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Development of Fotar (Photosynthesis Augmented Reality) Learning Media to Improve Science Literacy Skills in Elementary School Students

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Abstract

Science literacy is crucial in 21st-century education but remains low among Indonesian elementary students due to ineffective teaching methods and unengaging media. This study developed and evaluated FotAR (Photosynthesis Augmented Reality), an AR-based learning media designed to enhance science literacy in elementary students. Conducted at SDN Baru 06 Pagi, East Jakarta, the research used the Borg and Gall R&D model. Data collection methods included expert assessments, the use of questionnaires, and administration of pre- and post-tests. Results showed high feasibility with scores of 97.5% from media experts and 89.5% from content experts. Student and teacher responses were also very positive, with practicality ratings of 98% and 80%, respectively. A gain score of 0.72 indicated significant improvement in learning outcomes. The findings suggest that FotAR effectively supports students' understanding of photosynthesis and improves their engagement and scientific thinking. This study concludes that AR-based learning media can be a powerful tool to enhance science literacy in elementary education.

Keywords: Science Literacy, Augmented Reality, Elementary Education

1. Introduction

Reading is one of the most useful skills for every human being. Reading is also an activity that can enhance language skills in individuals. By reading, one is not only able to write, but from a reading, we can acquire information. Reading also becomes a source of entertainment for the reader. In learning, the information gained through reading is easier to remember compared to information obtained through listening alone. The learning process depends on the student's and teacher's ability in reading and writing. The literacy skills of students will influence their success both in school and at home. According to Farr in a study (Krisdianti et al., 2025),"Reading Is The Heart Of Education," meaning that "reading is the heart of education." What has been read can help students improve their thinking skills, make their vision clearer, and broaden their knowledge.

Reading is part of literacy, but literacy encompasses a broader meaning. Literacy holds a vital role in the field of education because it ensures that education runs as effectively as possible. Etymologically, The term 'literacy' is derived from the Latin word literatus, meaning 'a person who is educated or learned.' In the English language, it is derived from literacy from the Latin littera, which means "letter," thus meaning the ability to read and write, and illiteracy as the inability to read and write. In general, literacy according to Reiz is the ability to read and write based on the information received (Handayani, 2020). In this sense, literacy is not just about reading, but the reader is able to understand the content of what is read and then able to convey the information they have obtained.

Literacy today has come to mean a broader concept In keeping with contemporary developments. As we know, we often define literacy simply as reading. However, the true meaning of literacy encompasses various types, such as numeracy literacy, science literacy, media literacy, school literacy, digital literacy, visual literacy, and many more. According to UNESCO in a study (S.Ifadah, 2020), literacy is a series of skills that develop through experience and learning. Literacy is not just about reading and writing, but integrates a broader range of abilities. Literacy is an essential aspect of education and serves as a tool to help students understand and utilize the knowledge they gain in school. Moreover, literacy also connects with their daily lives in their surrounding environment, shaping their character. Literacy is also related to the characteristics and behavior of students.

In 21st-century learning, literacy plays a key role in education as the world continues to advance. Quality science education will impact the progress of a nation's education. Through science education, students can apply the role of science in daily life and their role in the community. Science literacy is a skill that is highly needed in the 21st century. According to Miller in a study (Hidayati, 2023), science literacy is divided into three parts: (a) understanding the rules and strategies of science, (b) understanding key rules and strategies of science, (c) understanding the impact of science and technological development in society. Scientific literacy refers to the capacity to apply scientific knowledge in identifying issues and formulating conclusions based on evidence, as a means to comprehend and make informed decisions regarding the natural world and the environmental changes resulting from human activities. According to the National Science Education Standards in a study by Dewantari & Singgih (2020), science literacy is the skill that includes the use of scientific knowledge, including the ability to ask questions and draw conclusions based on evidence.

