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Development of augmented reality and virtual reality learning media on human respiratory system material

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Abstract

The traditional learning media for the human respiratory system at SMA Mujahidin rely heavily on textbooks and Power Point presentations. To enhance this experience, we have developed Augmented Reality (AR) and Virtual Reality (VR) tools that feature realistic 3D animations. These immersive visualizations provide students with a more tangible and concrete understanding of respiratory anatomy and function. The purpose of this study is to create a flipbook learning medium that integrates AR and VR technologies, ensuring the content is both valid and practical for classroom use. We employed a Research and Development (R&D) approach, adapting Thiagarajan's original 4D model into a streamlined 3D framework: Define, Design, and Develop. This methodology aims to deliver an engaging, effective learning tool that enhances students' mastery of the human respiratory system. The data collection instruments included interview sheets, expert validation questionnaires, and student response questionnaires. Validation was carried out by three material experts, three media experts, and three language experts, with each obtaining a percentage of 92.37% for material experts, 95% for media experts, and 93.33% for language experts, indicating that the media is categorized as highly valid. The product trials were conducted in two stages: a small-scale trial involving 22 students (20% of the Grade XI population) and a large-scale trial involving 56 students (50% of the Grade XI population at SMA Mujahidin Pontianak). The results showed that the media received positive feedback, with student response rates of 84.95% in the small-scale trial and 82.6% in the large-scale trial. These findings indicate that the Augmented Reality and Virtual Reality-based learning media are feasible

Abstrak. *Media pembelajaran pada materi sistem pernapasan manusia di SMA Mujahidin masih terbatas menggunakan buku paket dan power point. Untuk itu, media pembelajaran Augmented Reality dan Virtual Reality yang dikembangkan merupakan media yang menampilkan visualisasi animasi 3D tampak nyata, sehingga memberikan pemahaman siswa lebih konkret dalam belajar, khususnya materi sistem pernapasan manusia. Penelitian ini bertujuan untuk mengembangkan media pembelajaran flipbook berbasis Augmented Reality dan Virtual Reality pada materi sistem pernapasan manusia yang valid dan layak digunakan. Penelitian ini menggunakan pendekatan Research and Development (R&D) dengan model pengembangan 4D yang dikembangkan oleh Thiagarajan, namun dimodifikasi menjadi 3D (define, design, development). Validasi dilakukan oleh tiga validator ahli materi, tiga validator ahli media, dan tiga validator ahli bahasa dengan masing-masing memperoleh persentase sebesar 92,37% ahli materi, 95 % ahli media dan 93,33% ahli Bahasa yang menunjukan bahwa media tersebut dikategorikan sangat valid. Uji coba produk dilakukan dalam dua tahap, yaitu uji coba skala kecil terhadap 22 siswa (20% dari siswa kelas XI) dan uji skala besar terhadap 56 siswa (50% dari siswa kelas XI SMA Mujahidin Pontianak). Hasil uji coba menunjukkan bahwa media memperoleh tanggapan positif dengan persentase respon siswa sebesar 84,95% pada uji coba skala kecil dan 82,6% pada uji coba skala besar. Hasil tersebut menunjukkan bahwa media pembelajaran Augmented Reality dan Virtual Reality yang dikembangkan layak digunakan.*

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A. Introduction

The learning process is a form of educational communication that involves three main components: the teacher as the sender of the message, the student as the receiver, and the subject matter as the content of the message. The success of learning is significantly influenced by the quality of interaction between teachers and students; therefore, learning media that support effective communication are essential (Resti et al., 2024).

One of the current innovations in education is the use of interactive learning media based on digital technology. Interactive learning media enables direct interaction between students and learning materials through a combination of visual, auditory, textual, and animated elements. This type of media, including computer applications, educational software, and web-based learning platforms, has been proven to be more engaging, participatory, and supportive of independent learning compared to conventional, textbook-based methods (Prabowo & Wakhudin, 2024). Consequently, the development of more innovative learning media is necessary to create a more enjoyable learning environment and enhance students' comprehension of the material.

