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Augmented Reality As A Learning Media Based On Scientific Literacy

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ABSTRAK

Perkembangan teknologi digital telah membawa transformasi didalam dunia pendidikan, yang kini mengarah pada penggunaan teknologi untuk memperkaya proses pembelajaran. Salah satu inovasi teknologi yang berpotensi besar didalam pendidikan adalah Augmented Reality (AR). Tujuan: Penelitian ini bertujuan untuk mengkaji penggunaan Augmented Reality sebagai media pembelajaran yang dapat meningkatkan literasi sains siswa, khususnya didalam memahami konsep-konsep sains yang kompleks. Tujuan lainnya adalah untuk mengetahui bagaimana AR dapat meningkatkan minat, motivasi, serta keterlibatan siswa didalam proses belajar. Metode: temuan ini mempergunakan metode Systematic Literature Review (SLR), yang dilakukan dengan mengidentifikasi, menyeleksi, serta menganalisis berbagai studi terdahulu mengenai penerapan AR didalam pembelajaran sains. Data diperoleh dari berbagai database akademik seperti Google Scholar, ScienceDirect, serta JSTOR. Kriteria inklusi serta eksklusi yang jelas digunakan untuk memilih temuan yang relevan serta memberikan kontribusi signifikan terhadap pemahaman efektivitas AR didalam pendidikan sains. Hasil: Hasil dari analisis literatur menunjukkan bahwa penggunaan AR didalam pembelajaran sains dapat meningkatkan pemahaman siswa terhadap konsep-konsep abstrak serta memperkaya pengalaman belajar mereka. AR memberikan pengalaman belajar yang lebih menarik serta interaktif, yang dapat meningkatkan motivasi serta keterlibatan siswa. Selain itu, AR juga mendukung berbagai gaya belajar, seperti visual, kinestetik, serta auditori, sehingga membantu siswa memahami materi sains secara lebih mendalam serta kontekstual. Meskipun begitu, beberapa tantangan terkait infrastruktur, kesiapan guru, serta biaya masih menjadi hambatan didalam implementasi AR di sekolah-sekolah.

Kata Kunci: augmented reality, literasi sains, pembelajaran interaktif, pendidikan sains, teknologi pendidikan

ABSTRACT

The development of digital technology has brought about a transformation in the world of education, which is now leading to the use of technology to enrich the learning process. One of the technological innovations that has great potential in education is Augmented Reality (AR). This study aims to examine the use of Augmented Reality as a learning medium that can improve students' scientific literacy, especially in understanding complex scientific concepts. Another objective is to find out how AR can increase students' interest, motivation, and involvement in the learning process. This finding uses the Systematic Literature Review (SLR) method, which is carried out by identifying, selecting, and analyzing various previous studies on the application of AR in science learning. Data were obtained from various academic databases such as Google Scholar, ScienceDirect, and JSTOR. Clear inclusion and exclusion criteria were used to select relevant findings and make significant contributions to understanding the effectiveness of AR in science

education. The results of the literature analysis indicate that the use of AR in science learning can improve students' understanding of abstract concepts and enrich their learning experience. AR provides a more engaging and interactive learning experience, which can increase student motivation and involvement. In addition, AR also supports various learning styles, such as visual, kinesthetic, and auditory, thus helping students understand science materials more deeply and contextually. However, several challenges related to infrastructure, teacher readiness, and costs are still obstacles to implementing AR in schools.

***Keywords**: augmented reality, science literacy, interactive learning, sciences education, educational technology*

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INTRODUCTION

In the era of globalization marked by rapid advances in information and communication technology, the world of education has undergone a very significant transformation (Suprapto et al., 2022). Technological advances have changed the way humans access information, communicate, and even the way humans learn (Solehatin et al., 2023). Education, which in the past was conventional with lecture methods and the use of printed media such as textbooks and whiteboards, is now slowly shifting towards a more interactive and digital direction (Hakiki et al., 2022). One concrete manifestation of this development is the integration of technology in learning, known as technology-enhanced learning (N. Abdullah et al., 2022). Various innovations such as e-learning, virtual classrooms, and mobile learning have been widely used to increase the effectiveness of the learning process (Nurroniah et al., 2023)

