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Developing Augmented Reality-Based Flashcards to Enhance Science Literacy in Elementary Schools

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ABSTRACT

One of the basic skills that elementary school students must have is science literacy. However, the educational attainment of primary school students in a rural location remains unfulfilled. This study aims to develop flashcard-based learning media equipped with Augmented Reality (AR) technology to improve elementary school students' science literacy. The research method used is Research and Development with the ADDIE development model. Data collection methods used questionnaires and tests, while the instruments used were validation questionnaires and pre- and post-tests. Data analysis in this study used the N-Gain test. The validation results from experts indicate that the AR-based flashcard learning media is considered fasible to be implemented in the classroom for cultivate students' science literacy. Before conducting the hypothesis test, a prerequisite test was conducted, showing the data is normally distributed, as well as a homogeneity variance. The results of the N-Gain test showed a value that indicating an improvement of students' science literacy after using this learning media. Based on the research results, it can be concluded that flashcard-based learning media with Augmented Reality technology is effective in improving the science literacy of elementary school students.

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Introduction

Education is the fundamental pillar in enhancing the quality of human resources. Education serves as a fundamental pillar, imparting knowledge while also shaping human character (Paul-Mgbeafulike, 2023; Tomaskinova et al., 2012; Dixit, 2024). In primary education, a fundamental competency that pupils must acquire is scientific literacy. Scientific literacy encompasses not only the comprehension of fundamental concepts and

principles of science but also the capacity for critical thinking, problem-solving, and the application of knowledge in quotidian contexts (Nugraha, 2021; Roberts & Bybee, 2014; Vieira & Tenreiro-Vieira, 2016; Osborne, 2023). Scientific literacy poses a challenge within the educational sphere; nonetheless, over the past two decades, science has emerged as a prominent topic in discussions regarding the aims of science education in elementary schools (Pratiwi et al., 2019; Akerson & Bartels, 2023; Vieira & Tenreiro-Vieira, 2016). It is a crucial competency for the 21st century and is essential for enhancing life skills (Riskiono et al., 2020; Tomovic et al., 2017; Hicks et al., 2017).

Science literacy can be defined as scientific knowledge and ability to analyze questions, synthesize knowledge, be able to provide explanations for scientific phenomena, and make conclusions based on real conditions. The nature of science has an awareness of the meaning of science and technology to shape the natural, intellectual and cultural environment, and is willing to engage in science issues (Narut & Supradi, 2019; Osborne, 2023). Science literacy is considered important to educational goals because it is related to science issues that students should have and do after the teaching and learning process. Science literacy emphasizes the construction of knowledge in the meaningful use of science concepts, critical thinking and balanced decision making on problems relevant to students' lives (Pratiwi et al., 2019; Tomovic et al., 2017; Vieira & Tenreiro-Vieira, 2016). Based on PISA (Program for International Student Assessment) research conducted from 2006 to 2019, Indonesia is ranked 62nd out of 70 countries, which puts it in the 10 countries with the lowest literacy levels. This literacy problem needs to be a major concern for the Indonesian people, especially at the elementary school level (Hidayati et al., 2024; Sholikah & Pertiwi, 2021). One of the factors contributing to low literacy is the lack of innovation in learning methods and media applied by teachers. However, students nowadays need innovative media, methods, and learning strategies.

Students nowdays include in digital native generation who is more familiar with technology. The use of technology has become increasingly common among this generation. In their daily activities they prefer to use smartphones and the internet (Tamboo et al., 2024; Dingli et al., 2015). Likewise, the learning process should also utilize the internet and smartphones to create interactive media to support learning. With the help of smartphones and the internet students are able to get a real learning experience, projecting an image into a real form (Augmented Reality). According to Tamboo et al. (2024); Chen et al (2017); Bower et al (2014), Augmented Reality (AR) is a combination of visual objects with the real world directly. Its technology provides a real learning experience that can display three-dimensional images as they look real, so students can learn interactively and in real time (Riskiono et al., 2020; Geroimenko, 2020). Students will more easily recognize the image than the writing (Fitriyani & Nulanda, 2017). Therefore, Augmented Reality can be used in flashcards that are attractively designed to support and facilitate learning because they are easy to use and can be used simultaneously by teachers and students. In addition, flashcards are also easy to carry and practical in use. Flashcards are simple media from paper materials that display images and explanations briefly and clearly (Febrianto et al., 2020; Astuti & Chandra, 2023; Fitriyani & Sari, 2024).

