

Development of Augmented Reality-Based Flashcard Learning Media on Human Respiratory System Materials

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Abstract: Teachers have not been optimal in developing technology-based learning media in the form of interactive games, so that student learning outcomes on human respiratory system materials in elementary schools are still low. This study aims to describe the design, feasibility, and effectiveness of Augmented Reality-based flashcards for improving the learning outcomes of grade V students on the human respiratory system. This research is a Research and Development (R&D) with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The research subjects amounted to 27 students in class V. Data collection techniques included observation, interviews, questionnaires, documentation, and pretest and posttest assessments. Data were analyzed using normality tests, Paired Sample t-Test, and N-Gain tests. The flashcard media was developed using Canva and integrated with AR technology through the Assemblr Edu platform to support concrete and interactive visualization of concepts. Integrating AR-based flashcards into interactive edugames for elementary students. This Augmented Reality contains explanations of respiratory organs, organ functions, interesting facts, respiratory organ disorders, and human breathing mechanisms. The validation results showed that the media was highly feasible to use, with validation by material experts at 91.07% and by media experts at 95.37%. The responses of teachers and students also showed very positive results with percentages of 96.59% and 90%, respectively. The effectiveness of the media was demonstrated by an increase in the average score from 55.25 on the pretest to 74.25 on the posttest, with a Sig. p-value of < 0.001 and an N-Gain score of 0.4581 in the medium category. The findings of the study show that AR-based flashcards have been successfully developed, are highly feasible, and are effective in improving student learning outcomes, serving as an innovative learning medium that supports engaging and interactive science learning.

Keywords: Augmented Reality; Flashcard; Human Respiratory System; Learning Outcome.

Introduction

Education is a necessity for every human being, as it must create an interesting learning atmosphere that engages students in developing their potential, so that they become a quality and competent generation in terms of attitudes, knowledge, and skills. In its implementation, education has the goal of developing students' potential as subjects of educational actors [1]. Education in Indonesia aims to develop students with faith, noble character, creativity, critical thinking, and the ability to adapt to changing times, in accordance with the national goals of education in Permendikdasmen No. 13 of 2025, which can be achieved through an interesting, fun, and challenging learning process.

Learning is a process of interaction involving students, teachers, and learning resources within a learning environment. Ideal learning is learning that is able to encourage students' creativity as a whole, make students active, achieve learning objectives effectively and take place in fun conditions [2]. In basic education, ideal learning fosters students' curiosity and activeness by emphasizing the value of process rather than results [2], where teachers serve as facilitators who guide and encourage students' responsibility in achieving learning goals.

Science learning combines science concepts with life skills to form students' analytical thinking skills. Science learning focuses on scientific activities that provide direct

learning experiences to students to be able to understand nature scientifically and develop cognitive, psychomotor, and social skills [3]. Ideal science learning encourages students to observe, question, try, and deduce their own knowledge from the results of their exploration [4]. Based on this, ideal science learning must include or facilitate two elements: understanding concepts and process skills. The success of science learning in elementary education is evident in the achievement of predetermined learning outcomes and objectives. Based on Permendikdasmen Number 13 of 2025, the learning outcomes of IPAS Phase C in the concept understanding element emphasize the ability of students to simulate using simple media about the human organ system and how to maintain its health. The implementation of ideal science learning is reflected in the scope of science material in Elementary Education.

The scope of science learning in Elementary Education includes a variety of scientific concepts, one of which is the material on the human respiratory system studied in grade V. This material demands not only an understanding of the structure and function of the respiratory organs, but also an understanding of complex and abstract biological processes, such as the mechanisms of inspiration and expiration, which cannot be directly observed by students. Because of its abstract nature, science learning should ideally be supported by the use of visual and interactive media that are able to visualize the concept in real

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life so as to make it easier for students to understand [5]. The use of learning media can help make abstract scientific concepts more concrete and easier for students to understand through interactive, objective visualizations [6]. The implementation of technology-based learning media is an important strategy for improving the quality of 21st-century learning, particularly in elementary school science education. Technology enables learning materials to be delivered in a more interactive, engaging, and student-centered manner that aligns with the characteristics of modern learners.