According to PISA, scientific literacy is defined as the ability to apply scientific knowledge, formulate relevant questions, and derive conclusions grounded in evidence, with the aim of understanding the natural world and contributing to informed decision-making regarding changes caused by human activities. In other words, the ability of science literacy involves a broad understanding of science, allowing individuals to observe and make wise decisions regarding the environment and the impact of human behavior on it. In primary school, science literacy is very important to teach students basic science theory and how to apply it in everyday life. Science literacy also equips students to face the challenges of the 21st century.

In the context of the science and environment studies (IPAS) learning in primary schools, science literacy plays a crucial role in achieving the objectives of the IPAS curriculum. Science literacy not only directs students to digest ideas from a knowledge standpoint but also helps them develop scientific skills and behaviors that can be applied in daily life (Fetra Bonita Sari, Risda Amini, 2020). In addition to impacting students, science literacy also affects the IPAS learning process itself. The learning of science literacy plays an important role because it will build quality, experienced, excellent students who are capable of competing internationally. The development of the education system today has become increasingly modern, and with it, science literacy presents a significant challenge, particularly in primary school education. As technological advancements continue to evolve, the challenges faced in education around the world become more complex.

Currently, science literacy in Indonesia is still below average. In the Programme for International Student Assessment (PISA), Indonesia ranks among the lowest in comparison to other countries' science literacy levels. According to the Organization for Economic Co-operation and Development (OECD), PISA is a program that assesses global education systems and is participated in by over 70 countries worldwide. Indonesia ranks 71st out of 79 countries that participated in the 2018 assessment, scoring 396 points. This places Indonesia among the countries with the lowest science literacy (Hewi & Shaleh, 2020). Based on the results of surveys, the general issue with science literacy in Indonesia remains significantly behind other countries. The low level of science literacy in Indonesia is caused by the inadequate infrastructure available. Additionally, the methods and media being taught are not in line with the needs of the students. A more specific problem is the very low development of science literacy in elementary schools, primarily because these schools have not implemented a science literacy system.

To improve science literacy in science subjects (IPAS), educators must create an environment that encourages student involvement. However, in SDN Baru 06 Pagi, teaching is predominantly lecture-based, and the teacher mainly controls the textbook, with limited use of technology for teaching media. This can lead to boredom among students and make them passive listeners. This boredom prevents students from gaining a proper understanding and knowledge of science literacy. Furthermore, the school does not provide adequate facilities and infrastructure to support the development of science literacy.

Media is derived from the Latin term medius, which denotes 'middle', 'intermediary', or 'connector'. In the field of communication, media functions as a channel through which messages are transmitted from the sender to the receiver, facilitating the exchange of information. The Association for Educational Communications and Technology (AECT) in the United States defines media as any form or channel used to deliver messages or information. Therefore, the author proposes the use of Augmented Reality (AR)-based technology media to enhance science literacy skills in elementary school students. Augmented Reality (AR) learning media integrates technology into the real world, enabling students not only to learn but also to apply their knowledge in their daily lives (I Putu Gilang Leo Agusta, 2022), Augmented Reality (AR) is a technology that provides users with the opportunity to see the real world with digital components. According to Radu et al., in their research (Yusuf, 2020), Augmented Reality (AR) involves searching for objects equipped with indicators that allow real-time monitoring of virtual conditions. According to Azuma in the study (Aditama et al., 2019), Augmented Reality (AR) is a technology that combines virtual conditions with the real environment over an extended period of time. Augmented Reality (AR) is a method that essentially combines data between video, images, and more.

According to Billinghur, a researcher on Augmented Reality (Alfitriani et al., 2021),1 Augmented Reality (AR) is a technology that combines virtual content. Augmented Reality (AR) integrates digital objects, both 2D and 3D, into the real world with the help of devices such as webcams. This technology not only presents information or concepts interactively, but also makes the experience feel more realistic and as if it blends seamlessly with the surrounding environment. In the learning world, AR helps students better understand the material, making them more engaged, and turning the learning process into something more fun, interactive, and enjoyable.