This study addresses the issues of inadequate scientific literacy among primary school pupils and the restricted implementation of technology-enhanced learning media in educational institutions. Observations at three primary schools revealed that most teachers exclusively utilise PowerPoint as their instructional media. This adversely affects students' motivation to learn. They felt boredom to learn because of monotaneous learning media which is used in the classroom. This also affect to students' science literacy which reinforced by the results that indicated most of science literacy of students below the Criteria for

Learning Objectives Attainment. The research gap is evident in the scarcity of studies on the development of flashcard-based learning media integrated with Augmented Reality (AR) technology for primary school science subjects. Previous research has predominantly concentrated on early childhood or secondary education levels, neglecting to specifically address their efficacy in enhancing the science literacy of elementary school children regarding the Social Sciences subject, particularly the structure and function of the five senses.

However, the role of technology in the learning process is important because it can provide interactive and varied learning (Nurfadhillah et al., 2021; Mariscal et al., 2023; Tuma, 2021). One of the technologies that help the learning process is learning media. Learning media is closely related to learning methods and strategies. One of the learning media that can be combined with Augmented Reality (AR) technology is flascard. Augmented Reality (AR) based flascard media is the media chosen by researchers. This research combines flascard learning media with technology, namely Augmented Reality (AR) is expected to be a more interesting, interactive learning media, and can improve elementary school science literacy skills.

Learning media is a tool in the learning process, so that learning objectives can be achieved effectively and efficiently (Nurrita, 2018; Miaz et al., 2019). Learning media is also everything that functions to visualize material, can provide stimulation of thoughts, feelings, and creativity of students so that it can encourage the creation of an optimal learning process (Zaki & Yusri, 2020; Widyaningrum et al., 2022). One of the learning media is Flashcard andaugmented reality.

Flashcards are instruments that facilitate the retention and review of content, including definitions, phrases, symbols, foreign language spellings, and formulas (Saputri, 2020; Astuti & Chandra, 2023). Flashcards have numerous advantages and downsides. The benefits of flashcards are pragmatic due to their compact size; accessible since educators require no specialised skills for their use; memorable as they convey concise information on each card; and enjoyable, as they facilitate playful learning, thereby preventing monotony (Pradana & Santosa, 2020; Fitriyani & Sari, 2024). The drawbacks of flashcard learning medium include: visuals being less visual; images being ineffective due to excessive complexity; and size limitations (Angreany & Saud, 2017; Astuti & Chandra, 2023). This flashcard could be enhanced by the latest technologies, such as augmented reality.

Augmented Reality (AR) is a technology that integrates several dimensions into a real world by overlaying virtual elements over real objects (Rusnandi et al., 2016; Chen et al., 2017). Augmented Reality (AR) employs software that operates through multiple stages. The program acquires items as photos or videos and subsequently transmits them to the CPU. The processor analyses the object with the available tools to identify specific patterns. Subsequently, it executes object detection to ascertain the location of the pattern relative to the virtual object. It recognises the pattern and correlates it with the knowledge it has acquired. The software captures the virtual object and subsequently displays it directly (Isnaini & Rahayu, 2023; Bower et al., 2014). According to this framework, Augmented Reality (AR) is categorised into two types: Marker Augmented Reality and Markerless Augmented Reality. Marker Augmented Reality necessitates a marker as a trigger to provide digital elements, typically in black and white graphics. Markerless Augmented Reality operates without the necessity of markers, enabling users to present digital elements devoid of specialised tools (Isnaini & Rahayu, 2023).