Based on preliminary research data obtained through observations, interviews, and documentation activities conducted with homeroom teachers and grade V students at SD Negeri Gondoriyo Semarang, the researcher found that teachers have not been effective in developing technology-based learning media, namely interactive edugames. This is shown from the use of media in the learning process. Teachers still rely on media around RPPM, visual media, audiovisual videos (YouTube), and PowerPoint presentations that do not actively involve students. As a result, students are less involved in the learning process and become only passive listeners [7]. This is also due to the lack of variety in the media used, which decreases learning motivation and leads to low student participation in discussions and other learning activities [8]. This condition certainly affects students' learning outcomes, especially in abstract material such as the human respiratory system. On the other hand, the potential for technology, such as learning applications, simulations, or augmented reality-based media, is very large for supporting students' understanding, especially of abstract science materials such as the human respiratory system [9].

Student learning outcomes in respiratory system material remain low, as evidenced by the average summative score (SAS) at the end of the semester for class V, placing the science subject in the third position with the lowest score. In the material, 14 out of 27 students (51.85%) have achieved or exceeded the KKTP, while 13 (48.15%) have not met it. This shows that students' understanding of the material has not reached the expected level. Respiratory system materials require an understanding of the structure, function, and process of breathing, which is not easy to master without the support of learning media [10]. In addition, the use of less interactive learning media also causes students to have difficulty understanding the concepts conveyed [11].

Based on the problems described, efforts are needed to improve the quality of the learning process by using technology-based learning media that are interesting and interactive. One of the innovative solutions is the development of Augmented Reality (AR)-based flashcard learning media. Flashcards are visual media in the form of cards containing pictures, words, or symbols that help students understand the material simply and gradually [12]. Flashcards serve to attract attention, clarify ideas, and present concepts that cannot be displayed in real life [13]. Flashcard development should focus on components such as instructions for use, brief explanations, and attractive visuals, which can be integrated with AR technology to enhance interactivity.

Augmented Reality (AR) is a technology that integrates virtual objects into the real environment, resulting in more concrete and interactive learning visualizations [14]

The combination of flashcards with AR allows the presentation of three-dimensional objects, animations, and sounds through digital devices such as smartphones or tablets. In this study, the media was developed using the Assemblr EDU application to integrate AR content into flashcards through QR codes or markers. The use of AR visualization helps students understand respiratory system material more realistically, increases interest and learning engagement, and strengthens understanding of abstract concepts [15], so that it becomes a relevant alternative to improve the quality of learning in science.

Previous research has shown that Augmented Reality-based flashcard media can significantly improve students' science knowledge and is considered feasible, practical, and effective based on expert validation, teacher and student responses, and high gain scores [16]. In addition, the development of interactive edugame-based quartet card media has been proven effective in improving student learning outcomes, as evidenced by increases in pretest and posttest scores and high N-Gain scores [17]. However, these studies still have limitations because they focus only on relatively simple subjects, such as the life cycles of animals and changes in object shape, and have not integrated augmented reality technology into more complex science materials at the elementary school level. Therefore, this research aims to address this gap by developing augmented reality-based flashcards in the form of interactive edugames to improve the learning outcomes of grade V students on the human respiratory system.

Based on the description of these problems, this study aims to develop the design of Augmented Reality-based flashcard learning media on the human respiratory system, test its feasibility through expert assessment, and test the media's effectiveness in improving the learning outcomes of grade V students at SD Negeri Gondoriyo Semarang.

Research Methods

Type of Research

This study employed a Research and Development (R&D) approach. R&D is a research method used to develop a specific product and examine its effectiveness [18]. The development model applied in this study was the ADDIE model.

Research Procedure

The research and development procedure using the ADDIE model includes five main stages, namely: 1) The analysis stage, which is carried out by identifying the needs and problems at the research site. 2) Design stage, which includes material design, flashcard visual design, and preparation of research instruments. 3) The development stage, creating media using the Canva application for two-dimensional visual design and Assemblr Edu for the integration of AR content in the form of three-dimensional objects, which are then validated by media experts and material experts. 4) Implementation stage, which involves conducting product trials on small groups and large groups of class V students. 5) Evaluation stage, which assesses feasibility, practicality, and the effectiveness of the media based on the data obtained [19].

