



Development of Interactive Media Based on Augmented Reality on Human Respiratory System Materials in Elementary Education

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Abstract

Augmented Reality (AR) is a promising technology for enhancing student learning by enabling interactive visualisation of abstract concepts. However, studies on AR-based interactive media for complex topics, such as the human respiratory system, in elementary science subjects are limited. This study aimed to develop and evaluate AR-based interactive media for fifth-grade students, focusing on feasibility and student engagement. The research employed a Research and Development (R&D) approach using the ADDIE model. Data were collected through validation sheets from material and media experts, teacher assessments, and student response questionnaires. The participants included two material experts, two media experts, two elementary science teachers, and 22 students, divided into small and large trial groups. The development process utilised applications such as Assemblr Edu, Canva, and Google Camera. Results revealed strong feasibility, with scores of 4.4 (material experts), 4.0 (media experts), 4.3 (teacher media validation), and 4.25 (teacher material validation). Student responses indicated high acceptance, with 94% in small groups and 90.5% in larger groups. The findings conclude that AR-based interactive media is feasible, engaging, and effective in supporting science learning. Thus, although AR-based media is considered highly feasible and effective in increasing student interest and engagement in the human respiratory system subject. The study suggests that further studies are needed that not only focus on user experience but also directly measure the larger-scale, long-term impact on conceptual understanding and learning outcomes.

Keywords:

Augmented Reality, Human Respiratory System, Interactive Media

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Abstrak

Augmented Reality (AR) adalah teknologi yang menjanjikan untuk meningkatkan pembelajaran siswa melalui visualisasi interaktif konsep-konsep abstrak. Namun, penelitian tentang media interaktif berbasis AR untuk topik kompleks seperti sistem pernapasan manusia dalam mata pelajaran sains dasar masih terbatas. Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi media interaktif berbasis AR untuk siswa kelas lima, dengan fokus pada kelayakan dan keterlibatan siswa. Penelitian ini menggunakan pendekatan Penelitian dan Pengembangan (R&D) dengan model ADDIE. Data dikumpulkan melalui lembar validasi dari ahli materi dan media, penilaian guru, dan kuesioner respons siswa. Peserta terdiri dari dua ahli materi, dua ahli media, dua guru IPA SD, dan 22 siswa yang dibagi menjadi kelompok uji coba kecil dan besar. Proses pengembangan menggunakan aplikasi seperti Assemblr Edu, Canva, dan Google Camera. Hasil menunjukkan kelayakan yang kuat, dengan skor 4,4 (ahli materi), 4,0 (ahli media), 4,3 (validasi media guru), dan 4,25 (validasi materi guru). Respons siswa menunjukkan penerimaan yang tinggi, dengan 94% dalam kelompok kecil dan 90,5% dalam kelompok yang lebih besar. Temuan ini menyimpulkan bahwa media interaktif berbasis AR layak, menarik, dan efektif dalam mendukung pembelajaran sains. Dengan demikian, meskipun media berbasis AR dianggap sangat layak dan efektif dalam meningkatkan minat dan keterlibatan siswa dalam mata pelajaran sistem pernapasan manusia. Penelitian ini menyarankan penelitian lebih lanjut diperlukan yang tidak hanya berfokus pada pengalaman pengguna tetapi juga secara langsung mengukur dampak skala yang lebih besar dan jangka panjang terhadap pemahaman konseptual dan hasil pembelajaran.

Kata Kunci:

Augmented Reality, Sistem Pernapasan Manusia, Media Interaktif

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INTRODUCTION

Education plays a pivotal role in shaping the quality of human resources, which is essential for national development and progress. Quality education is not solely determined by curriculum content but also by the effectiveness of teaching methods and learning media (Fadilah et al., 2023). At the elementary level, particularly in science education, conventional methods such as lectures, textbook readings, and static illustrations continue to dominate (Nandari et al., 2023). However, these approaches often fail to engage modern learners, especially Generation Alpha (2010–2025), who have grown up immersed in digital environments and expect learning experiences that are interactive, fast-paced, and visually stimulating (Mohsen et al., 2025).