Based on the background and the gap, the purpose of this research is to develop learning media in the form of Augmented Reality (AR)-based flashcards that can improve the science literacy of elementary school students. This media is expected to provide a

learning experience that is more interesting, in-depth, and easy to understand. By combining the use of Augmented Reality-based Flashcards, the teacher has created interactive learning that provides real experience, so that students are not only familiar with the theory but also observe the structure and organs which is microscopis or invisible to the naked eye. The use of augmented reality-based flashcard media makes it easy for teachers to display something that is difficult to display and bring it into the classroom (Utami et al., 2021; Listiani & Paramartha, 2025). In addition, in using flashcard media based on augmented reality, students also show more motivation in learning when compared to conventional learning.

This research presents the novelty that integration of Augmented Reality (AR) technology in educational flashcard learning media specifically designed to enhance the science literacy of elementary school students. Unlike conventional flashcards, the development of this media combines interactive three-dimensional visualization that can be accessed through digital devices, thereby creating a more immersive and contextual learning experience. This approach not only introduces scientific concepts visually and engagingly but also stimulates active student involvement in exploring scientific phenomena. This research provides a new contribution to the field of science education at the elementary level by bridging the gap between traditional learning approaches and the use of innovative technology that is adaptive to the digital era. Through this research, it is expected that students are easier to understood science concepts in the social science subject especially in invisible to the naked eye material. This research is expected to make a positive contribution in the world of education, especially in improving the quality of science learning and students sceince literacy at the elementary school level by utilization of Augmented Reality (AR) technology to make an innovative solution in facing the challenges in digital era.

Method

The research method used is research and development or in foreign languages called Research and Development (R&D). R&D is a research method commonly used in creating or developing an effective product after going through several tests (Nugraha, 2021). The model used in R&D is using the ADDIE development model (Figure 1), which has the aim of creating a product through several procedures that are tested through several stages systematically (Setiawan et al., 2023), which then needs evaluation and improvement to meet the expected indicators according to the standards, quality and effectiveness implemented (Wardhani, 2024). The stages of the ADDIE model are analyze, design, development, implementation, evaluation.

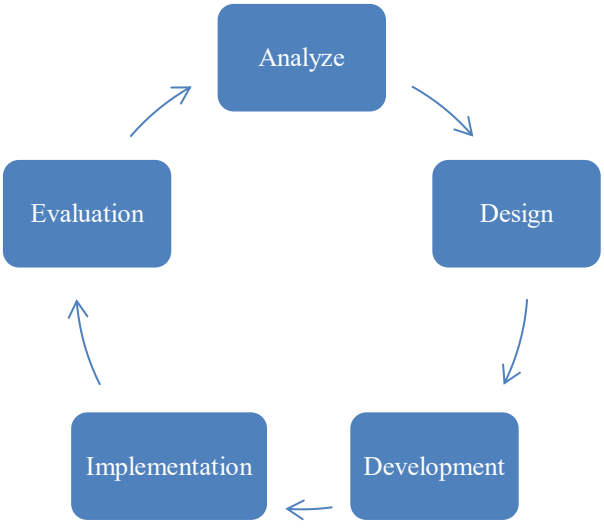

Figure 1. Stages of the ADDIE Model

In detail, the stages of research on the development of Augmented Reality (AR) Based Flashcard Learning Media to Improve Elementary School Science Literacy include the analysis stage is divided into 3 stages, for isnstance, the problem analysis stage, which is carried out through interviews, observations and tests at SDN 1 Pule, SDN 2 Pule, and SDN 3 Pule. questionnaires interviews and observations, interview questionnaires are used to collect data from sources directly (Anggreani & Satrio, 2021) and observation questionnaires are used to collect data by directly observing the learning process activities taking place (Nurfadhillah et al., 2021). Based on the findings, most fifth grade students and teachers are still limited in the use of technology-based media, teachers only use powerpoint media when teaching which makes students less motivated in participating in the learning process in class. Teachers are still limited to using powerpoint media because they are required to carry out administration at school. Furthermore, the ability of science literacy in fifth grader students is still limited as seen from the results of the pretest that has been done. The needs analysis stage, namely the distribution of media needs questionnaires that refer to Augmented Reality (AR) Based Flashcard Learning Media to improve science literacy. Based on the results obtained, a percentage of 90% of students agree with the existence of Augmented Reality (AR) Based Flashcard Learning products to improve science literacy. The material analysis stage is analyzing learning outcome, learning objective, and material to be taught about anatomy and physiology in the eye organs.