Research Subject

The subjects of this study are 27 students in grade V of SD Negeri Gondoriyo Semarang for the 2025/2026 school year. The research subjects were divided into 2 groups: small-group test subjects and large-group test subjects. The small-group test was carried out with 7 students, with the criteria being 2 high-ability, 3 medium, and 2 low. The selection of this group aims to represent the variety of students' academic abilities so that the developed media can be tested at various levels of understanding. Ability grouping is based on students' cognitive ability or initial ability, which refers to their prior learning outcomes. Early learning is an important factor that affects learning outcomes and students' understanding of concepts in learning [20]. As for the large-group test, it was conducted with 20 students.

Research Instrument

The research instrument was validated through assessments by material and media experts. Media expert validators assess the aspects of appearance, design, interactivity, ease of use, and technical quality of the developed learning media. Meanwhile, the material expert validator assesses the material's suitability, the concept's accuracy, and the language's appropriateness for elementary school students. Teacher and student response questionnaires were used to assess the practicality of the developed product [21]. The reliability test using Cronbach's alpha yielded a coefficient of 0.738, indicating that the research instrument is considered reliable. The pretest and posttest instruments are prepared based on learning objectives to measure student learning outcomes on the human respiratory system material. Pretest and posttest questions are multiple-choice items aligned with learning indicators, with each correct answer earning 1 point to assess student achievement of learning outcomes before and after the implementation of the learning media.

Data Collection Technique

Data collection is an important stage that determines the quality of research results [22]. In this study, the data collection technique used non-test and test methods. Non-test techniques include observation, questionnaires, interviews, and documentation [18]. Observations were conducted to examine the learning process, media use, and activities of teachers and students in class V. Structured interviews were conducted with teachers to obtain information on the initial conditions of the learning process, obstacles faced, and the availability of learning media. Questionnaires are given to students and teachers to see the needs of teachers and students, while documentation is used to collect supporting data such as teaching modules, student learning outcomes, infrastructure, and learning activities.

The test technique was carried out through pre-test and post-test to measure students' cognitive abilities prior to and following the treatment [23]. Pre-test is used to determine initial ability, while post-test is used to measure the improvement of learning outcomes, so that the effectiveness of the media can be objectively known [24].

Data Analysis Technique

Data analysis was conducted to address the research problems and answer the formulated questions. Data analysis in this study includes analyzes of design development, feasibility, and product effectiveness. The design development analysis was carried out descriptively, based on the ADDIE model, to ensure the media's suitability for learning needs. Feasibility analysis was carried out through the assessment of material and media experts using percentages to determine the feasibility level of the product [18]. Meanwhile, the effectiveness analysis was carried out using pre-test and post-test data with normality tests, Paired Sample t-Test, and N-Gain tests to determine the distribution of data, differences in learning outcomes, and improvement of student learning outcomes [25].

Results and Discussion

The research and development of augmented reality-based flashcard media in science subjects, especially human respiratory system materials in grade V of SD Negeri Gondoriyo, Semarang City, resulted in three research objectives, namely: 1) Design of the development of Augmented Reality-based Flashcard learning media, 2) The feasibility of Augmented Reality-based Flashcard learning media, and 3) The effectiveness of Augmented Reality-based Flashcard learning media.

Design and Development of Augmented Reality-Based Flashcard Learning Materials

The design of the development of augmented reality-based flashcard learning media in this study is prepared based on the stages of the ADDIE model, which includes analyze, design, development, implementation, and evaluation.

Analysis

The analysis stage is the first step in the ADDIE model. In the analysis stage, information was collected about existing problems, school potential, and school needs [9]. This stage aims to obtain the data and information needed for the research [26]. The researcher identified learning needs, student characteristics, school potential, and problems faced in learning social studies, especially in the material of the human respiratory system. The analysis results indicate that there are issues in the science learning process, particularly that teachers have not optimally developed technology-based learning media that are interactive games, so that student learning outcomes are still low, as seen from the Final Semester Summative learning results, which show that there are still 48.15% of students who have not reached the KKTP. In addition, students have difficulty distinguishing among names, functions, disorders, and systems of the respiratory organs due to the presence of unfamiliar terms in daily life.