One of the latest forms of technology that is starting to get widespread attention in the world of education is Augmented Reality (AR), or in Indonesian it is called augmented reality (A. A. Abdullah et al., 2022). This technology combines the real world with digital elements in real-time, creating an immersive and interactive experience for its users (Gopalan et al., 2023). In other words, AR allows the integration of digital visual information, such as images, sounds, animations, or 3D objects, into the real environment through devices such as smartphones, tablets, or head-mounted displays (López-Belmonte et al., 2023). This technology is different from Virtual Reality (VR), which completely creates a virtual environment and replaces the real world; AR enriches the perception of the real world with contextual digital layers (Wahyuni et al., 2025)

This phenomenon is very relevant to be applied in the world of education, especially as a learning medium that is able to bridge the gap between abstract concepts and real experiences (Sesmiarni et al., 2023). In education, one of the main challenges is how to deliver complex learning materials effectively and easily understood by students (Habiddin et al., 2022). Concepts in the fields of science, mathematics, engineering, and history are often difficult to understand through verbal explanations or two-dimensional visualizations alone (Yeztiani et al., 2022). This is where AR comes as an innovative solution that provides an experiential learning experience, where students can learn through direct experiences that are strengthened by technology (Purnama et al., 2024)

Pedagogically, the use of Augmented Reality in learning has great potential to support various learning styles of students, both visual, kinesthetic, and auditory (Afnan et al., 2023). Through the display of three-dimensional objects that can be manipulated, rotated, and observed from various angles, visual students will get a more concrete picture of the concepts being taught (Rozi et al., 2021). For kinesthetic students, direct interaction with AR objects through touch or physical movement can strengthen understanding of concepts through motor experiences (Faridi et al., 2021). The integration of sound or narration in AR content will support students with auditory learning styles. This approach is also in line with the theory of constructivism in education, which emphasizes the importance of active student involvement in the learning process so that knowledge can be built meaningfully (H. Setiawan et al., 2021)

AR also allows for deeper personalization of learning (Rahmi et al., 2025). Students can learn at their own pace, explore additional materials according to their interests, and repeat learning experiences without limits. This certainly supports the student-centered learning approach, where students become active subjects in the educational process (Nabil et al., 2023). In addition, teachers also benefit from the availability of innovative media that make it easier to explain abstract material, increase the appeal of learning, and motivate students to be more enthusiastic in learning (Fitrianingsih, 2024)

The application of Augmented Reality also has a positive impact on increasing student engagement and motivation to learn (Candra Sari et al., 2022). Research (Zumbach et al., 2022) shows that AR-based learning experiences tend to attract more students' attention than traditional methods. This is due to AR's

ability to create an immersive, fun, and different learning atmosphere from the usual. By presenting elements of surprise, simulation, and interaction, AR can stimulate students' curiosity and enthusiasm, so that they are encouraged to explore more deeply into the material being taught (Shaumiwaty et al., 2022). In addition, AR can also encourage collaboration between students in learning activities, especially in project-based learning that involves problem solving and teamwork (Twiningsih & Elisanti, 2021)

The use of AR as a learning medium is inseparable from various challenges (Turan & Atila, 2021). Some of them are limited technological infrastructure, teacher readiness in adapting new media, and limited human resources in developing AR content that is relevant to the curriculum (Karimah et al., 2023). In addition, there are also challenges in terms of budget, because hardware and software that support AR are still relatively expensive for most educational institutions in developing countries (Erwis et al., 2024). However, along with the increasing openness of access to technology and the increasing number of local developers who are starting to create education-based AR applications, these obstacles are slowly starting to be overcome (Li & Guo, 2021)

In education in Indonesia, the use of Augmented Reality is still relatively new and uneven (Setiawaty et al., 2024). However, a number of initiatives have been carried out by the government, educational institutions, and technology developers to introduce AR as part of educational innovation (Demircioglu et al., 2022). The development of applications such as AR-based textbooks, interactive science modules, and AR-based educational games is the first step towards digital transformation in the world of education (Rosidah et al., 2021). This innovation is in line with the Merdeka Belajar program launched by the Ministry of Education, Culture, Research, and Technology, which emphasizes the importance of flexible, technology-based learning and adapting to the needs of the times (B. Setiawan et al., 2023)

