, this study developed AR-based interactive learning media and evaluated its feasibility and effectiveness in improving students' conceptual understanding. The use of AR technology enables the visualization of abstract concepts in the form of three-dimensional representations that can be directly explored by students. This approach allows students to interact with learning materials in a more active and meaningful way. Previous studies have shown that AR-based learning can enhance students' motivation, engagement, and learning outcomes (Umam et al., 2024; Varlık, 2025).

Product Description

The product developed in this study is an AR-based interactive learning media in the form of an application designed to support elementary-level science (IPAS) learning. This application integrates instructional content with AR technology to create a more engaging and meaningful learning experience (Umam et al., 2024). The use of AR enables the integration of real and virtual environments, allowing students to interact with three-dimensional objects in real time.

In this study, AR features are used to display 3D models of the human respiratory system, including the nose, trachea, lungs, and diaphragm. Students can manipulate these objects by rotating, zooming, and observing them from different perspectives, which helps deepen their understanding of structure and function. These findings are consistent with previous studies indicating that interactive visualization supports conceptual learning (Siburian et al., 2024).

The application also includes several supporting features, such as learning materials, AR visualizations, instructional videos, and evaluation quizzes. These features are designed to provide a comprehensive learning experience through multiple representations, including visual, textual, and interactive formats. The integration of these features supports students in understanding complex concepts more effectively (Nadela et al., 2022).

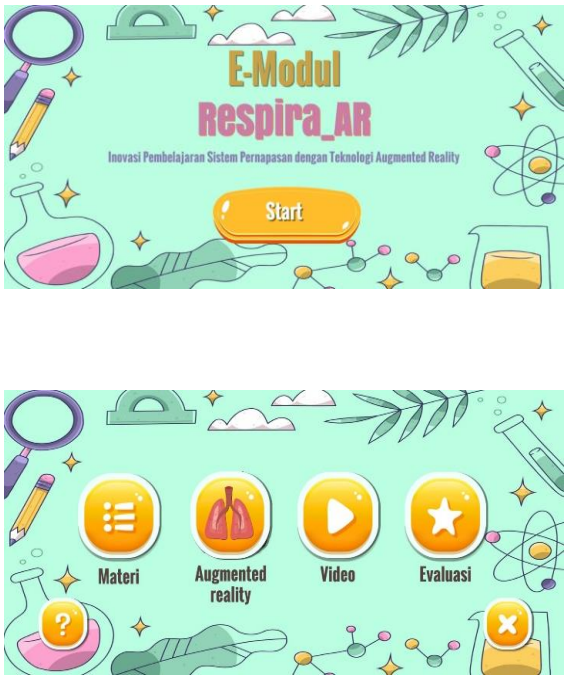

Figure 1.

The main interface of the Augmented reality media

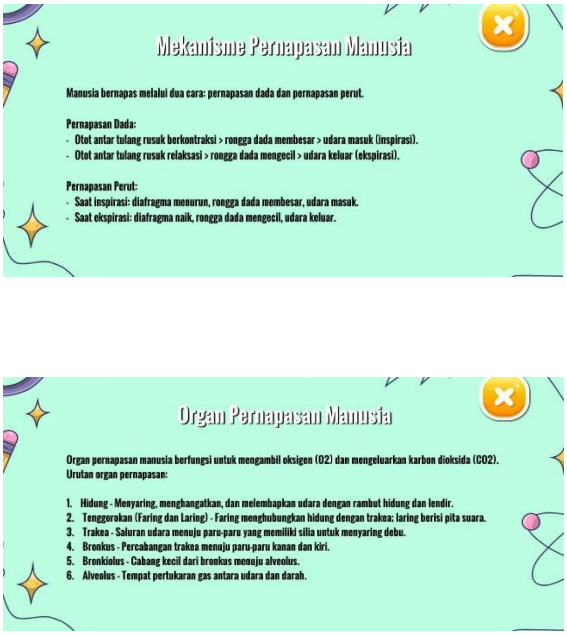

Figure 2. Substance material (content)