The potential of SD Negeri Gondoriyo is quite good, namely, the availability of adequate facilities to support the learning process. These facilities include projectors, loudspeakers, microphones, and WiFi networks available in each high classroom, making it very possible for the development and utilization of technology-based learning

media. Therefore, researchers designed and developed learning media in the form of augmented reality-based flashcards as a solution to these problems because augmented reality media can help abstract learning concepts become real [27]

Design

The Design stage is a systematic stage that aims to prepare a learning media plan based on the results of a needs analysis [28]. In the design stage, the researcher developed a flashcard media concept that combines visual elements, text, and augmented reality. The process of designing flashcards and flashcard boxes is carried out using the Canva application, which is used to create an attractive visual appearance of the card, including the selection of colors, images, typography, and layouts. Canva is an online-based graphic design platform that provides a wide selection of templates that can be used to create learning media [29]. Canva is able to attract students because of its attractive appearance, which can increase the effectiveness of delivering materials [30]. Each card has two sides: the front and the back.



Figure 1. Flashcard front design



Figure 2. Flashcard back design

Figure 1 shows the design of the front of the flashcard containing the title of the flashcard, an image, and the name of the respiratory organ arranged in a simple and informative manner. This presentation aims to make it easier for students to quickly recognize organs, attract attention, and connect visual appearance with the scientific terms they have learned [31]. Figure 2 shows the design of the back of the flashcard. The section is embedded with a QR code or marker that can be scanned using a smartphone device to access Augmented Reality content directly. This feature allows students to see visualizations of the respiratory organs in a more interactive and contextual form, thus helping to clarify concepts [32].

This two-sided design is an application of Jean Piaget's cognitive theory of concrete operational stages. At this stage, the child is more likely to understand things

through concrete objects [33]. On the front of the flashcard box, there is the title or name of the flashcard, an image of the respiratory organ, and the name of the flashcard compiler. Meanwhile, on the back of the flashcard box, there is information on how to use an augmented reality-based flashcard, as shown in Figure 3. The integration between informative packaging and interactive cards ensures that these media serve not only as teaching aids but also as a systematic self-study resource for primary school pupils.



Figure 3. Flashcard box design

The development of augmented reality content is carried out using the Assembler Edu application. Assembler Edu is a mobile application development platform with three-dimensional features and augmented reality technology [34]. Assembler Edu provides an attractive visual display and easy access to features, making it easier for students and teachers to use. Through this application, researchers designed and integrated three-dimensional (3D) objects of respiratory organs that appear when the card is scanned, equipped with visualizations to help understand concepts more clearly. The app's content structure is systematically designed to support the learning flow (Figure 4).

The developed content features visualizations of the organs of the human respiratory system as interactive 3D objects accessible via marker scanning, object visualization, and real-space placement. The presentation supports more concrete and interactive learning [35]. In addition, the main menu provides navigation to materials, explanations of organ functions, interesting facts, and information about respiratory system disorders.



Figure 4. Initial view after scan



Figure 5. Main menu



Figure 6. Explanation of organ function



Figure 7. Interesting fact display



Figure 8. Interference Display

Presenting material through 3D visualization and interactive icons helps students better understand the structure and function of the respiratory organs. Additional material, including interesting facts and explanations of disorders of the respiratory organs, is also designed to increase students' curiosity, engagement, and understanding of the importance of maintaining a healthy respiratory system [36].