One significant challenge in science instruction is helping students understand abstract concepts, such as the human respiratory system. Traditional resources, which rely heavily on two-dimensional diagrams and verbal explanations, are often insufficient for conveying dynamic physiological processes, resulting in low engagement and poor comprehension (Safitri et al., 2023). To address this, educational innovations must provide tangible, interactive, and multisensory experiences that enhance accessibility and foster deeper understanding (Sugiarto, 2023).

Augmented Reality (AR) offers a promising solution by overlaying digital objects onto real-world environments, enabling students to explore scientific phenomena through interactive 3D visualisations (Juliati et al., 2024; Nursyaidah et al., 2025; Pradita et al., 2024). AR-based learning media have been shown to increase motivation, engagement, and conceptual understanding by transforming science lessons into immersive experiences (Julita & Purnasari, 2024; Siregar et al., 2025). Despite these benefits, AR remains underutilised in elementary science education, with most applications concentrated at higher education levels (Pradana, 2020).

In an interview with a grade V teacher at MI Muslimin, it was noted that students struggle with understanding concepts in the

Natural Sciences, particularly the human respiratory system. The lack of teaching aids hampers deep comprehension of the material, which requires clear visualisation for better mastery. The teacher emphasised that, since the respiratory system is abstract and involves interconnected organs, effective teaching requires more than verbal explanations or textbook images. Despite this, most fifth-grade students have smartphones that could enhance their learning experience.

The application of Augmented Reality (AR) in learning has great potential. Still, the existing literature shows that research in this field, particularly that focusing on complex topics such as the human respiratory system at the primary school level, remains limited (Anggraeni et al., 2024; Sari et al., 2025; Masruroh et al., 2023). Although AR has been shown to increase motivation and conceptual understanding by transforming science lessons into immersive experiences (Carera et al., 2025; Ndraha & Harefa, 2023). Its use remains suboptimal in primary education (Dzofiroh et al., 2025). These limitations highlight the need for media innovations that bridge the gap between abstract concepts and students' understanding, especially among younger generations accustomed to digital environments (Kalyani, 2024). Therefore, research such as this is essential for developing and validating AR-based learning media that are not only engaging but also effective in supporting the teaching and learning process.

Platforms such as Assemblr Edu provide educators with user-friendly tools to design interactive AR content (Suaib & Sutriyani, 2024; Subhan et al., 2023), while complementary applications like Canva enhance visual presentation (Lestari et al., 2025; Musannadah & Jannah, 2023). A needs analysis involving fifth-grade teachers at MI Muslimin confirmed that students struggle to grasp the respiratory system due to the lack of suitable media, despite having access to smartphones capable of running AR applications (Alfarizi et al., 2024; Susilawati et al., 2020). This highlights the untapped potential of integrating AR into classroom instruction to meet the developmental needs of digital-native learners.

Accordingly, this study aims to develop and validate AR-based learning media on the

human respiratory system for fifth-grade science lessons. The objectives include designing the media, conducting validation by material and media experts, refining the product based on feedback, and testing its implementation in classroom contexts. By applying a systematic development approach, the study seeks to create learning media that not only enhance student comprehension but also provide teachers with innovative instructional support. Integrating AR into elementary science education offers significant potential to bridge the gap between abstract concepts and students' understanding. This research contributes to the field by proposing a practical and pedagogically sound AR-based media model that can enrich science learning and better align with the expectations of today's digital-native students.