At SMA Mujahidin Pontianak, the biology learning process, particularly on the topic of the human respiratory system, still relies on printed textbooks and PowerPoint presentations. Based on interviews with Biology teachers, these learning media are considered suboptimal due to limited visualizations of respiratory organs and the complexity of the material, making it difficult for students to fully understand the structure and function of the organs. As a result, the learning process tends to be monotonous and less motivating for students.

To address this issue, the development of AR and VR-based learning media is considered highly relevant. These technologies can provide interactive three-dimensional representations of respiratory organs, enabling students to understand abstract concepts in a more concrete and realistic manner. Previous studies have also shown that the use of AR and VR in science learning can enhance students' motivation, engagement, and comprehension of complex material (Bacca et al., 2015; Radianti et al., 2020).

On the other hand, the results of student interviews show that students prefer technology-based learning media that are more interactive, engaging, and entertaining, as these can increase their motivation in the learning process. In response to these conditions, one of the potential solutions is the use of AR and VR-based flipbook media, which are not only interesting and enjoyable but also highly relevant to the respiratory system material and aligned with students' needs.

Augmented Reality is a technology that combines the real world with virtual elements in the form of two-dimensional or three-dimensional images. AR enables the visualization of three-dimensional objects integrated into the real environment through Android devices, while VR creates immersive simulated learning environments (Untari et al., 2022; Syarif & Astuti, 2023; Pratiwi et al., 2022). The combination of AR and VR is believed to positively impact students' learning motivation, engagement, and the development of higher-order thinking skills (HOTS).

Previous studies have also shown that the application of AR and VR media in learning has a significant positive impact on students' motivation, engagement, and higher-order thinking skills (Prabowo & Wakhudin, 2024; Salsabila et al., 2023; Aripin & Suryaningsih, 2019; Darojat et al., 2022). Therefore, this study aims to producing AR and VR-based flipbook learning media on the human respiratory system material at SMAS Mujahidin Pontianak. It is expected that this media will provide a creative and innovative learning experience that students can use both in the classroom and at home.

B. Material and method

This research is a type of research and development (R&D) that adopts the 4D model (Define, Design, Develop, Disseminate) developed by Thiagarajan but modifies it into a 3D model (Define, Design, Develop) due to time and cost constraints.

The first stage, **Define**, focuses on needs analysis through structured interviews with teachers and students, as well as a review of syllabus documents to identify learning problems related to the human respiratory system material. Activities at this stage include a preliminary and final analysis to study the curriculum and syllabus, an analysis of student characteristics to identify issues with the existing learning media, a concept analysis to determine the material, and the formulation of learning objectives, which serve as the foundation for developing AR- and VR-based flipbook media.

The second stage, **Design**, involves designing media prototypes by considering aspects such as images, visuals, audio, and text innovatively. The design process includes selecting topics, creating storyboards, and developing flipbook media equipped with text and barcodes. These barcodes are linked to web platforms such as Meshy.ai, Tripo3D.ai, and Sketchfab.com to integrate AR and VR elements. According to research by Permana et al. (2024) The flipbook measures 21 cm x 28 cm. This flipbook was developed in two versions, namely Augmented Reality (AR)-based and Virtual Reality (VR)-based, both of which were adjusted to align with the learning objectives and material characteristics of the human respiratory system.

The third stage, **Develop**, involves a validation process by nine experts, consisting of three material

experts, three media experts, and three language experts. The data collection instruments included validation sheets and student response questionnaires, both designed using a 5-point Likert scale. The product trials were conducted in two stages: (1) a small-scale trial involving 20% of the total number of Grade XI MIPA students, and (2) a large-scale trial involving 50–60% of the students in the same grade (Prayitno, 2017). The purpose of these trials was to determine the feasibility of the AR- and VR-based flipbook media for the human respiratory system material, following revisions based on expert and user feedback.

The data from the validation results and student responses were analysed quantitatively and descriptively using a percentage formula to determine the level of validity and feasibility of the media. The interpretation of the results was based on the 5-point Likert scale, as described in Table 1. Furthermore, the level of validity of the learning media data that will be obtained from the score of assessment items can be calculated using the Formula 1 (Munawaroh et al., 2023).