The creation of augmented reality-based flashcard media is grounded in the theories of Piaget and Bruner. The design of the double-sided flashcard is an application of

Piaget's cognitive theory at the concrete operational stage, because elementary school students are more likely to understand through concrete objects [33]. By separating the organ name and the visual on the one hand, and interactive technology on the other, students are invited to recognize the object in real life before delving into its function in the abstract. The use of QR codes on the back side to access Augmented Reality (AR) is relevant to Bruner's theory at the iconic stage, which is the representation of knowledge through visual media [37]. Barcodes serve as a bridge from the observation of two-dimensional images to interactive exploration of three-dimensional models, where scanned barcodes are transformed into dynamic 3D models that can be rotated, zoomed in, and viewed from various angles.

Development

At the development stage, all the plans that have been made are then realized. The development stage aims to produce a valid and ready-to-use learning product [28]. This stage involves creating flashcard learning media based on a pre-made design. After the media is finalised, the researcher prints it and conducts validation tests with media and material experts to assess the feasibility of the content and design. The results of the feasibility test by media and material experts meet the criteria and are very feasible with revision. Based on the validation results, revisions were made to improve the product and better prepare it for use in learning. Aspects of material expert validation include: (1) Suitability of the material with CP and TP, (2) Suitability with the level of understanding of students, and (3) Suitability of the material with the media. Validation aspects from media experts include: (1) Suitability between flashcards and CP and TP, (2) Flashcard suitability with efficiency, and (3) Suitability of flashcard design with material.

Implementation

The implementation stage involves conducting trials in small and large groups. At this stage, the researcher implements the developed media in the actual learning environment [38]. Implementation activities are carried out after augmented-reality-based flashcard products are deemed feasible by validators. Furthermore, the researcher tested the media in small groups and then with large groups to evaluate its effectiveness and students' responses to the developed learning media.

Evaluation

The last stage is evaluation. At this stage, the researcher assesses the quality, feasibility, and effectiveness of the augmented reality-based flashcard product and ensures that the development goals have been achieved [39]. The researcher also conducted a product feasibility test using a questionnaire, collecting responses from teachers and students to assess the developed media's feasibility. In addition, the researcher analyzed data on pre-test and post-test results using normality tests, paired sample t-tests, and N-Gain analysis to determine the improvement of student learning outcomes [40].

Feasibility of Augmented Reality-based Flashcard learning media

The feasibility of augmented reality-based flashcard media for human respiratory system material is determined through validation by subject-matter and media experts. The material validation test is a process of assessing the feasibility of the content of teaching materials in learning media, conducted by experts before they are used in learning activities. This process is intended to ensure that the developed material aligns with the established learning objectives [41]. Meanwhile, the media validation test is an assessment stage of learning media that is developed based on certain aspects that have been predetermined to ensure its feasibility of use [42].

Table 1. Validation Results of Material and Media Experts.

Validator	Percentage	Criteria
Material	91.07%	Highly Worth It
Media	95.37%	Highly Worth It

Based on Table 1, the validation results for the material experts yielded a score of 51/56. The assessment conducted by material experts covered three indicators: the alignment of the material with CP and TP, the appropriateness of the material to students' level of understanding, and the compatibility of the material with the media. Overall, the score was 91.07%. According to the eligibility criteria, the score indicates that the material in augmented reality-based flashcard media falls into the "Very Feasible" category. This indicates that the material has been prepared systematically, is relevant to the curriculum, and aligns with students' characteristics, thereby supporting the learning process optimally [43].

The media expert validation results obtained a score of 103 out of a maximum score of 108. The assessment by media experts includes three indicators: the flashcard's suitability for CP and TP, its efficiency, and the suitability of its design for the material. Overall, the score was 95.37%. According to the eligibility criteria, the value indicates that augmented-reality-based flashcard media falls into the "Very Feasible" category. This high value indicates that the media has an attractive appearance, is easy to use, and can present the material effectively [44].

The high level of material and media feasibility is influenced by the integration of visual design, appropriate content, and Augmented Reality technology, which can visualize abstract concepts into more concrete terms. The use of AR allows students to understand the material more deeply through direct interaction with 3D objects, thereby increasing engagement and learning effectiveness. This is in line with research that states that AR media can help understand concepts and improve the quality of students' learning experience [45].