From an academic perspective, the use of Augmented Reality in learning also contributes to the development of teaching and evaluation methodologies (Lo et al., 2021). Teachers and educational researchers can develop blended learning or hybrid learning approaches, which combine face-to-face learning with AR-based digital interactions. (Ningrum et al., 2021). This opens up opportunities for data collection and evaluation of the learning process in more depth and in real time. For

example, with AR, teachers can monitor how often students interact with certain objects, the level of understanding achieved, and how students respond to the learning activities provided (Cahyana et al., 2023)

The use of Augmented Reality as a learning medium is not just a technology trend, but rather part of the evolution of education towards a more adaptive, contextual, and learner-centered approach. By utilizing the potential of AR, the learning process is no longer limited by space and time, but can take place dynamically and be relevant to the needs of the 21st century. Therefore, there needs to be ongoing support from various parties - from the government, technology developers, educators, to the community - to encourage the adoption of AR in the world of education, so that learning becomes more meaningful, enjoyable, and has a positive impact on future generations (Ati et al., 2022)

In facing the challenges of 21st-century education, there is an urgent need to create learning methods that are not only informative but also transformative, interactive, and contextual. One of the main problems in science learning in Indonesia is the low level of scientific literacy of students, as reflected in the results of international studies such as PISA (Program for International Student Assessment), where Indonesia consistently ranks low in terms of understanding and applying scientific concepts in real life. Low student engagement with science material is often caused by conventional learning approaches that are too theoretical, lack visualization, and are not relevant to everyday life. In addition, limited laboratory facilities and interesting learning media are significant obstacles in developing scientific competencies as a whole.

The integration of Augmented Reality (AR) technology as a learning medium offers great potential to bridge the gap between theory and practice. AR can present abstract concepts in interactive 3D visual forms, strengthen understanding, and stimulate students' interest in learning. The main goal of utilizing AR in science education is to improve scientific literacy through more meaningful, contextual, and enjoyable learning experiences. By providing a learning environment that allows students to explore, observe, and simulate directly through digital devices, it is hoped that students can develop critical, analytical, and reflective thinking skills, which are the main components of scientific literacy.

There is a research gap that needs to be considered. Although a number of findings have explored the use of AR in education, most are still limited to technical

aspects or case studies. There are not many findings that deeply examine the effectiveness of AR in improving students' scientific literacy at the elementary and secondary education levels, especially in Indonesia. On the other hand, there is no systematic approach that integrates AR into inquiry-based learning strategies or scientific approaches as recommended in the Independent Curriculum. Therefore, a comprehensive study is needed that not only views AR as a visual aid but also as a medium that can shape students' scientific thinking through active and reflective learning experiences.

The urgency of this finding lies in the need to present innovative solutions in the world of education that are able to overcome the limitations of conventional science learning, especially in areas that do not yet have adequate laboratory facilities. Amid the digitalization and post-pandemic educational transformation, AR integration is no longer just an option but a strategic need to create education that is equal, inclusive, and adaptive to changing times. Therefore, the development and application of AR as a learning medium based on scientific literacy needs to be encouraged systematically, through synergy between research, curriculum development, and teacher training to maximize the potential of this technology in supporting the quality of more humanistic and meaningful science learning.

In this study, *scientific literacy* refers to the definition proposed by the OECD (2018), which describes it as the ability of individuals to engage thoughtfully with science-related issues and apply scientific knowledge in real-life contexts. Additionally, Bybee (1997) emphasizes that scientific literacy encompasses understanding scientific concepts, interpreting data, engaging in critical thinking, and making evidence-based decisions. This operational definition highlights that scientific literacy goes beyond the mastery of scientific facts and involves a holistic capacity to think scientifically in a meaningful and contextualized manner.

To enhance clarity and conciseness, the original text has been condensed by removing repetitive descriptions of AR's benefits. The explanation regarding AR's ability to support concept comprehension, accommodate various learning styles, and enhance student motivation has been consolidated into a single cohesive paragraph that presents its pedagogical potential in a concise yet comprehensive way. Furthermore, sections discussing the challenges of AR implementation and ongoing developmental efforts have been streamlined to avoid redundancy and maintain focus, resulting in a more structured and reader-friendly introduction.