Based on the needs analysis, the design stage is carried out by collecting materials and making designs through Assemblr Studio platform: Explore 3D & AR, after the design is complete, the design link is made into a barcode and inserted into the Flashcard that has been designed through the canva platform and finally printed. Then, the development stage is conducted in the research on the development of augmented reality (AR)-based flashcard learning media to improve science literacy goes through several stages, namely expert validation on media, language and material and limited scale trials on 40 students / respondents with different levels of science literacy. Data analysis in this study uses quantitative data analysis which aims to analyze the data obtained (Saputri, 2020) through a validation questionnaire for media, language and material experts and science literacy tests. questionnaire and test instrument items are first validated through a validation test with the product moment correlation formula and a reliability test with the Cronbach alpha formula. After that, a validation questionnaire test is carried out to determine the feasibility of the media based on the indicators determined by the researcher, the validation questionnaire test is submitted to media experts, linguists and materials. The variables, data and instruments in this study are described in the Table 1 below.

Table 1. Variables, data and research instruments

Variables	Data	Instrument
Media	Media Expert Validation Results	Validation Questionnaire Sheet
	Language Expert Validation Results	Validation Questionnaire Sheet
	Material Expert Validation Results	Validation Questionnaire Sheet
Science Literacy	Differences in science literacy in students before and after using Augmented Reality (AR) based flashcard learning media.	Pretest-Posttest Science Literacy
	Improvement of science literacy in students	Pretest-Posttest Science Literacy

The implementation stage is to conduct a large-scale test using the media that has gone through revisions or improvements at the development stage and data collection in the form

of student science literacy test results and student and teacher responses to the media (Shafa et al., 2022). This study used a sample of 221 elementary school students divided into three schools, namely SDN 1 Pule with 115 students, SDN 2 Pule with 28 students, and SDN 3 Pule with 78 students. Pretest and posttest are conducted in implementation. The prestest of science literacy test is given before implementation, then its posttest is given after implementation. After implementation, the evaluation stage, the researcher conducts an evaluation with the aim of knowing the success rate of media development based on the results of data analysis and makes product revisions (Utami et al., 2021). The revise of augmented reality flashcard media is conducted to improve its function and could be feasible to be implemented in classroom. Then, it cou be implemented in other classroom outside subject and feasible to cultivate science literacy in elementary school students.

Distribution of pretest-postest to the students to see their science literacy skills with indicators, namely 1) critical thinking skills, 2) problem solving skills 3) application of science knowledge in everyday life 4) meaningful construction of knowledge 5) balanced decision making on relevant issues faced by students before and after using Augmented Reality (AR)-based flashcard learning media using hypothesis testing with paired sample t-test formula by going through the prerequisite test, namely normality test with Kolmogorov-Smirnov formula and homogeneity test with lavene formula assisted by SPSS version 25. To determine the increase in science literacy in students through the N-Gain test with normal indicators if it can show the level of effectiveness adjusted to the criteria of the normalized gain table. The N-Gain criteria used as the basis for the achievement of the value of augmented reality (AR)-based flashcard learning media to improve science literacy obtained in the N-Gain formula can be understood through the following Table 2:

Table 2. Normalized Gain Criteria

N-Gain Score	Normalized Gain Criteria
Score > 0.70	High Score
0.30 ≤ Score ≥ 0.70	Medium Score
Score < 0.30	Low Score

Results and Discussion

The development of augmented reality (AR) based flashcard learning media based on needs analysis conducted by researchers using, the results obtained from analyzing most fifth grade students and teachers are still limited in the use of technology-based media, teachers only use powerpoint media when teaching which makes students less motivated in participating in the learning process in class. Teachers are still limited to using powerpoint media because they are required to carry out administration at school. Furthermore, the ability of science literacy in fifth grader students is still limited as seen from the results of the pretest that has been done. According to Pradana & Santosa (2020) basically an educator needs to learn technology that is increasingly advanced and sophisticated. AI (Artificial Intelligence) is currently being used as a strategy to make it easier for someone to find solutions or develop something based on current technological developments (Wicaksana & Anistyasari, 2020). Based on the reasons teachers use powerpoint media, it is because there are rules that require teachers to carry out administration. Administrative demands are a problem for teachers because they are less focused on teaching and reduce interest and motivation to teach (Rosyada et al., 2024).