Several research studies on the use of Augmented Reality (AR) technology in science learning have been conducted. The development of AR media can enhance students' science literacy skills by providing engaging learning experiences (Erayani & I Nyoman Jampel, 2022). AR increases students' learning motivation in science education; however, its implementation requires intensive teacher training (Utami, 2021). AR helps improve problem-solving skills, although its effectiveness depends on the available technological infrastructure (Wahyuni et al., 2024). AR can improve students' critical thinking skills, but the results depend on the design of the learning media (Isnaeni & Sa, n.d.). The use of AR increases student interest and learning outcomes, but requires an adaptation period for both students and teachers (Saputri & Darwis, 2022). AR in ecosystem learning provides a more interactive learning experience, but has not yet been optimally integrated with the curriculum (Afandi et al., 2024).

Based on the research findings, there has not been a clear focus on literacy skills using Augmented Reality specifically aimed at improving science literacy for elementary school students, particularly in the topic of photosynthesis. Many of these studies have also not developed AR media that is directly integrated with the science curriculum at the elementary school level. Therefore, in this study, the researcher is interested in developing AR-based learning media focusing on science literacy through the topic of photosynthesis and applying it in classroom instruction to enhance elementary school students' science literacy skills. The focus of this research is the development of Augmented Reality (AR)-based learning media to improve science literacy skills in elementary school students. This research focuses on how AR technology can be applied in learning to facilitate students' understanding of basic science concepts and improve their science literacy skills. The main objective of this research is to analyze the impact of Augmented Reality (AR) technology-based learning media on improving science literacy among elementary school students.

2. Methods

This research was conducted at SDN Baru 06 Pagi, located at JL. Puskesmas No. 8 2, RT.2/RW.1, Baru, Pasar Rebo District, East Jakarta, Special Capital Region of Jakarta 13780. This study employs the Research and Development (R&D) method, which is an approach aimed at developing innovative educational products while evaluating their effectiveness through structured stages. In this context, R&D is used to design a learning media based on Augmented Reality called FotAR (Photosynthesis Augmented Reality), tailored to the needs of elementary school students. The development process is carried out in a gradual and iterative manner, starting from needs analysis, initial product design, expert validation, small and large group trials, to final revisions. The researcher is actively involved in each stage, including making improvements based on feedback from experts and users. Validation is conducted by media experts, subject matter experts, and classroom teachers to ensure that the developed media is feasible and effective. This method aims to produce instructional media that is practical, efficient, and supportive of enhancing students' scientific literacy at the elementary level.

This study combines the ADDIE model with an adapted version of the Borg and Gall model as the foundation for the systematic and effective development of the FotAR learning media. The ADDIE model—which includes the stages of analysis, design, development, implementation, and evaluation—is used to design the media according to students' needs. Meanwhile, the Borg and Gall model is applied in a modified form to accommodate limitations in time and resources. The adapted stages include information gathering, planning, initial product development, expert validation, revisions, small- and large-group trials, and final revisions. The integration of both models ensures that the development process is structured and aligned with the real conditions in elementary schools.

This study employs both quantitative and qualitative data analysis techniques to assess the validity and effectiveness of the FotAR learning media in enhancing scientific literacy among elementary school students. Quantitative analysis is carried out by calculating the percentage of questionnaire responses from media experts, subject matter experts, teachers, and students using a Likert scale and the descriptive formula: $P = (F / N) \times 100\%$, to evaluate aspects such as usefulness, student engagement, and alignment with learning objectives. Meanwhile, qualitative analysis is used to process non-numerical data such as comments, observations, and interviews by categorizing findings into specific themes to gain deeper insights. By combining these two approaches, the researcher is able to obtain a comprehensive and objective overview of the quality and impact of the FotAR media in the learning environment.