METHODS

This study employed the Research and Development (R&D) method, which is designed to create and validate innovative educational products. R&D emphasises a systematic process of identifying needs, designing instructional solutions, developing prototypes, validating them with experts, and testing their effectiveness in classroom contexts (Nurhikmah et al., 2024; Sairi, 2020). The development framework adopted in this study was the ADDIE model, which consists of five stages: (1) Analysis, to identify students' learning needs and curricular requirements (Sari et al., 2023); (2) Design, to establish learning objectives, select relevant content, and design instructional strategies (Suyuti et al., 2023); (3) Development, to produce the initial version of the AR-based media and conduct expert validation (Maskur, 2023); (4) Implementation, involving small- and large-scale trials with students and teachers to assess usability and engagement (Syawaludin et al., 2020); and (5) Evaluation, to measure media effectiveness and refine the product based on feedback.

The population consisted of all fifth-grade students and one class teacher at MI Al-Muslimin, totalling 17 students. Purposive sampling was employed, as only participants directly exposed to the AR-based media were considered relevant for data collection. Primary data sources included material

experts, media experts, a science teacher, and students. Secondary sources included books, journals, and documents that supported theoretical and methodological foundations.

Data were collected through expert validation sheets, student questionnaires, observation sheets, interviews, and pre-test and post-test assessments of learning outcomes. Expert validators reviewed the instruments for content validity, and reliability was assessed using Cronbach's Alpha; coefficients above 0.70 were considered acceptable. Student responses were analysed using percentage scores, while expert and teacher validations were measured using Likert-scale analysis.

Experts assess AR media based on detailed criteria to ensure its material and technical suitability. The material aspects assessed include the accuracy, completeness, and appeal of the content, as well as the consistent use of language in accordance with the correct rules. Meanwhile, media validation focuses on functionality and usability, including design appeal, visual quality, ease of interaction, and smooth operation without obstacles. Quantitative data from this assessment is then analysed using a Likert scale, with categories ranging from 'Very Poor' to 'Very Good'. The results of trials with students, both small and large groups, are assessed using the Guttman scale, where "yes" or "no" responses are converted into percentage scores to determine the level of user acceptance and the suitability of the media.

Data analysis used a combination of qualitative and quantitative techniques, including media design elaboration, Likert-scale analysis of content and media expert validation, and Guttman-scale percentage analysis of results from small- and large-group trials to determine the acceptance and feasibility of the AR media. This methodological approach ensures that the AR-based learning media developed are not only theoretically sound but also pedagogically valid, practical for classroom use, and effective in enhancing students' conceptual understanding of the human respiratory system.

RESULTS AND DISCUSSION

The development of an Augmented Reality (AR)-based teaching module for the fifth-grade science subject on the human respiratory system was carried out systematically through several stages, following the ADDIE framework. These stages included analysis, design, development, and validation, which were essential to ensure that the media created was pedagogically appropriate, technologically feasible, and aligned with curriculum objectives. Each stage is described in detail as follows.

Analyze Stage

The first step in the development process was to conduct a comprehensive analysis of students' learning needs, the subject matter's characteristics, and the classroom challenges. Observations during science lessons in fifth grade revealed several issues that hindered the learning process. Many students showed signs of low attention span, such as chatting with peers, appearing disengaged, or failing to focus during class discussions. These behavioural indicators suggested that the instructional strategies and learning media used were ineffective at maintaining student concentration.

The challenges were particularly evident in the topic of the human respiratory system. In most cases, teaching relied heavily on two-dimensional illustrations from textbooks or wall charts. These static representations were insufficient to demonstrate the dynamic and complex processes involved in respiration. For example, the mechanisms of inhalation and exhalation, the exchange of gases in the alveoli, and the coordinated functioning of the respiratory organs were complicated for students to visualise. As a result, students experienced conceptual difficulties, resulting in low mastery of the material.

Teachers also noted the absence of three-dimensional models or interactive media that could support the explanation of abstract concepts. Although simple teaching aids such as diagrams and textbooks were available, they could not stimulate curiosity or foster a deeper understanding. Consequently, students often viewed science lessons as monotonous and less engaging.