Table 2. Results of Teacher and Student Responses

Response	Percentage	Criteria
Teacher	96.59%	Highly Worth It
Student	90%	Highly Worth It

Based on Table 2, the teacher's response to the use of augmented reality-based flashcard media was 96.59%, indicating that the media is very feasible and of very good

quality in terms of appearance, content, and ease of use. The teacher considers that this media can support the delivery of material in a more engaging and systematic way, as well as help explain abstract concepts more concretely. In addition, the integration of Augmented Reality technology in learning media is considered effective in improving the quality of learning because it can combine visual, interactive, and contextual elements [41].

Students' responses to the use of augmented reality-based flashcard media reached 90%. They met very feasible criteria, indicating very positive responses, especially in increasing interest, ease of understanding the material, and involvement in learning. Students feel more interested and motivated to participate in learning because the media used is interactive rather than monotonous. In addition, 3D visualization helps students understand the material more easily, thereby increasing active engagement during the learning process. The implementation of Augmented Reality-based media has also been shown to enhance students' learning interest and conceptual understanding through a more realistic and engaging learning experience [46].

The effectiveness of Augmented Reality-based Flashcard learning media

The effectiveness of augmented reality-based flashcard media in this study was evaluated by analysing student learning outcomes using pre- and post-tests, including normality tests, paired-samples t-tests, and N-Gain tests.

The normality test is conducted as a preliminary step to determine which statistical test to use. The normality test is conducted to determine whether the research data are normally distributed [47]. In this study, normality testing was performed using the Shapiro-Wilk test. The test selection was based on a relatively small sample size, namely fewer than 50 students in the research class. The decision criteria for the normality test state that if the significance value (Sig.) is greater than 0.05, the data are considered normally distributed. Conversely, if the significance value (Sig.) is less than 0.05, the data are considered not normally distributed.

Table 3. Normality Test Results.

Category	Sig	Information
Pre-test	.236	Normally Distributed
Post-test	.427	Normally Distributed

Based on the normality test results table above, the pre-test and post-test scores for the large-group trial were calculated using SPSS 31. The results of the Shapiro-Wilk test showed a significance value of 0.236 for the pre-test and 0.427 for the post-test. Based on the normality test criteria, data are considered normally distributed if the p-value is greater than 0.05 [18]. Therefore, since the pre-test significance value was $0.236 > 0.05$ and the post-test significance value was $0.427 > 0.05$, both datasets fulfilled the assumption of normality.

After the data meet the Normality test, the Paired Sample t-Test is used to determine whether there is a significant difference between the pre-test and post-test results. The Paired Sample t-Test is a statistical test for

comparing 2 paired groups [48]. The decision-making criterion is that if the significance value (Sig) is < 0.05 , then H_0 is rejected and H_1 is accepted, indicating a significant difference.

Table 4. Paired Sample t-Test Test Results.

Aspects	Mean	Improvement	Two-Sided p
Pre-test	55.25	19	<0.001
Post-test	74.25		

Based on the results of the paired-samples t-test, the average pre-test score of students was 55.25, while the average post-test score increased to 74.25 after using Augmented Reality-based flashcard media in learning. The results of the analysis showed a significance value (Two-Sided) < 0.001 or less than 0.05, so that H_0 was rejected and H_a was accepted [49]. Thus, the use of Augmented Reality-based flashcard media significantly improves student learning outcomes in human respiratory system materials.

Table 5. N-Gain Test Results

Aspects	Mean	Improvement	N-Gain	Criteria
Pre-test	55.25	19	0.4581	Medium
Post-test	74.25			

The N-Gain test was carried out by measuring the magnitude of the improvement in student learning outcomes between before and after treatment, or by using media [50]. The N-Gain value is calculated as the difference between the pretest and posttest scores, then compared to the maximum score achieved. The analysis results revealed an average N-Gain score of 0.4581, which falls into the medium category. This result indicates a moderately effective improvement from pre-test to post-test scores, meaning that the use of augmented reality-based flashcard media was able to significantly enhance students' learning outcomes in science subjects, particularly on the human respiratory system material for fifth-grade students at SD Negeri Gondoriyo, although the improvement had not yet reached the high category.