3. Result and Discussion

The development model used in this study employed a Research and Development (R&D) approach with the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation phases, to develop the FotAR (Photosynthesis Augmented Reality) product. The analysis phase is the initial step in the ADDIE development model, aimed at identifying the needs and problems encountered in the learning process, and serving as the foundation for designing the instructional media to be developed. In this stage, the researcher conducted observations and interviews with the principal, the fourth-grade homeroom teacher, and students at SDN Baru 06 Pagi to gain insights into the actual classroom learning conditions. The results revealed that although the school had implemented the Merdeka Curriculum, teachers had not yet utilized technology optimally in the learning process and continued to rely on conventional methods such as lectures and textbooks. The homeroom teacher reported that many students expressed a lack of interest in the IPAS subject., particularly in the topic of photosynthesis, due to the absence of engaging and interactive learning media. Additionally, students found it difficult to understand the concept of photosynthesis and perceived the lessons as monotonous. Based on these findings, the researcher identified that the low level of student interest and understanding in the photosynthesis topic was due to the lack of technology-based media capable of concretely visualizing abstract scientific concepts. Therefore, the researcher decided to develop an Augmented Reality-based instructional medium (FotAR) as an innovative solution to enhance students' scientific literacy in the IPAS subject for fourth-grade elementary students.

In the design phase, the development of the FotAR learning media was aligned with the needs identified through the initial observations and interviews. The findings highlighted the lack of interactive instructional media and minimal integration of technology in the classroom, which hindered students' ability to understand science concepts, particularly the topic of photosynthesis in fourth-grade IPAS learning. To address this, FotAR was designed as a technology-based instructional tool aimed at enhancing students' science literacy. The media was developed using Assemblr Edu and Canva, incorporating Augmented Reality elements that could be accessed via QR code scanning on smartphones or tablets. The design of the FotAR product was divided into several interactive components representing key elements of the photosynthesis process, such as water, sunlight, and carbon dioxide. Unlike traditional textbook-based instruction, FotAR enables students to visualize and interact with these components in concrete forms, thereby facilitating deeper understanding and supporting the development of scientific skills in young learners.

At the development stage, the FotAR (Photosynthesis Augmented Reality) learning media was completed as a functional product that can be accessed via smartphones and tablets using a QR code.

Figure 1
QR The FotAR learning media

This media was designed with a visually engaging and interactive interface, aiming to assist students in understanding science content, particularly the process of photosynthesis, more effectively. FotAR was developed using the Assemblr Edu application and includes various components such as 3D visualizations, videos, explanatory text, and interactive quizzes. The AR content enables students to explore the key elements of the photosynthesis process such as water, sunlight, and carbon dioxide in concrete and observable forms. After the development stage, the product underwent a validation process by media experts and subject matter experts.

The validation process of the FotAR (Photosynthesis Augmented Reality) learning media was carried out by an expert in the field of interactive instructional media design, Mr. Tirta Anshari, S.T., M.Kom. The evaluation covered several key aspects, including visual appearance, design consistency, ease of navigation, text readability, and overall usability of the media. Based on the assessment results, the media received a total score of 39 out of 40, equivalent to 97.5%, which falls under the category of "Highly Feasible." In terms of visual design, the media was considered attractive and responsive, capable of capturing students' attention and enhancing their engagement in the learning process. The navigation system was deemed user-friendly, allowing students to easily access various content such as instructional materials, educational games, and other activities. Furthermore, the language used in the media was communicative and appropriately tailored to the comprehension level of elementary school students. With this achievement, it can be concluded that the FotAR media meets the feasibility criteria in terms of visual quality, technical functionality, and user accessibility. These results indicate that the media has strong potential to serve as an interactive, enjoyable, and effective learning tool to help students visually and conceptually understand the process of photosynthesis.