The design and development of augmented reality (AR)-based flashcard learning media is made using the Assemblr Studio platform application: Explore 3D & AR and Canva to make it easier for students to access and use the media. The purpose of developing this

media is to cultivate science literacy in elementary school students. the development results are presented in the following figure.

Figure 2. Front and back views of the flashcards

Figure 2 shows the design of the front and back views of the learning flashcards used in Augmented Reality (AR)-based media. On the front of the flashcard there is an image or illustration of the material that attracts students' attention and a QR code that can be scanned to access AR content. Meanwhile, the back of the flashcard contains a brief and clear explanation of the material being studied, making it easier for students to understand the concept. The QR code can be scanned using the Assemblr Studio or Assemblr Edu application which can be downloaded through the play store, then for the material and quiz section as follows.

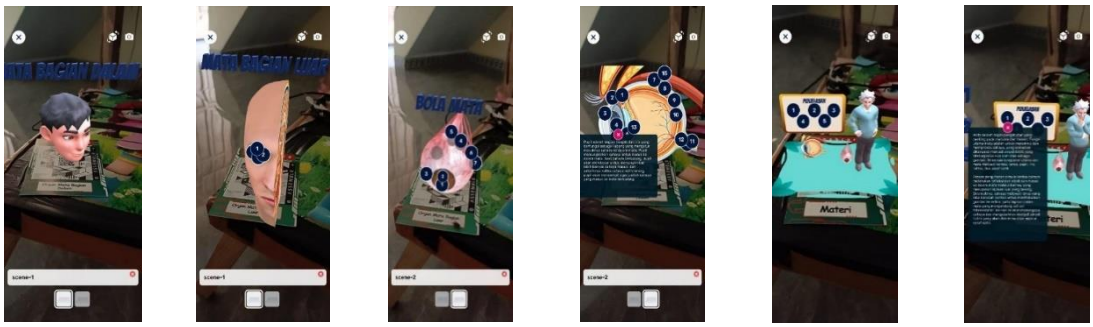

Figure 3. Eye organ material in humans using Augmented Reality (AR)

Figure 3 displays learning materials about the human eye presented through Augmented Reality (AR) technology. In this picture, there is a three-dimensional representation of the anatomical structure of the eye that looks real and interactive. Through AR, students can observe the parts of the eye in detail from various points of view, making it easier to understand the functions and relationships between eye organs. The use of this technology provides a more interesting learning experience and motivates students to be more active in learning the material. With clear and dynamic visualization, eye organ material becomes easier to understand.

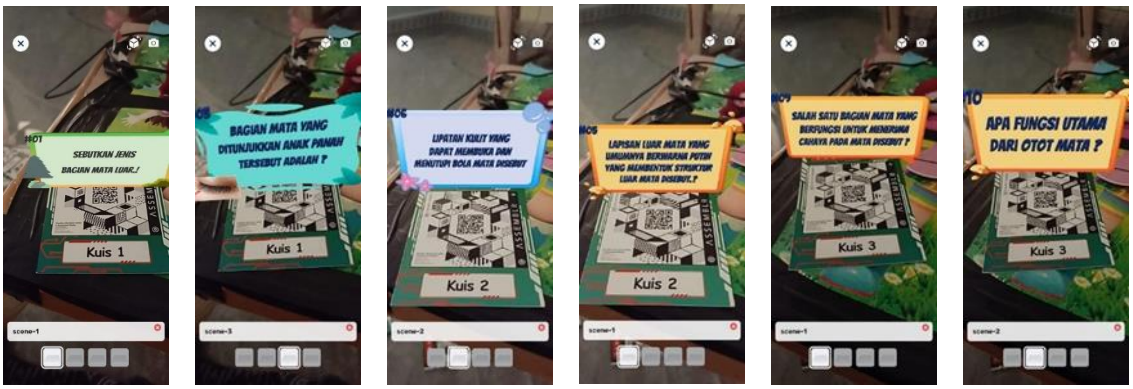

Figure 4. Quiz on eye organ material in humans using Augmented Reality (AR)