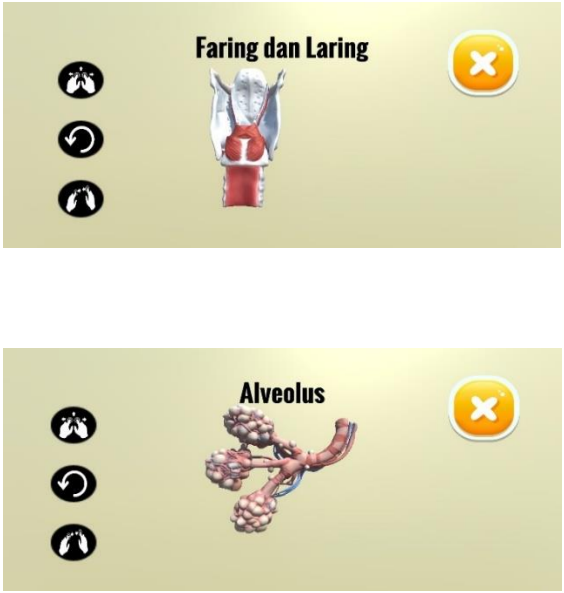

Figure 3. Augmented reality Object

Figure 4. Small-scale product trial

Figure 5. Large-scale product trial

Expert Validation Results

The validation of the developed Augmented Reality (AR)-based interactive learning media was conducted by three experts, namely a subject matter expert, a media expert, and a language expert. This validation process aimed to determine the content validity and overall feasibility of the developed media prior to its implementation in the learning process (Umam et al., 2024) .

The assessment instrument employed a Likert scale ranging from 1 to 4. The data obtained from expert judgments were analyzed using Aiken's V to determine the level of validity of each aspect. Aiken's V is commonly used to assess content validity based on expert agreement, where values closer to 1 indicate a higher level of validity (Siburian et al., 2024) .

The subject matter expert evaluated aspects such as content accuracy, alignment with the curriculum, depth of material, and suitability for elementary school students. The media expert focused on interface design, visual appearance, navigation, and interactivity. Meanwhile, the language expert assessed clarity, readability, and the appropriateness of language used in the media (Stanič & Špernjak, 2025) .

The results of the expert validation based on Aiken's V are presented in Table 1.

Table 1. Expert Validation Results (Aiken's V)

Assessment Aspect	Aiken's V	Criterion
Subject matter expert	0.91	Highly Valid
Media expert	0.89	Highly Valid
Language expert	0.87	Highly Valid

The results indicate that all aspects of the developed AR-based interactive learning media fall into the "highly valid" category, with Aiken's V values exceeding 0.80. This suggests a strong level of agreement among experts regarding the quality and feasibility of the media (Varlık, 2025) .

The high score in the subject matter aspect indicates that the content is accurate, relevant, and well-aligned with the curriculum. Similarly, the media aspect demonstrates that the application has an effective interface design and interactive features that support student engagement. The language aspect also shows that the media uses clear and appropriate language, making it suitable for elementary school students (Nadela et al., 2022) .

These findings are consistent with previous studies which emphasize that learning media with high validity levels are more likely to be effective and appropriate for classroom implementation (Putri et al., 2021) . In addition, well-validated interactive media can significantly support students' engagement and conceptual

understanding in science learning (Carolina, 2022).

Practicality Test Results

Following the expert validation stage, the practicality of the developed Augmented Reality (AR)-based interactive learning media was evaluated to determine its ease of use and user acceptance in a real classroom setting. This stage is important to ensure that the media is not only valid in terms of content and design but also applicable and user-friendly when implemented in the learning process (Umam et al., 2024).

The practicality test was conducted through a small-scale trial involving both teachers and students. Data were collected using response questionnaires administered after the implementation of the media. The questionnaire employed a Likert scale ranging from 1 to 4, covering several aspects, including ease of use, clarity of display, attractiveness of the media, and its usefulness in supporting the learning process (Siburian et al., 2024) . Similar results were reported by Mokmin et al. (2025), who found that interactive digital media enhances student participation in learning.