Meanwhile, as a basis for determining the level of validity of AR and VR-based flipbook media, the assessment criteria listed in Table 1 are used. After the validity of the media is determined based on these criteria, the next step is to analyze the students' response to the learning media. This analysis aims to measure the percentage of student response rate to the media that has been developed, as presented in Table 2. The calculation of student responses is carried out using the Formula 2. From the results of the student responses that have been obtained, the average student response is searched using the Formula 3.

$$P = \frac{\sum x}{\sum x_1} x100\% \text{.....Formula 1}$$

$$Student\ response = \frac{Obtained\ data\ score}{Maximum\ total\ score} x100\% \text{...Formula 2}$$

$$\bar{R} = \frac{\sum Student\ response\ (\%)}{N} \text{.....Formula 3}$$

Description:
P = Validity value in percentage form
∑X = Total score from expert assessment
∑X1 = Highest total score
100 = Constant
$\bar{R}$ = Average student response
∑ = Student response: number of student responses
N = Number of students

The augmented reality *and* virtual *reality-based flipbook learning media* developed on human respiratory system materials for grade XI students of SMA Mujahidin Pontianak was declared to be of good quality and feasible to be used in learning activities. This media meets the validity criteria with a minimum score of 61% with **valid criteria** from expert researchers. Data on student responses were obtained through the distribution of student response questionnaires, which were analyzed using a 5-point Likert scale. The results of the questionnaire were then processed and evaluated based on the criteria of the percentage of student response scores. The details of the Likert scale used are presented in Table 3.

Table 1 Assessment score criteria

Assessment criteria	Positive score	Negative score
Strongly agree	5	5
Agree	4	4
Quite agree	3	3
Disagree	2	2
Strongly disagree	1	1

Table 2 Criteria for the percentage of validity of learning media

Percentage (%)	Validity criteria
81 – 100	Very valid
61 – 80	Valid
41 – 60	Quite valid
21 – 40	Invalid
0 – 20	Invalid

(Source: Febrianti et al., 2024)

Table 3 Interpretation criteria for student response scores

Criterion	Percentage (%)	Information
Very positive	82 – 100	No revision required
Positive	64 – 82	No revision required
Quite positive	46 – 64	No revision required
Negative	28 – 46	Revision
Very negative	10 – 28	Revision

(Source: Nengsih, 2023)

C. Results and discussion

The product of this research is a learning medium in the form of a flipbook integrated with augmented reality (AR) and virtual reality (VR) technology, focusing on the human respiratory system material. The improvement of the media was carried out based on suggestions and feedback from expert validators. The validation process involved nine experts, divided into three groups: three material experts, three media experts, and three language experts. This research employed the Four-D (4D) development model by Thiagarajan, which was modified into a Three-D (3D) model consisting of three main stages: **define**, **design**, and **develop**.

Define

The **define stage** in this study establishes and determines learning conditions through end-to-end analysis, analysis of student characteristics, concept analysis, and the formulation of learning objectives. (Sarinah et al., 2024). The analysis stage began with interviews conducted with a biology teacher at SMA Mujahidin Pontianak to gather information related to the Grade XI biology syllabus, Core Competencies (KI), Basic Competencies (KD), and learning obstacles. The results of these interviews revealed that students experienced difficulties in understanding the material, particularly regarding the human respiratory system. These difficulties stem from the use of conventional learning media, such as printed books, overly textual PowerPoint presentations, and unclear illustrative images, making it hard for students to properly visualize the respiratory organs. Consequently, student engagement in learning decreases, and the learning process becomes monotonous and ineffective. This is also influenced by teacher centred learning methods and limited media that fail to present the material interactively (Yuniarti et al., 2023).

Further curriculum analysis showed that the school implements the Independent Curriculum for Grade X and the 2013 Curriculum for Grades XI and XII. Based on these conditions, the learning media developed do not specifically incorporate KI and KD, allowing them to be applicable across different curricula. However, syllabus, KI, and KD analyses are still carried out as a conceptual foundation for the development of flipbook learning media based on AR and VR.