Figure 4 shows the display of an interactive quiz related to human eye organ material using Augmented Reality (AR) technology. This quiz is designed to test students' understanding after learning the material with 3D visualization of the eye organs. Through the AR application, students can directly answer questions digitally which supports the learning evaluation process in real time. This quiz feature allows teachers to quickly and effectively determine students' science literacy level. With this interactive approach, students become more motivated to learn and remember the material they have learned. The results of the validation test on the media, material, language and test questionnaire instruments using the product moment correlation test are as follows.

Table 3. Validation test results

Instrument	Number of Items	Valid	Drop
Media Questionnaire	20	16	4
Questionnaire Material	20	17	3
Language Questionnaire	20	16	4
Test	30	28	2

Table 3 presents the results of instruments that were declared valid and dropped from the total number before being entered in the product moment correlation formula. For the media, material and language questionnaire instruments in this study using a total of 15 questionnaire items that were declared valid while for the test using a total of 25 test items. Basically, the number of items used in the study has represented each indicator on each instrument. Furthermore, valid instruments are tested for reliability using the Cronbach alpha formula with the following results.

Table 4. Reliability Test Results

Instrument	Score	Description
Media Questionnaire	.816	Reliable
Questionnaire Material	.832	Reliable
Language Questionnaire	.830	Reliable
Test	.844	Reliable

In Table 4 presented all questionnaires and tests in this study are declared reliable or it can be said that the instrument can be consistent in measuring what is measured. Before the media is implemented to elementary school students, researchers first conduct a media feasibility test to media, material and language experts. The results of media, material, and language feasibility are presented in the following Table 5, Table 6, and Table 7.

Table 5. Media Expert Validation

Aspects	Criteria	Score
Design	Presentation	28
	Attractiveness	9
	Design	8
	Layout	27
	Usage	8
Total Score		80
Percentage		86%
Description		Valid

Table 6. Material Expert Validation

Aspects	Criteria	Score
Material	Relevance	14
	Content eligibility	25
	Presentation Feasibility	12
Total Score		51
Percentage		85%

Description	Valid

Table 7. Language Expert Validation

Aspects	Criteria	Score
Language	Straightforward	22
	Communicative	12
	Orderliness and cohesiveness of thought	10
	Accuracy in the use of language	18
	Sentence accuracy	10
Total Score		72
Percentage		96%
Description		Very Valid

Flashcard learning media based on augmented reality (AR) has been declared valid and can be used in research after being tested by media expert validators, material expert validators and language expert validators. In table 5 the media is declared valid with a percentage score of 86%, it states that the media is interesting and can support the learning process. in table 6 the material is declared valid with a percentage score of 85%, then table 7 the language is declared very valid with a percentage score of 96%, it is stated that the material is in accordance with the CP and TP in Science and Social subjects using the independent curriculum while the language used in the media can be declared standard and easily understood by students.

Students' science literacy skills before and after using augmented reality (AR)-based flashcard learning media can be seen from the results of data analysis through pretest-posttest. The data analysis test to see the comparison of students before and after using the media uses a prerequisite test, namely normality with the Kolmogorov-Smirnov formula and homogeneity with the lavene formula and hypothesis testing with the paired sample t-test formula. The test results can be seen in Table 8 below.

Table 8. Prerequisite Test and Hypothesis Test Results

Science Literacy Score	Highest Score	Lowest Score	Average	*Kolmogorov-Smirnov*	*Lavene*	*Paired Sample T-test*	*N-Gain Score*
				Sign.	***Sign.***	**Sign.**	
Pretest	45	65	55	.115	.840	.0,03	0,62
Posttest	80	95	87,5	.132			

Table 8 shows that there is a significant difference in science literacy before and after using augmented reality (AR)-based flashcard learning media. Table 8 shows the average value of the N-Gain score is 0.62 which is a moderate category, it may be asserted that students' scientific literacy has greatly and markedly improved. This also indicates the effectiveness of learning media in improving students' science literacy.