The findings from classroom observation and teacher interviews indicated that the main problems could be categorised into two aspects: (1) motivational issues, as students lacked enthusiasm due to repetitive and conventional learning methods; and (2) conceptual issues, since abstract scientific processes were presented without adequate visualisation or interaction. These findings justified the need for innovative media that integrates interactive technology to support student comprehension. AR technology was identified as a promising solution due to its ability to present realistic, engaging, and interactive three-dimensional representations of scientific phenomena.

Design Stage

The second stage involved designing the AR-based teaching module using Assemblr Edu as the main platform. The design process consisted of four aspects: content design, structure design, learning design, and media design.

1. **Content Design:** The learning materials were carefully selected and adapted from the curriculum to ensure relevance, simplicity, and appropriateness for fifth-grade students. Content focused on introducing the respiratory organs, explaining the breathing mechanism, and relating it to daily life applications such as exercise and health.
2. **Structure Design:** A logical sequence of topics was established, beginning with the basic identification of organs, progressing to a step-by-step explanation of respiration, and concluding with its functional significance. This structure aimed to scaffold student understanding gradually.
3. **Learning Design:** Learning objectives were defined in alignment with the curriculum's competency standards. Interactive activities, such as exploring 3D models, labelling organ structures, and simulating respiratory processes, were planned to promote active participation. Evaluation instruments such as quizzes and short-answer tasks were also designed to assess conceptual mastery.
4. **Media Design:** 3D objects were created in Assemblr Edu, enabling students to

visualise respiratory organs in augmented reality. Visual elements were supported with labels, short descriptions, and animations to clarify complex processes. The final AR product was made accessible via a QR code and link, enabling students to interact with the media on their personal devices. To increase practicality, the media was embedded in Canva and integrated with worksheets and learning activities. This approach ensured that the media could be accessed flexibly and supported both classroom-based and independent learning.

The design phase prioritised not only technological functionality but also pedagogical suitability, ensuring that the media addressed both motivational and conceptual challenges identified during the analysis stage. By utilising platforms like Assemblr Edu and Canva and providing flexible access via QR code and link, this exemplifies advanced, technology-driven, and student-focused planning, establishing a robust foundation for subsequent development stages.

Development Stage

After the design process, the development of the teaching module continued, with validation by experts and practitioners to ensure accuracy, clarity, and feasibility. Validation involved material experts, media experts, and classroom teachers.

Material Expert and Teacher Validation

The results of the material validation are summarised in Table 1, which includes eight indicators related to content accuracy, presentation, and language.

Table 1. Material Expert Validation and Teachers

Questions	Expert		Teacher	
	Score	Category	Score	Category
Learning material in accordance with learning outcomes	5	Very good	4	Good
Coverage of material in accordance with learning objectives	5	Very good	5	Very good
The material on the learning media is conveyed thoroughly and	4	Good	3	Enough

completely about the Human Respiratory System				
Augmented Reality Learning Media can stimulate students' curiosity about the material.	5	Very good	5	Very good
Augmented Reality Learning Media is presented in an interesting way	5	Very good	4	Good
Augmented Reality learning media design is appropriate and in accordance with the material in primary school	5	Very good	5	Very good
Consistent in the use of terms and symbols in Augmented Reality media	4	Good	4	Good
Language use is in accordance with the General Guidelines for Indonesian Spelling (PUEBI)	4	Good	4	Good
Total	40		43	
Average	4.0	Good	4.3	Very good

The material expert awarded a total score of 40, with an average of 4.0, and categorised it as “Good.” Strengths noted included strong alignment with learning outcomes, stimulating presentation, and the ability to foster curiosity. However, the expert recommended improvement in the completeness of material coverage and greater consistency in terminology and language accuracy. The classroom teacher gave a slightly higher score of 43, with an average of 4.3, falling into the “Very Good” category. The teacher praised the engaging presentation and the curriculum's relevance, but also pointed out minor weaknesses in completeness and clarity of language. These results indicate that the AR-based media was judged to be highly relevant and effective, although minor refinements in depth of content and linguistic precision were suggested.