The results of the practicality test are presented in Table 2.

Table 2. Practicality Test Results

Respondent	Percentage (%)	Criterion
Teacher	93.75	Highly practical
Students	88.40	Highly practical

The results indicate that the developed AR-based interactive learning media falls into the "highly practical" category. The score obtained from the teacher reflects that the media is easy to operate, systematically organized, and supports the delivery of learning materials effectively. Meanwhile, the students' responses show that the media is attractive and relatively easy to use, although some students may still require brief guidance during initial use (Stanič & Špernjak, 2025)

From a usability perspective, the high level of practicality suggests that the integration of AR technology into learning media can create a more engaging and interactive learning experience. The use of AR in learning environments is known to enhance student engagement and support more effective learning processes (Varlık, 2025) . In addition, AR allows students to directly interact with learning objects, which can increase their motivation and interest in the learning process (Umam et al., 2024) .

These findings indicate that the developed media is not only feasible in terms of validity but also practical for implementation in real classroom settings. The high practicality level demonstrates that the media can be effectively used to support elementary school science learning, particularly in helping students understand abstract concepts such as the human respiratory system (Varlık, 2025) .

Feasibility Test

After the practicality test, medium-scale trial was conducted to examine the feasibility of the Augmented Reality (AR)-based interactive learning media on a broader scale. This trial involved 42 students using a pretest–posttest design to assess the improvement in students' conceptual understanding after using the developed media.

The results of the feasibility test are presented in Table 3.

Table 3. Feasibility Test Results

Aspect	Indicator	Value	Description
Descriptive Data	Pretest Mean	67.97	Initial Score
	Posttest Mean	77.26	Improved Score
	Std. Deviation (Pretest)	14.44	Data Variation
	Std. Deviation (Posttest)	10.43	Data Variation
Normality Test	Pretest Sig.	0.561	Normal Distribution
	Posttest Sig.	0.060	Normal Distribution
Paired t-test	t-value	-8.072	Significant
	Sig. (2-tailed)	0.000	Significant
	Mean Difference	-9.29	Score Improvement
Effect Size	Cohen's d	-1.246	Large Effect

Based on the descriptive analysis, the mean pretest score was 67.97, while the mean posttest score increased to 77.26. This result indicates an improvement in students' learning outcomes after using the AR-based learning media.

Before conducting further statistical analysis, a normality test was performed using the Shapiro–Wilk test. The results showed that the significance values for the pretest and posttest were 0.561 and 0.060, respectively, both greater than 0.05 ($p > 0.05$). This indicates that the data were normally distributed and met the assumptions required for further analysis.

Furthermore, the results of the paired sample t-test revealed a significant difference between the pretest and posttest scores. The t-value was -8.072 with a significance value of 0.000 ($p < 0.05$), indicating that the improvement in students' learning outcomes after using the media was statistically significant.

In addition, the effect size analysis showed a Cohen's d value of -1.246, which falls into the large effect category. This finding indicates that the AR-based learning media has a strong impact on improving students' learning outcomes.

Based on these results, it can be concluded that the developed learning media is not only practical but also demonstrates good performance in improving students' conceptual understanding in a larger-scale classroom setting. Therefore, the media is considered feasible to proceed to the effectiveness testing stage.

Effectiveness Test Results

After the normality assumption was met, further analysis was conducted to evaluate the effectiveness of the developed Augmented Reality (AR)-based interactive learning media. The effectiveness test employed a Pretest–Posttest Control Group Design involving 30 students in the control class and 35 students in the experimental class. This test aimed to measure the extent to which the use of the developed media could improve students' conceptual understanding of the human respiratory system (Umam et al., 2024).