To analyse student characteristics, researchers conducted interviews with 10 Grade XI science (MIPA) students to identify the obstacles they face during the learning process. The results indicated that students feel less motivated due to the passive nature of conventional learning. In contrast, students expressed interest in technology-based media, such as smartphones, which they perceive as more engaging and effective for understanding the material. This finding aligns with the research of (Effendi & Wahidy, 2019), which emphasizes that integrating technology into learning is essential in the digital era, as its dynamic, creative, and innovative characteristics have become an integral part of modern education. Similar findings were reported by Anam and Kusuma (2021), who state that digital media can create a more dynamic learning environment, increase student interaction and engagement, and accelerate students' conceptual understanding.

At the concept analysis stage, the core learning materials were determined based on the Grade XI science (MIPA) syllabus from the 2013 Curriculum, which includes: (1) the structure and function of the human respiratory system, (2) respiratory mechanisms, and (3) diseases or disorders of the respiratory system. All of this material is visualized in AR and VR-based flipbook media, aligned with predetermined learning indicators.

The final stage of the **define phase** is the formulation of learning objectives, designed based on the results of the concept analysis. These objectives serve as the primary reference in the media development process to ensure alignment with students' learning needs and characteristics.

Design

The design stage is the second step after *the definition* stage. The results of the analysis obtained at the *defining stage* became the foundation for the process of designing Augmented Reality and Virtual Reality-based flipbook media. At this stage, design development includes determining learning topics, selecting appropriate media formats, and the process of creating media through supporting applications. Details of this design process are presented in Table 4.

Develop

The development stage aims to revise and validate the AR and VR-based flipbook media to ensure their suitability for use in learning, through product validation and trials. Expert validation involves an overall assessment and suggestions for improvement of the developed media, covering aspects such as content, media design, and language use. The purpose of expert validation is to determine the feasibility of the developed learning media based on the suggestions and feedback obtained, so that the product can be categorized as suitable for use.

Expert validation focuses on the human respiratory system material contained in the barcode embedded within the product. Material validation is conducted to assess the alignment of the learning media content with the curriculum and learning objectives. The validated aspects include content feasibility, presentation structure, and language use. The validation results showed an average validity score of 90.36%, with a content feasibility score of 92.22%, a presentation feasibility score of 83.33%, and a language use score of 95.55%, as shown in Table 5.

According to the criteria established by Khairunnufus et al. (2019), values above 81% fall into the "very valid" category. Therefore, these results indicate that the AR and VR-based flipbook media developed for the human respiratory system material are suitable for use. These findings also confirm that the content has been aligned with the Core Competencies (KI) and Basic Competencies (KD) outlined in the learning objectives.

Table 4 Design stage results

Step	Result
Define a topic	Flipbook format is 21cm x 28cm (Permana et al., 2024). The flipbook section consists of two main parts, namely the initial part, including the front cover and the main material, and the content part includes the description of the material on the barcode and instructions for using the media. The determination of media topics is based on the K13 XI MIPA syllabus, which includes three subjects: the structure and function of the respiratory system, respiratory mechanisms, and diseases or abnormalities in the human respiratory system.
Format selection	Flipbook format is 21cm x 28cm (Permana et al., 2024). The flipbook section consists of two main parts, namely the initial part, including the front cover, and the main material. The content section includes the description of the material on the barcode and instructions for using the media.
Create AR and VR media.	Create a storyboard flipbook using the Canva application and create material content on the barcode using *the Meshy.ai, My WEBAR,* and *Sketchfab.com platforms.*

Table 5 Results of the expert validation assessment

Assessment indicators	Percentage (%)	Criterion
Eligibility of the content of the material	92,22	Very valid
Eligibility	83,33	Very valid
Language use	95,55	Very valid
Average	**90,36**	**Very valid**

Table 6 Results of media expert validation assessment

Assessment indicators	Percentage (%)	Criterion
Augmented reality and virtual reality app design	91,42	Very valid
Media attractiveness	88,33	Very valid
Media utilization and management	95	Very valid
AR and VR	97,77	Very valid
Average	**93,13**	**Very valid**