To explicitly demonstrate the novelty of this study, a brief research mapping has been included in the form of a simple table outlining the focus, limitations, and relevance of previous studies. For instance, Gopalan et al. (2023) explored AR usability but did not address its pedagogical impact, while Shaumiwaty et al. (2022) concentrated on student motivation without evaluating its effect on scientific literacy. This study seeks to fill that gap by offering a systematic review of AR integration within science literacy education, particularly at the primary and secondary school levels, aligned with Indonesia's Merdeka Belajar curriculum framework.

Based on the background, research objectives, identified research gaps, and the urgency of innovation in science learning, the researcher considers it important to raise this topic into a scientific study. Hence, the researcher selected the title: *"Augmented Reality as a Learning Media Based on Science Literacy"* as the central focus of this research, with the aim of contributing meaningfully to the advancement of science education in the digital era.

To guide this study, the following research question is formulated: "How does the use of Augmented Reality as a learning medium affect student activity and scientific literacy in science education?" This research question will serve as the basis for exploring the effectiveness of AR in enhancing both engagement and learning outcomes, particularly in fostering students' scientific literacy.

METHOD

This study adopts a Systematic Literature Review (SLR) approach to synthesize and critically evaluate existing research on the use of Augmented Reality (AR) as a learning medium grounded in scientific literacy. The review follows a structured procedure involving the identification, selection, appraisal, and synthesis of relevant studies. The inclusion criteria for selecting articles are as follows: (1) publication year between 2021 and 2025, (2) language limited to English and Indonesian, and (3) research types including quantitative, qualitative, R&D, and experimental studies specifically related to AR and science literacy in educational contexts. The search strategy involved the use of Boolean operators with keywords such as "augmented reality" AND "science literacy" AND "education" across three major academic databases: Google Scholar (for open-access scope), ScienceDirect (for peer-reviewed scientific journals), and JSTOR (for interdisciplinary educational

insights). Searches were filtered based on titles, abstracts, and full texts to ensure topic relevance. To ensure the credibility and quality of the studies, each selected article was assessed using the CASP (Critical Appraisal Skills Programme) checklist and categorized by level of evidence to distinguish between high-quality empirical research and theoretical discussions. After selection, a thematic synthesis method was employed for data analysis, focusing on key themes such as types of AR used, dimensions of scientific literacy addressed, learning outcomes reported, and pedagogical frameworks applied. This structured method allows the researcher to derive meaningful conclusions about the effectiveness and implementation challenges of AR in science education and to formulate recommendations for policy, curriculum, and classroom integration based on sound evidence.

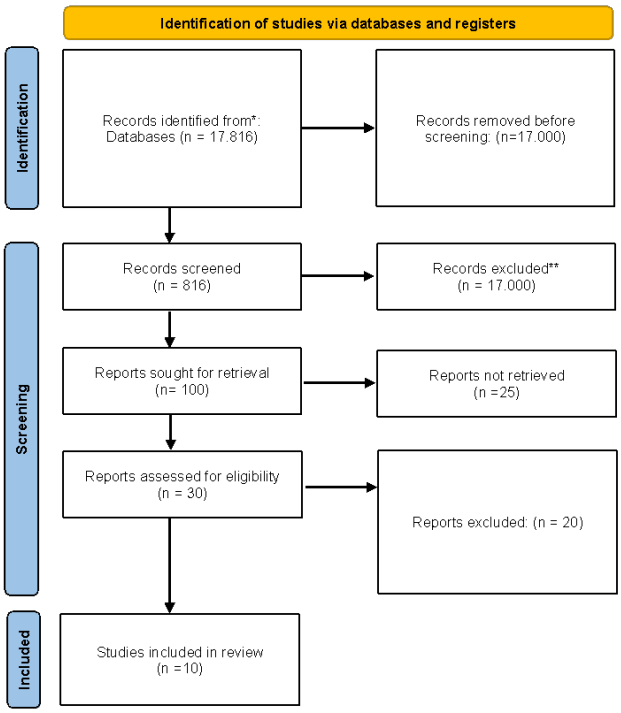

Figure 1. *PRISMA Flow Diagram*

RESULTS AND DISCUSSION

This study systematically reviewed ten relevant articles from 2021 to 2025, examining how Augmented Reality (AR) is used to enhance scientific literacy in primary and secondary education settings. The literature reveals a consistent trend: AR-based educational media, particularly those developed with platforms such as Assemblr EDU, are effective in increasing students' engagement, conceptual