Before the learning process began, both the experimental and control classes were administered a pretest to measure students' initial understanding of the human respiratory system. After the learning process, a posttest was conducted to assess changes in students' conceptual understanding in both groups. The improvement in learning outcomes was then analyzed using normalized gain (N-gain) to determine the effectiveness of the instructional process

The results of the effectiveness test are presented in Table 4.

Table 4. The Effectiveness Test Results

Class	Pretest	Postest	N-gain	Category
Control	45.39	49.35	0.07	Low
Experi Mental	42.56	75.59	0.75	High

Based on the descriptive analysis, the mean pretest score in the control class was 45.39 and in the experimental class was 42.56, indicating that the initial abilities of both groups were relatively comparable and categorized as low. After the learning process, the mean posttest score in the control class increased slightly to 49.35, whereas in the experimental class it increased significantly to 75.59.

In terms of N-Gain, the experimental class obtained a score of 0.75, which falls into the high category, while the control class only achieved a score of 0.07, categorized as low. This indicates that the improvement in learning outcomes in the experimental class was substantially higher than that in the control class.

The difference in improvement suggests that the use of Augmented Reality (AR)-based interactive learning media has a more significant impact compared to conventional instruction. The AR media proved to be effective in enhancing students' conceptual understanding of the human respiratory system.

The improvement in students' learning outcomes in the experimental class can be attributed to the characteristics of the developed media, which integrates three-dimensional visualization, interactivity, and real-world representation. Through AR technology, abstract concepts can be visualized in a more concrete and engaging manner, making it easier for students to understand the structure and function of the human respiratory system.

Furthermore, the interactive features embedded in the media promote active student participation during the learning process. Students are not merely passive recipients of information but are actively involved in exploring the learning materials, which aligns with constructivist learning principles. As a result, the developed media not only functions as an instructional tool but also facilitates more effective knowledge construction.

These findings indicate that the AR-based interactive learning media developed in this study has a high level of effectiveness in improving students' conceptual understanding. The significant difference in N-Gain values between the experimental and control groups confirms that the integration of AR technology contributes positively to improving the quality of learning.

Student Score Distribution

The distribution of student scores provides a more detailed picture of changes in students' conceptual understanding after the implementation of Augmented Reality (AR)-based interactive learning media. This analysis focuses on the experimental class to examine patterns of improvement more comprehensively, while also providing a general comparison with the control class.

During the pretest, most students in the experimental class were categorized in the medium and low levels, indicating that their initial understanding of the human respiratory system was not yet optimal. However, after the implementation of AR-based learning media, a significant shift in score distribution was observed, with the

majority of students reaching the high category in the posttest.

The distribution of student scores is presented in Table 5.

Table 5. Distribution of Pretest and Posttest Student Scores

Category	Score Range	Pretest (Number of Students)	Posttest (Number of Students)
High	≥ 70	6	29
Moderate	40 – 69	19	6
Low	< 40	10	0
Total		**35**	**35**

The shift in score distribution indicates that the improvement in learning outcomes was not limited to a small group of students but occurred broadly across the class. The absence of students in the low category in the posttest and the strong dominance of the high category suggest that the AR-based learning media effectively accommodated students with diverse ability levels.

In comparison, the control class showed minimal change in score distribution, with only slight improvements that did not result in meaningful category shifts. This finding is consistent with the N-Gain results, which indicate that the control class experienced only a low level of improvement, while the experimental class achieved a high level.

These findings suggest that AR-based interactive learning media effectively supports students with varying levels of initial understanding. Students who were initially in the low and medium categories demonstrated substantial improvement after interacting with the media. This improvement reflects the role of features embedded in the media, such as three-dimensional visualization, interactivity, and immediate feedback, in facilitating deeper and more gradual conceptual understanding.

Thus, the distribution of student scores reinforces the conclusion that AR-based learning media not only improves learning outcomes quantitatively but also enhances the overall quality of students' conceptual understanding in a more equitable manner.