Table 7 Results of linguistic validation assessment

Assessment indicators	Percentage (%)	Criterion
Language use	94,44	Very valid
Businesslike	96,66	Very valid
Communicative	100	Very valid
Interactive dialogue	90	Very valid
Average	**95,275**	**Very valid**

Learning media encompasses various elements, including tools, environments, and any form of activity that is deliberately designed to enhance knowledge, shape attitudes, or develop skills for the individuals who use them (Aghni, 2018). Validation by media experts aims to assess both the visual and technical aspects of the learning media. The assessment was conducted based on several indicators, including AR/VR application design, media attractiveness, media utilization and management, and the effectiveness of AR/VR use. The average media expert validation score obtained was 93.13%, with the AR/VR application design indicator scoring 91.42%, media attractiveness scoring 88.33%, and the effectiveness of AR/VR use reaching 97.77%, as shown in Table 6. According to the standard set by, learning media is categorized as valid if it achieves a score of at least 71%, indicating that the media is highly feasible in terms of design and technical aspects. These results show that the media's visual design is easy to understand, supported by appropriate choices of typeface and color combinations. This finding is consistent with the research, which revealed that proper visual design can attract students' attention and help them focus more effectively on the presented information.

Validation of linguistic aspects is carried out to ensure the clarity of delivery, readability of the text, and the accuracy of diction selection in the presentation of learning materials. The four main indicators assessed include linguistic structure, straightforward, communicative, and interactive-dialogical language. The validation results showed an

average validity rate of 95.275%, with the scores of each indicator being 94.44% for language structure, 96.66% for straightforwardness, 100% for communication, and 90% for interactivity as described in Table 7. According to Bintiningtiyas and Lutfi (2016), who stated that a score above 61% is included in the valid category, this medium is stated to be very feasible in terms of language.

Present input from each design aspect according to the validator suggestions (such as Table 4) is implemented into the product development stage to improve the quality of the developed media. The revisions carried out include aspects of the front cover design, the content of the main material, the procedure for using media, the components and functions of the organs that make up the respiratory system, the mechanism of the respiratory process, and the types of diseases related to the human respiratory system. Details of these changes can be seen in Table 8.

Table 8 The media revision results are based on validator assessments (in Indonesian)

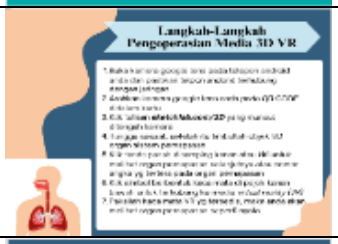
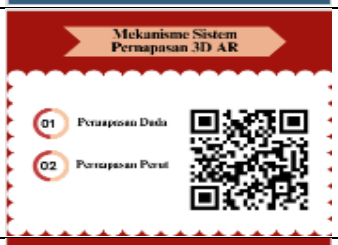
No.	Media section	Images before revision	Images after revision
1	Front cover		
2	Subject matter section		
3	Media operation steps		
4	Organs and functions that make up the respiratory system.		
5	Mechanisms of the respiratory system		
6	Diseases of the respiratory system		

Table 9 Student response results

No.	Test scale	Mean	Criteria
1.	Small	84.95%	Very positive
2.	Large	82.55%	Very positive

Student response results

The product trial stage in this study involved evaluating students' responses to the use of AR and VR-based learning media on the human respiratory system material at SMAS Mujahidin Pontianak. Student responses covered various aspects, including assessments of content quality, visualization, three-dimensional images, and the level of interest in the developed media. A low response rate may indicate a lack of interest and participation among students in the learning process using these media. The results of the validation regarding the aspect of interest showed that AR-based learning media were considered interesting by students. Interest is related to students' internal drive and curiosity toward a particular object, activity, or experience, which generally arises naturally from the activity itself, such as enthusiasm during the learning process (Awe & Benge, 2017). In terms of appearance, the validation results also showed that AR-based media can foster learning motivation in students. Motivation is defined as a change in energy within an individual, characterized by specific feelings and reactions aimed at achieving a goal (Anggraini & Sukartono, 2022).