The acquisition of N-Gain in this medium category can be caused by the limited time of media use in the learning process, so that students have not been able to maximize the optimal use of the available features. In addition, differences in students' ability and learning readiness also affect the level of improvement in learning outcomes obtained [51]. Students with diverse learning abilities need varying amounts of time to understand material through augmented reality-based media, especially since this technology is still relatively new in elementary education. In addition, the limitations of the specifications of the smartphones used by students have not been fully addressed in order to optimally access Augmented Reality content. The main obstacles to the implementation of AR in education are the limited infrastructure and uneven availability of hardware in schools [52]. Because loading 3D objects takes longer, some students have difficulty accessing information quickly, which ultimately affects the effectiveness of material distribution. Students with inadequate devices need more time to troubleshoot than to understand the material.

These findings are in line with previous studies that also obtained N-Gain in the moderate category on the use of Augmented Reality (AR)-assisted interactive multimedia

[53]. The study shows that differences in learning ability, student readiness, and responsiveness to technology-based learning affect improvements in student learning outcomes. In addition, AR-based media can support various learning styles through a combination of visuals, audio, and direct interaction, making learning more engaging and meaningful. This can also be seen in this study, where the visualization of respiratory organs as 3D objects helps students understand abstract concepts more concretely. Thus, even though the improvement is in the medium category, augmented reality-based flashcard media has still proven effective in improving student learning outcomes.

The improvement in pre-test and post-test scores indicates that students' post-test results were higher than their pre-test results. The average pre-test score was 55.25, and the average post-test score was 74.25, resulting in a 19-point increase. There was an improvement in learning outcomes, as indicated by the increase in the average pre-test and post-test scores [54]. Thus, learning outcomes improve when students use augmented-reality-based flashcard media.

The improvement in learning outcomes of grade V students at SD Negeri Gondoriyo after the use of Augmented Reality (AR)-based flashcard media is not a coincidence but the result of the systematic integration of technology designed to touch various aspects of students' cognition. The use of the Canva application combined with Assembler Edu allows the presentation of materials to be no longer abstract, but rather presented in the form of interactive and real 3D visualizations in front of students. This triggers high curiosity, so the level of student involvement in the learning process increases compared to conventional methods that tend to be monotonous [55]. Technically, this medium is effective because it can cover various learning styles at once, ranging from visual and auditory to kinesthetic, through direct interaction with digital objects. Through augmented reality-based flashcard media, it is possible to see boring 2D objects as 3D models that can be rotated and viewed from various angles [56]. Students not only watch but also control their own learning media, accelerating their understanding of concepts.

Conclusion

This research is a Research and Development (R&D) with the ADDIE model. The flashcard media was developed in Canva and integrated with augmented reality via the Assemblr Edu platform to support concrete, interactive visualization of concepts. The novelty of this research lies in integrating visual flashcards with Augmented Reality technology into interactive edugames to create more concrete, engaging, and interactive science learning media for elementary school students. This Augmented Reality contains explanations of respiratory organs, organ functions, interesting facts, respiratory organ disorders, and human breathing mechanisms. The validation results showed that the media was highly feasible to use, with validation by material experts reaching 91.07% and by media experts reaching 95.37%. The responses of teachers and students also showed very positive results with percentages of 96.59% and 90%, respectively. The media's effectiveness was demonstrated by an increase in the average score from 55.25 on the pretest to 74.25 on the posttest, with Sig. p-value of < 0.001 and an N-Gain score of 0.4581 in the

medium category. Augmented reality-based flashcard media has practical implications for IPAS learning by facilitating interactive, game-based learning, helping teachers present material in a more concrete, engaging way, increasing student involvement in games, and supporting the implementation of technology-based learning. However, this study still has limitations, including reliance on smartphone specifications and on platforms with access restrictions. Therefore, further research is recommended to develop media across different materials and levels, improve interactive features, and optimize content to be lighter and more accessible in a wider, more sustainable manner.

Author's Contribution

M.N.P. Azzahra: contributes to product development, conducts research, and writes research results. A.E. Andriani: contributes to the preparation, monitoring, and revision of the research process.

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