Discussion

The findings show that AR-based media can help elementary students understand the human respiratory system more meaningfully. The main strength of the media lies in its ability to convert invisible biological processes into interactive three-dimensional objects. This feature directly addresses one of the central problems in science learning, namely the gap between abstract concepts and students' concrete operational thinking. The result is consistent with Rini et al. (2022) and Siburian et al. (2024), who argued that respiratory system learning requires visual support because the organs and processes cannot be observed directly.

The high validation score suggests that media quality cannot be separated from instructional design. A visually attractive product alone is not enough; content accuracy, sequence of material, readable language, and age-appropriate interaction are essential. In this study, the AR media was built around learning objectives and conceptual indicators, so the technology functioned as a bridge to understanding rather than as decoration. This point strengthens the argument of Alifah et al. (2025) and Rahayu and Wulandari (2024) that the ADDIE model can guide technology-based media development in a more pedagogically controlled manner.

The practicality results also indicate that AR media can be implemented in elementary classrooms when the interface is simple and the learning flow is clear. The teacher's high response score reflects that the media supports instructional explanation, while the student response shows that the media invites curiosity and active participation. Nevertheless, the observation that some students needed initial guidance should be noted. AR media still requires teacher facilitation, especially at the beginning of use, so that students do not focus only on the visual effect but also on the scientific meaning of what they observe.

The intermediate trial provides evidence that the media has a strong educational effect. The increase from 67.97 to 77.26, supported by $p < .001$ and a large effect size, shows that students' learning improvement was substantial. This finding goes beyond a descriptive increase in scores; it suggests that AR helped students reorganize their understanding of respiratory organs and their functions. In classroom practice, such improvement is relevant because conceptual understanding is not formed only by memorizing terms, but by seeing relationships among structures, functions, and processes.

The effectiveness test further confirms the value of AR-based learning. The experimental class achieved a high N-gain, while the control class remained in the low category. This difference may be explained by the active learning opportunities provided by AR. Students could observe respiratory organs from different angles, manipulate objects, connect visual representations with explanations, and answer evaluation questions. This sequence aligns with constructivist learning principles, where students build understanding through exploration and interaction rather than passively receiving information.

Compared with previous studies, this research contributes in two ways. First, it does not stop at product validation but follows a staged testing process, from practicality and feasibility to effectiveness. Second, it places AR within instructional design and conceptual understanding assessment. Therefore, the novelty of this study is not simply the use of AR, but the use of AR as part of a structured learning system. This is important for elementary science learning, because technology should be selected and organized based on students' learning needs, not merely because it is new.

Theoretically, the findings support the view that multimedia and interactive visualization can reduce the cognitive distance between abstract science concepts and students' concrete experiences. Practically, the media can be used by elementary teachers to enrich science learning, especially when schools have access to smartphones or tablets. However, implementation should be accompanied by teacher guidance, clear instructions, and classroom management strategies. Without these supports, students may become more interested in the visual display than in the scientific concept being learned.

This study has several limitations. The media was developed for one topic, namely the human respiratory system, and the sample was limited to fifth-grade students in one district. Future research may develop AR media for other science topics, involve more diverse school contexts, and add learning analytics or adaptive feedback features. Further studies may also examine long-term retention to determine whether students' conceptual understanding remains stable after the learning intervention.

CONCLUSION

The AR-based interactive learning media developed in this study was found to be valid, practical, feasible, and effective for supporting fifth-grade students' conceptual understanding of the human respiratory system. Expert validation showed high content, media, and language validity, while teacher and student responses indicated that the media was easy to use and suitable for classroom learning.

The main contribution of this study is the integration of AR technology with structured instructional design and staged product testing. The effectiveness test showed that the experimental class achieved a high N-gain score (0.75), whereas the control class remained in the low category (0.07). This finding demonstrates that AR can help students understand abstract science concepts through concrete visualization, interaction, and guided exploration.

The media is recommended as an instructional alternative for elementary science learning, particularly for topics that require visualization of internal body processes. Future development should expand the media to other science concepts, strengthen adaptive feedback, and test its long-term impact on students' conceptual retention.

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