Media Expert and Teacher Validation

Validation by the media expert and the classroom teacher focused on design, usability, and visual appeal, as shown in Table 2.

Table 2. Media Expert Validation and Teachers

Questions	Expert		Teacher	
	Score	Category	Score	Category
The attractive design and appearance of the main screen	3	Enough	5	Very good
The regularity of the display of each page	4	Good	4	Good
Ease of interaction on Augmented Reality media	4	Good	4	Good
Quality and appearance of Augmented Reality interactive media	4	Good	5	Very good
The suitability of the selection of fonts, sizes and shapes	4	Good	3	Enough
The use of colour in the Augmented Reality media is consistent in each scene	4	Good	5	Very good
Augmented Reality media design looks creative and interesting	4	Good	4	Good
The use of Augmented Reality media facilitates the introduction of the human respiratory work system	4	Good	4	Good
Augmented Reality Media can be used in 5th-grade science lessons in primary school	5	Very good	5	Very good
Augmented Reality learning media can be operated well	4	Good	4	Good
Total	40	Good	43	Very good
Average	4.0		4.3	

The media expert gave a score of 40 (average 4.0), categorised as “Good.” Positive aspects included usability, colour consistency, and design creativity. However, the main screen's attractiveness was rated only “Enough,” suggesting that improvements in visual aesthetics were needed. The classroom teacher's assessment was higher, with a total score of 43 (average 4.3, “Very Good”). The teacher highlighted the engaging visual design,

the quality of the presentation, and its suitability for fifth-grade students. Nevertheless, the font selection was rated as “Enough,” indicating a need for refinement in typography and readability. Together, these evaluations demonstrated that the AR media was both usable and engaging, but improvements in screen design and font presentation would enhance its overall quality.

Product Revision and Refinement

The final stage involved synthesising expert and teacher feedback into revisions of the AR media. Based on the validation results, the following improvements were made:

1. Content Depth: Additional explanations were added to enhance completeness, particularly in describing the function of the respiratory organs.
2. Language Clarity: Revisions were applied to ensure consistency of terms and compliance with standard spelling and grammar rules.
3. Design Aesthetics: The main screen was redesigned with more appealing visuals, and font choices were adjusted to improve readability for young learners.

After revisions, the AR media was retested in the classroom, showing improved student engagement and more precise comprehension of respiratory processes.

In conclusion, the media expert assigned an average rating of 4.0 (Good), highlighting the need for improvements in the primary screen design's attractiveness. Concurrently, classroom teachers assigned a grade of 4.3 (Very Good) and recommended enhancements to font selection, size, and shape to improve readability. In response to this feedback, the revision phase was executed methodically: the depth of content was augmented with supplementary explanations; linguistic clarity was refined to ensure uniform terminology; and design aesthetics were improved by reconfiguring the main screen and modifying font selections to facilitate readability for young learners. The enhancement of this prototype product ensures that the produced AR media is credible, captivating, and functional, facilitating the science learning process in elementary education for the implementation stage.

Figure 1 was the initial product, and Figure 2 featured six key scenarios from the

Human Respiratory System in the final product image, which serves as the interface for the integrated AR learning materials and gives students various points of access.



Figure 1. Initial Main Interface Display of AR Media Before Revision



Figure 2. Final Main Interface Display of AR Media

Media Integration

The integration of Augmented Reality (AR)-based media into the learning module was designed to provide students with multiple access points for studying the human

respiratory system. Instead of relying solely on QR codes that require scanning, all AR media links were also combined into a single file. This approach enabled students to directly access interactive objects by clicking image elements within the file, thus simplifying usability and promoting independent learning. The media file included six major scenes: (1) the human respiratory system (overview), (2) the nose (external structure), (3) the nose structure (internal anatomy), (4) outer lungs, (5) inner lungs (bronchi), and (6) alveoli. Each scene provided three-dimensional visualisations to improve students' comprehension of abstract respiratory processes.