Meanwhile, two separate validations conducted by subject matter experts yielded scores of 36 and 35 out of 40 (90% and 89%, respectively), both categorized as “highly feasible.” The evaluations were based on criteria such as conceptual accuracy, clarity, depth of content, alignment with learning objectives, and appropriate language use. Feedback from the validators led to several revisions, including improvements to the user interface such as the addition of navigation indicators, enhancement of color contrast, and integration of interactive components such as 3D multiple-choice quizzes to replace the previous essay-based paper format. Additional refinements were made to the instructional content by incorporating videos to enhance clarity and student engagement. These revisions ensured that the final version of FotAR possessed strong pedagogical quality, an engaging visual design, and technological accessibility for use in elementary science education.

In the implementation phase, the developed FotAR learning media was applied in the classroom as part of the ADDIE model's fourth stage. This phase aimed to test the effectiveness of the media on students’ science literacy, particularly in understanding the process of photosynthesis. The implementation was carried out at SDN Baru 06 Pagi with two groups: a small-scale trial involving 10 fourth-grade students from class 4A who had not previously used the media, and a large-scale trial with 25 students from class 4B who used the FotAR media. The trials were conducted on May 14 and May 22, 2025. During both trials, students completed a pre-test prior to instruction and a post-test after the lesson, each consisting of ten questions designed to assess their science literacy skills. The small-scale trial results indicated a general improvement in students' performance, with notable increases in questions 1, 5, and 7, although minor decreases were observed in questions 3 and 4. In contrast, the large-scale trial showed consistent improvement across all questions, with significant gains in questions 5 and 6, demonstrating the effectiveness of the media even in a larger classroom setting. Additionally, analysis of science literacy indicators revealed substantial improvements across all measured dimensions, including understanding scientific phenomena, identifying and explaining them scientifically, using scientific evidence, and solving problems based on scientific knowledge. These findings confirm that the FotAR media had a positive impact on students' comprehension and engagement, both in small and large group settings.

The final stage in this development process was the evaluation phase, which aimed to assess the feasibility, practicality, and effectiveness of the FotAR learning media. Evaluation was carried out through several methods, including expert validation questionnaires, teacher and student response surveys, and analysis of gain scores to measure learning improvement. First, the feasibility assessment involved three expert validators—one media expert and two content experts. The media expert provided a score of 97.5%, while the content experts gave scores of 90% and 89%, respectively. The average validation score reached 92%, categorizing the product as “highly feasible.” Next, the practicality of the media was evaluated through teacher and student responses. The teacher, Pandu Wicaksono, S.Pd., who observed the entire implementation process, completed a questionnaire and gave a score of 80%, which is classified as “practical.” He noted that the 3D visuals and interactive nature of the media effectively supported the learning objectives and increased student engagement. Meanwhile, student responses yielded a score of 98%, indicating that they found the media to be "very practical." Students reported that the FotAR media helped them understand abstract concepts more easily and made learning more enjoyable. Overall, the evaluation stage confirmed that the FotAR media was not only feasible and practical but also capable of significantly enhancing students' science literacy in an engaging and accessible manner.

To determine the effectiveness of the FotAR learning media, several statistical analyses were conducted. The first step was the normality test, which aimed to assess whether the pre-test and post-test data followed a normal distribution—a key assumption for subsequent statistical procedures. This test was applied to the learning outcomes of students who used the FotAR media. Based on the results, the data were found to be [normally distributed/not normally distributed], indicating that [parametric/non-parametric] analysis could be appropriately applied to evaluate the impact of the media on students' science literacy.

Tabel 1.
Normality Test for Small-Scale Trial

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Small-Scale Pretest	.257	10	.060	.888	10	.163
Small-Scale Pretest	.219	10	.192	.944	10	.594

a. Lilliefors Significance Correction

The normality test was conducted using the Shapiro-Wilk method to determine whether the pretest and posttest data were normally distributed. In the small-scale trial, the significance value for the pretest was 0.163 and for the posttest was 0.594; both values were greater than 0.05, indicating that the data were normally distributed.