The learning media developed in this research has a main characteristic of integrating Augmented Reality (AR) technology with flashcards designed visually and interactively for the topic of the five senses. The characteristic of this media lies in its ability to combine 2D images with 3D objects that appear in real-time through mobile devices, allowing students to explore the structure and function of the five senses more concretely and in-depth. The implementation of augmented reality (AR)-based flashcard media can be accessed through gadgets (Pasande et al., 2025), teachers and students can use augmented reality (AR)-based flashcard media by opening the Assemblr Studio or Assemblr Edu application that has been installed and then scanning the barcode on the prepared flashcard then the images, material and quizzes can appear through the gadget display and can be directly used to clarify and

understand material about anatomy and physiology of the eye organs and improve science literacy in students.

This flashcards not only display textual information but are also equipped with moving visual elements and supporting sounds that enrich the students' learning experience. Flashcards are a form of educational media used by educators in the form of cards that contain images and words (Putri Wangi & Gede Angung, 2021). Flashcards have a size that can be adjusted to the needs of the teacher when teaching and to make them can be done by yourself or use ready-made ones (Iswari, 2017). While Augmented Reality (AR) is a technology-based media that integrates virtual and real worlds to obtain information from data collected from a system on a real object that is determined, so that the boundaries between the two are increasingly vague (Ashari et al., 2022). In line with the opinion (Mukti, 2019) Augmented Reality (AR) has features to include objects in virtual form (3D) into a virtual or digital world environment (Saputro & Saputra, 2015).

With this approach, Augmented Reality-based flashcard media can enhance learning interest, facilitate contextual understanding of scientific concepts, and encourage active student engagement in the learning process, especially in 5th-grade elementary school. Streghtennig with the reserach that shows by combining flashcard media with augmented reality technology it can provide a more interesting and in-depth learning experience, as well as improve the ability to understand science topics so that it can have an effect to students science comprehension and literacy (Suttrisno et al., 2024).

The development of Augmented Reality-based falshcard learning media has advantages and limitation. The advantages of this learning media, it successfully presents an innovative learning media that utilizes Augmented Reality (AR) technology to significantly enhance students' science literacy. Its advantages lie in its ability to present abstract material in a more concrete and engaging manner through 3D visual displays, interactive animations, and audio integration. This facilitates the visual and kinesthetic learning styles of elementary school students, thereby enhancing engagement, concept understanding, and information retention. Moreover, this media enables independent and exploratory learning, which fosters students' curiosity and scientific thinking skills which affect to their science literacy.

Although innovative, this media has several limitations. First, the dependence on technological devices such as smartphones or tablets can be a constraint in schools with limited access to digital resources and also the internet signal in several rural area. The limitations of augmented reality (AR) media require internet with stable speed and qualified gadget specifications or according to the standards of the Assemblr Studio or Assemblr Edu application (Ahmad et al., 2022). Second, not all students have adequate digital literacy levels, so more intensive guidance from teachers is needed in the initial use of the media. And also vice versa, It can happen that teachers have a limited understanding of the use of augmented reality due to a significant generational gap. Additionally, due to its AR-based nature, this media requires a well-lit learning space and device stability to ensure that digital objects can appear and function optimally. In terms of evaluation, the measurement of science literacy improvement is still limited to the cognitive aspect, not yet fully addressing the affective and psychomotor aspects of students.

Conclusion

The research and development findings indicate that the Augmented Reality (AR)-based flashcard learning media is both viable and successful in enhancing the science literacy of primary school students. The utilisation of educational media demonstrates a considerable enhancement in students' scientific literacy competencies. Statistical analyses indicated that the data exhibited normal distribution and homogeneity, with significant differences

observed pre- and post-treatment. The N-Gain number fell inside the medium range, signifying a substantial enhancement in students' science literacy. Consequently, the use of AR-based flashcard media has demonstrated its capacity to offer a more interactive and contextual learning experience, serving as an innovative option for the advancement of social science education at the elementary school level.

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