To obtain objective and measurable data on student responses, a questionnaire instrument using an assessment scale was employed. The distribution of the questionnaire was carried out in two stages (Rahmawati et al., 2021), namely a small-scale trial involving 20% of students and a large-scale trial involving 50% of the total Grade XI students at SMA Mujahidin Pontianak. This phased trial strategy follows the procedure proposed by (Prayitno, 2017), which emphasizes the importance of multi-level testing to obtain the results will be accurate if implemented in the classroom learning process, and it is sufficient to just test student responses. The application of AR and VR media in biology learning has been proven to enrich students' learning experiences and enhance their understanding of complex concepts (Riyanto et al., 2020; Harahap, 2019).

Based on the data in Table 9, the questionnaire analysis showed that the student response rate reached 84.95% in the small-scale trial and 82.55% in the large-scale trial, indicating that students responded very positively to the use of the media. The sampling technique employed was simple random sampling (Nurwhite et al., 2024), ensuring that the results are representative of general classroom conditions. These findings confirm that AR- and VR-based flipbooks are suitable for use as learning tools in biology.

The product developed in this study is a flipbook based on AR and VR for learning materials on the human respiratory system. Flipbook learning media is highly flexible and easy to use, allowing students to learn anytime and anywhere (Arisandhi et al., 2023). The use of AR-based flipbooks offers advantages in creating a more interactive and visual learning experience. Students can more easily understand the location and structure of the respiratory system through the visualizations provided by VR. AR enables the integration of the real world with virtual elements, creating a more interactive and immersive learning experience for students (Philosophy et al., 2024); Moreover, AR can be used to help visualize abstract concepts, making it easier for students to understand the structure and form of object models (Rojib & Ratnawati, 2024).

Augmented reality is easy to use independently in the learning process. This is consistent with the opinion of Rojib and Ratnawati (2024), who stated that augmented reality can provide a flexible learning experience, allowing students to study independently, in various locations, and at any time. Research on the application of augmented reality in science learning has shown significant impacts, including improved understanding of the material, increased student engagement and interest, better retention, stronger integration of theory with practice, and enhanced learning effectiveness in the digital era (Philosophy et al., 2024).

In relation to the global issue of education quality, the findings of this study emphasize the urgent need for Indonesia to improve science learning through the integration of digital technology. According to the OECD Programme for International Student Assessment (PISA) 2022 report, Indonesian students' scientific literacy performance remains below the OECD average, ranking 71st out of 81 participating countries with a score of 383 points. This is far behind East Asian countries such as Japan, South Korea, and Singapore, which achieved scores above 500 points (OECD, 2023). These results indicate that Indonesian students still face challenges in developing a deep understanding of scientific concepts and in applying them to real-world contexts.

In this context, the implementation of AR- and VR-based media represents a potential innovative strategy to bridge the gap in science learning in Indonesia. By utilizing interactive and immersive technology, students can gain a more concrete and participatory learning experience that aligns with the demands of 21st-century education. This approach can support efforts to increase motivation and conceptual understanding, and ultimately contribute to improving

Indonesia's ranking in international assessments such as PISA.

This research contributes to enhancing education and broadening understanding of the use of technology-based learning media. The implementation of flipbooks integrated with augmented reality and virtual reality has been proven to facilitate students' comprehension of scientific concepts in a more visual and interactive manner. The findings of this study provide a concrete illustration of the potential for integrating AR and VR technologies into learning activities and can serve as a reference for educators in adopting innovative learning approaches through the use of digital technology.

D. Conclusion

Based on the results of the data analysis in Table 8, students' responses to the augmented reality and virtual reality-based flipbook learning media on the human respiratory system material were very positive, indicating that the media is suitable for use in the learning process. The results of the small-scale trial showed a response percentage of 84.95%, while the large-scale trial showed a response percentage of 82.55%. Both results fall into the "very positive" category. These findings indicate that the augmented reality and virtual reality-based flipbook learning media play an important role in creating engaging and innovative learning experiences, thereby increasing the learning motivation of Grade XI students at SMAS Mujahidin Pontianak.

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