Table 3 provides a detailed overview of the creation of QR codes with AR media links for each distinct component of the human respiratory system, enabling students to focus on learning each element separately and promoting focused access and learning.

Table 3. QR Results of Comprehensive Development

Image	QR	Link
		https://asblr.com/bd1121
		https://asblr.com/097ea1
		https://asblr.com/f604a7
		https://asblr.com/a7129b
		https://asblr.com/e25474
		https://asblr.com/76deff

Implementation and Evaluation Stage

The implementation stage is a crucial phase in which validated AR-based learning media are tested directly with students to

assess their suitability and student responses. This study conducted trials on two scales: a small group consisting of five students and a large group involving 17 students. In the small-group trial, students were given teaching modules containing QR codes to access AR media. They completed worksheets and response questionnaires to measure their level of interest and ease of use. This approach enabled researchers to observe student interactions in depth and obtain direct feedback on their experiences.

Small Group Trial

The small group trial involved five fifth-grade students. Students were introduced to AR-based media through a teaching module containing a QR code that could be accessed via Assemblr Edu or Google Lens. The session included an introduction to AR media, exploration of respiratory system content, completion of student worksheets, and completion of questionnaires to measure responses.

Table 4. Small Group Questionnaire Results

No	Indicator	Score		Percentage
		Total	Maximum	
1	Attractive media design	5	5	100%
2	Visibility of 3D model size and shape	5	5	100%
3	AR media is fun as a learning medium	5	5	100%
4	Media runs smoothly without obstacles	3	5	60%
5	Usability (easy to operate)	5	5	100%
6	Attractive material design	4	5	80%
7	Understanding of material	5	5	100%
8	Accuracy of material delivery	5	5	100%
9	Clarity of language use	5	5	100%
10	Font size	5	5	100%
Total		47	50	94%

The overall small-group trial score was 94%, placing the AR-based media in the "very good" category according to the Guttman scale. Students consistently highlighted the

media's attractiveness, clarity, and engaging interactivity, though a few noted minor operational challenges, mostly due to device and connectivity limitations.

Large Group Trial

The large-scale trial expanded the evaluation to 17 students. While students expressed overall enthusiasm, the larger setting revealed more diverse responses, particularly regarding usability and language clarity.

Table 5. Large Group Questionnaire Results

No	Indicator	Score		Percentage
		Total	Maximum	
1	Attractive media design	17	17	100%
2	Visibility of 3D model size and shape	17	17	100%
3	AR media is fun as a learning medium	17	17	100%
4	Media runs smoothly without obstacles	10	17	59%
5	Usability (easy to operate)	16	17	94%
6	Attractive material design	17	17	100%
7	Understanding of material	14	17	82%
8	Accuracy of material delivery	17	17	100%
9	Clarity of language use	16	17	94%
10	Font size	15	17	88%
Total		156	170	90.6%

The large-group evaluation produced an overall suitability score of 90.6%, which is still categorised as "very good." Students praised the design and engaging content but reported usability issues linked to file size and unstable internet connectivity. The difference between small- and large-group results illustrates the importance of learning context. Small groups achieved slightly higher scores due to more intensive guidance and homogeneity in learning pace, which facilitated active engagement and comprehension. In contrast, larger groups showed greater variability in student responses, and technical and logistical challenges reduced overall effectiveness.

Discussion

The systematic development process, following the ADDIE model, culminated in a product deemed highly feasible and acceptable for fifth-grade students. The feasibility was quantitatively confirmed through expert and teacher validation, where material experts rated the media as "Good", and the classroom teacher provided an even higher rating of "Very Good". Similarly, media experts rated the product as "Good", a finding echoed by the teacher's "Very Good" rating. These consistently high validation scores indicate that the AR media is pedagogically sound, technologically functional, and highly relevant to the curriculum and student needs, thereby addressing the conceptual and motivational challenges identified in the initial analysis stage.