understanding, and scientific literacy. Most studies employed R&D methodologies (ADDIE and ASSURE), quasi-experiments, or classroom action research to evaluate AR interventions, often reporting significant gains in learning outcomes. For example, Nainggolan & Limiansih (2025) observed a 43% improvement in science literacy post-AR implementation, while Masriani et al. (2024) reported successive increases of 29.8% and 25.2% in literacy scores across two learning cycles. Similarly, Sari et al. (2024) reported a high N-Gain score of 0.83 after integrating AR into PBL-based booklets. Such data confirms that AR is not only a novelty but a measurable enhancer of educational effectiveness. However, not all studies reported quantitative results, and only a few explicitly measured effect sizes or long-term retention, highlighting a gap in rigorous impact analysis.

Table 1. Synthesis Analysis

No	Writer	Journal Name	Year	Method	Volume	Variables
1	(Yulia & Putri, 2024)	Flobamorata Elementary Education Journal	2024	R&D with the ADDIE model	5(3)	AR Media, Science Literacy
2	(Isnaeni & Sa'diyah, 2024)	Proceedings of the National Science Seminar	2024	AR integration in e-modules	N/A	Science Literacy, AR, E-Modules
3	(Rizqillah & Kholiq, 2023)	Physics Education Innovation	2023	R&D ASSURE model	12(3)	ARLISA Module, Science Literacy
4	(Agustin et al., 2025)	Pendas: Scientific Journal of Elementary Education	2025	Qualitative descriptive (interviews, observations)	10(01)	AR Media, Science Literacy, Ecosystem
5	(Nainggolan & Limiansih, 2025)	Cokroaminoto Journal of Primary Education	2025	ADDIE R&D model	8(1)	AR Media, Science Literacy, Solar Eclipse
6	(Masriani et al., 2024)	Arriving	2024	Classroom Action Research (CAR)	21(2)	AR, Science Literacy
7	(Sari et al., 2024)	MODELING: Journal of PGMI Study Program	2024	PBL-based AR media development	11(2)	AR Booklet, Science Literacy, Ecosystem
8	(Juniawan et al., 2023)	Cokroaminoto Journal of Primary Education	2023	Content analysis with PRISMA	6(2)	Learning Media, Scientific Literacy
9	(Khaerani et al., 2023)	Advances In Social Humanities Research	2023	Experimental design	1(12)	Steam, AR, Local Culture, Numeracy Literacy

No	Writer	Journal Name	Year	Method	Volume	Variables
10	(Azzarkasyi & Rizal, 2024)	Journal of Technology and Literacy in Education	2024	Quasi-experimental research	3(3)	AR, Science Literacy, Business, and Energy

The quality of the reviewed studies varied. Using the CASP checklist and Level of Evidence assessment, the majority were categorized as Level III evidence (quasi-experimental and R&D studies), indicating moderate strength. Only a few studies assessed long-term retention or control for confounding variables, revealing a need for more rigorous designs. Furthermore, a notable outlier was the study by Khaerani et al. (2023), which diverged from the AR focus by introducing a cultural gamification model unrelated to scientific literacy, suggesting inconsistencies in topic alignment within some literature.

Several challenges emerged regarding AR implementation, particularly in the Indonesian educational context. Infrastructure limitations, such as poor internet access, outdated devices, and a lack of teacher training, remain significant barriers. These are compounded by disparities in digital literacy between urban and rural schools. Addressing these challenges requires multi-level strategies: investment in digital infrastructure, government-supported teacher training programs, and integration of AR into national curriculum frameworks.

Interestingly, similar trends have been observed in other developing nations. For instance, AR-based science education in rural schools in the Philippines and India has also shown positive results but faced the same systemic issues, suggesting a global pattern among developing countries where innovation outpaces infrastructure readiness.

In practical terms, educators can still utilize low-bandwidth AR applications (like Assemblr's offline features) and blend AR media with traditional teaching to gradually adapt to technology. Academically, this review supports the potential of AR as a pedagogical tool to bridge the science literacy gap, provided its integration is accompanied by targeted teacher support and localized resource development. Future studies should focus on longitudinal designs, scalability, and comparisons between different AR platforms to guide effective and equitable adoption.