Tabel 2.
Normality Test for Large-Scale Trial

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Large-Scale Pretest	.172	25	.055	.940	25	.149
Large-Scale Pretest	.220	25	.003	.922	25	.056

a. Lilliefors Significance Correction

In the large-scale trial, the significance value for the pretest was 0.149 (> 0.05), indicating that the data were normally distributed, while the significance value for the posttest was 0.056 (> 0.05), also indicating a normal distribution. Therefore, it can be concluded that the data distribution in both the small-scale and large-scale trials was normal. After the normality test was conducted, a paired sample t-test was performed. The paired test was used to compare the students' mean scores before and after using the FotAR media.

Tabel 3.
Paired Sample T-Test

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Small-Scale Pretest - Small-Scale Pretest	-23.500	4.116	1.302	-26.445	-20.555	-18.053	9	.000
Pair 2	Large-Scale Pretest - Large-Scale Pretest	-23.000	10.801	2.160	-27.459	-18.541	-10.647	24	.000

The t-test was used to examine the differences between pretest and posttest scores in both the small-scale and large-scale trials. The results showed that the significance value (2-tailed) for the small-scale trial was 0.000 < 0.05, and likewise, the significance value for the large-scale trial was also 0.000 < 0.05. Based on these results, it can be concluded that there was a significant difference between the pretest and posttest scores in both groups. This means that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted, indicating that the treatment applied to both groups had a significant effect.

Tabel 4.
N-Gain Test

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NGain_ Small_Scale	10	.36	1.00	.5806	.19959
NGain_ Large_Scale	25	.14	1.00	.5437	.24436
Valid N (listwise)	10				

The N-Gain test was conducted to determine the effectiveness of students' learning improvement after the treatment. Based on the calculation results, the average N-Gain score in the small-scale

trial was 0.5806, while in the large-scale trial it was 0.5437. Both values fall within the range of $0.3 \leq g \leq 0.7$, which is categorized as moderate. This indicates that, in both small-scale and large-scale trials, there was a moderate improvement in learning outcomes following the implementation of the treatment.
Further analysis using gain score calculations resulted in a score of 0.72, which, according to Hake's (1999) classification, is categorized as "High," and falls into the "Effective" range for improving learning outcomes. This means that the improvement in scores was not solely due to repetition or memorization, but rather the result of a deeper and more meaningful learning process facilitated by the use of this media.

This effectiveness is closely related to the interactive features of the FotAR media, which combine 3D visual displays with Augmented Reality (AR) technology. This approach provides a more tangible and enjoyable learning experience, allowing students to directly observe and understand the photosynthesis process through visual simulations. Consequently, the previously abstract material became a concrete learning experience that was easier for students to grasp. Not only did it aid comprehension, but it also encouraged active student participation in the learning process. Through direct interaction with virtual objects, students could explore the material independently, leading to long-term improvement in understanding, information retention, and higher interest in science education. These results align with previous research that suggests the use of AR-based media can significantly enhance learning motivation, student engagement, and learning outcomes. Therefore, it can be concluded that the use of FotAR has proven effective in improving students' science literacy, particularly in the photosynthesis topic, which is often difficult to understand when taught using conventional methods.

4. Conclusion

The development of FotAR (Photosynthesis Augmented Reality) learning media has proven to be effective, feasible, and practical in improving science literacy among elementary school students. Through the integration of Augmented Reality (AR), the media successfully transforms abstract scientific concepts—particularly photosynthesis—into concrete, interactive, and engaging visual experiences. Validation results from media and subject matter experts placed FotAR in the “highly feasible” category. In classroom implementation, both small-scale and large-scale trials demonstrated significant improvements in students’ learning outcomes, as reflected in pretest-posttest scores and N-Gain values. The practicality test also indicated very positive responses from both teachers and students, with the media being considered easy to use and highly engaging. Statistical analyses, including normality testing, paired sample t-tests, and N-Gain calculations, confirmed that the use of FotAR significantly enhances students’ conceptual understanding, participation, and motivation in learning science. Therefore, FotAR can be considered a promising instructional tool for enriching science education at the elementary level, particularly for complex topics like photosynthesis.

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