This finding aligns with earlier studies that emphasise that AR-based media is most effective when supported by interactive, guided, and focused environments (Masruroh et al., 2023; Susilawati et al., 2020), a need well documented among elementary teachers (Syawaludin et al., 2020). It also aligns with Alfarizi et al. (2024), who reported that technical constraints, such as large file sizes and internet instability, often hinder scalability in digital learning.

The study's findings directly connect to the existing literature, reinforcing the paper's contribution to the field. The finding that AR media enhances student engagement aligns with previous research by Siregar et al. (2025), who found that AR-based learning media increases motivation (Yusa et al., 2023) and conceptual understanding (Carera et al., 2025; Suyuti et al., 2023). The results from the small- and large-group trials, which showed that the AR media was effective but faced technical challenges such as network issues and large file sizes, are consistent with the findings of Sari et al. (2025) and Alfarizi et al. (2024). Furthermore, the observation that the AR media's immersive and interactive nature helps students visualise the complex human respiratory system reinforces the assertion by Setiawan (2023) and Pradita et al. (2024) that AR can effectively present abstract concepts in a realistic, 3D format (Anggraeni et al., 2024; Nursyaidah et al., 2025). This explicit

connection demonstrates that the current study not only confirms the benefits of AR in education but also provides practical insights into its implementation challenges, contributing to a more nuanced understanding of this technology's role in elementary science education.

This study reveals technical constraints affecting large-scale digital learning, resulting in a slight reduction in group scores due to issues such as large file sizes and unstable internet connectivity. These challenges limit the scalability and adoption of digital learning tools in classrooms (Permana et al., 2022).

In conclusion, this study validates the AR-based module as a feasible tool for elementary science education. While the survey confirms high engagement, a clear area for further exploration is the direct impact on academic outcomes. Therefore, future research must shift focus from feasibility and engagement to conceptual mastery by employing quasi-experimental designs with pre-test and post-test assessments. Furthermore, studies should specifically compare AR effectiveness across varying group sizes and explore strategies to mitigate technical constraints (e.g., smaller file compression or offline modes) to ensure better scalability and contribute a more nuanced understanding of AR's long-term effect on student achievement, science (Parisu et al., 2025) and digital literacy (Kalyani, 2024), especially when compared to its broader application at higher levels of education (Pradana, 2020).

CONCLUSION

Based on expert validation and student trials, the Augmented Reality (AR) learning media on the human respiratory system proved feasible and highly effective in increasing student engagement and interest in elementary school. This study highlights the promising role of Augmented Reality (AR)-based media in enhancing student engagement and interest in elementary science learning, particularly in understanding the human respiratory system. By transforming abstract and complex concepts into interactive, immersive experiences, AR provides students with more accessible, enjoyable learning opportunities. Although this research did not directly

measure conceptual mastery, the consistently positive responses from students and teachers suggest that AR has the potential to support more effective student-centred learning processes.

The design and development of the AR media aligned with curriculum standards and were tailored to the characteristics of digital-native learners, emphasising the importance of innovative approaches in educational technology. While this study was limited to a single topic, it serves as a foundation for expanding AR applications into other science concepts and subject areas, as well as across different educational levels. Integrating AR into the classroom not only improves engagement but also creates dynamic and future-oriented learning environments.

Future research should focus on exploring the long-term effects of AR-based learning media on students' academic achievement, learning motivation, and digital literacy skills. Moreover, studies that compare AR integration in small and large group settings could provide deeper insights into how contextual factors influence effectiveness. Ultimately, the use of AR in education is not a temporary trend but a progressive step toward building immersive, meaningful, and adaptive learning experiences that align with the evolving landscape of 21st-century education.

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