Table 2. Literature Review Results

No	Author(s)	Title	Problem Addressed	Objective	Method	Key Results
1	Yulia & Putri (2024)	*Development of Interactive Media Assemblr Edu Based on Augmented Reality...*	Lack of interactive tech-based media in grade 6 science learning	Develop and evaluate AR media to improve scientific literacy	R&D (ADDIE)	Media are validated and effective in increasing science literacy
2	Isnaeni & Sa'diyah (2024)	*Optimizing Science Literacy Skills with Earth Exploration...*	Low interest and outcomes in science	Improve literacy via AR-based e-module	AR integration in the digital module	AR improves interaction and literacy outcomes
3	Rizqillah & Kholiq (2023)	*Validity Analysis of AR-Based Modules and Scientific Literacy (ARLISA)*	Need for interactive literacy-focused modules	Analyze the validity of ARLISA	R&D (ASSURE)	High validity (97%), suitable for use
4	Agustin et al. (2025)	*Analysis of AR Media Needs... on Ecosystem Material*	Limited tech use in primary science classes	Analyze needs for AR in literacy enhancement	Qualitative (interviews, obs)	AR supports literacy through interactive learning
5	Nainggolan & Limiansih (2025)	*Development of AR Media for Solar Eclipse...*	Low literacy & lack of media (per PISA)	Develop and test AR on the solar eclipse topic	R&D (ADDIE)	Validity: 93%; 43% increase in science literacy
6	Masriani et al. (2024)	*Application of AR to Improve Science Literacy...*	Poor science literacy & weak scientific thinking	Improve literacy using AR in the classroom	Classroom Action Research	29.8% (cycle 1) & 25.2% (cycle 2) increase; final score: 85.5%
7	Sari et al. (2024)	*AR-Based Booklet through PBL Learning on Ecosystem Balance*	Weak understanding of the ecosystem and literacy	Develop AR booklets using PBL to boost literacy	Development Research	N-Gain: 0.83 (high); AR effectively enhances understanding
8	Juniawan et al. (2023)	*Literature Study: Analysis of Science Learning Media...*	Ineffective media for literacy	Review learning media effectiveness	Systematic Literature Review (PRISMA)	AR, animations, and digital tools have been shown to improve literacy
9	Khaerani et al. (2023)	*Demo Slot Innovation... as Cultural Preservation*	Low "black scatter" literacy, unclear relevance to science	Strengthen cultural knowledge via gamification	Experimental (3 groups)	Not directly related to science literacy; topic misalignment

No	Author(s)	Title	Problem Addressed	Objective	Method	Key Results
10	Azzarkasyi & Rizal (2024)	*Improving Science Literacy Using AR-Based Media...*	Difficulty in abstract science concepts	Use AR to teach work & energy concepts	Quasi-experimental	Literacy improved; students showed high engagement with AR

Augmented Reality as a Catalyst for Active Learning and Scientific Literacy in Science Education: A Synthesis of Theory and Practice

The influence of Augmented Reality (AR) on student activity and learning outcomes in science learning has become a topic of increasing interest in the world of education, especially in facing the challenge of how to improve students' understanding of science concepts that are often considered abstract and complex. In recent years, the use of AR technology has shown great potential in overcoming these challenges, especially by providing a more interactive and immersive learning experience (Ardyansyah & Rahayu, 2023). Based on a number of findings that have been made, the use of Augmented Reality in learning media not only improves student learning outcomes but also plays a significant role in increasing their activeness during the learning process. The influence of AR on student activity and learning outcomes in science learning has been shown to have a significant impact, especially on elementary to secondary school students, as found in various published studies.

One of the findings that highlights the importance of AR in improving scientific literacy is the finding conducted by Yulia and Putri (2024). They developed an AR-based interactive media called Assemblr Edu to improve the scientific literacy of grade 6 students. This finding uses the Research and Development (R&D) model with the ADDIE approach (Analysis, Design, Development, Implementation, Evaluation). The results of this finding indicate that the AR media developed is very valid and effective in improving students' scientific literacy. This shows that Augmented Reality has a positive impact on improving student learning outcomes, because this media allows students to interact directly with the subject matter in a more enjoyable and easy-to-understand way. In addition, this finding also shows that AR can make students more active in learning, because this technology provides an experience that is not only more interesting but also facilitates their understanding of the material being taught.

Another study by Isnaeni and Sa'diyah (2024) also highlighted how the use of AR can optimize students' scientific literacy skills. They developed an AR-based e-module with the help of the Assemblr Edu application. This module aims to improve students' understanding of science material through a more interactive approach. These findings indicate that the integration of AR into the learning module has succeeded in creating more interactive and effective learning, which in turn improves student learning outcomes in science. This proves that AR not only increases student motivation but also encourages them to participate more actively in the learning process, which is very important in improving their learning outcomes.

In addition, research by Rizqillah and Kholiq (2023) revealed similar results in learning renewable energy material. They developed an AR-based module, named ARLISA, to help improve students' understanding of topics that are often considered difficult. By using the R&D model and the ASSURE approach, they succeeded in proving that this AR module has high validity (97%), which makes it very suitable for use in science learning. This shows that AR can simplify difficult material in a more interactive way, thereby increasing student activeness in learning and ultimately resulting in a significant increase in their understanding of science topics.

Student activity during learning is also a major concern in many findings involving AR. Agustin et al. (2025) conducted findings in elementary schools to analyze the need for the use of AR media in ecosystem material. Their findings showed that AR media can support the improvement of science literacy by providing a more interactive learning experience. By using AR technology, students not only gain deeper knowledge about ecosystems but are also more actively involved in the learning process. This shows that AR can stimulate students' interest and encourage them to be more active in participating in science learning, which ultimately has an impact on better learning outcomes.

In the findings conducted by Nainggolan and Limiansih (2025), which focused on the development of AR media to teach the topic of solar eclipse to fourth-grade elementary school students, it was found that the application of AR succeeded in significantly increasing students' science literacy scores. The results of these findings show a significant increase in student learning outcomes, with significant differences between the pretest and post-test. These findings also reveal

that the use of AR media is very good at helping students understand natural phenomena that are difficult to understand conventionally. In addition, AR media also increases student interaction with the material, making them more active in participating in learning.

Masriani et al. (2024) conducted findings at Madrasah Ibtidaiyah, which aimed to improve the science literacy of grade 5 students by using AR. The results of these findings indicate that the use of AR can significantly improve students' science literacy, with a significant increase from the first cycle to the second cycle. The application of AR in learning provides very positive results, not only in improving students' understanding of science material but also in increasing their activeness during learning. This is in line with other findings, which show that AR is able to encourage students to be more active in participating in teaching and learning activities, both through interaction with more interesting learning materials and through collaboration between them.

Sari et al. (2024) developed AR-based booklet media with a Problem-Based Learning (PBL) model to improve scientific literacy in ecosystem balance material. The results of this finding indicate that the use of PBL-based AR media not only improves students' scientific literacy but also encourages them to be more active in finding solutions to the problems presented. PBL itself has been proven effective in increasing student involvement in the learning process, and when combined with AR, learning becomes more interesting and enjoyable. This proves that AR can be used to support various learning models that increase student activity and learning outcomes.

Research by Juniawan et al. (2023) revealed that effective science learning media, including AR-based media, can improve science literacy in elementary schools. Using the Systematic Literature Review (PRISMA) approach, these findings identified that media such as video animation, ICT, and digital books have been shown to improve students' understanding of science material. This shows that learning media that integrates AR can help students be more active in learning, as well as improve their understanding of complex science concepts.

Findings by Azzarkasyi & Rizal (2024) regarding the use of AR in learning business and energy materials show that this technology can overcome the difficulties faced by students in understanding abstract concepts. By using AR media, students can more easily understand topics that were previously difficult to

explain conventionally. These findings also show a positive response from students to the use of AR in learning, which shows an increase in student activity and learning outcomes in science materials.

All these findings indicate that the use of Augmented Reality in science learning has a significant impact on student activity and learning outcomes. AR not only makes learning more interactive and fun but also allows students to understand complex science concepts more visually and practically. Thus, AR has the potential to improve the quality of education, especially in science learning, by increasing student motivation, activity, and understanding. Therefore, the use of AR as a learning medium based on scientific literacy can be an effective alternative to overcome the challenges faced in science education in schools.

The Relationship between Student Activeness and Increasing Science Literacy through the Use of Augmented Reality Media

The relationship between student activity and increasing scientific literacy through the use of Augmented Reality (AR) media is an interesting topic in the world of education, especially in science learning (Chang et al., 2016). Student activity in the learning process has a very important role, because the more actively students are involved, the more likely they are to understand and absorb the subject matter well. The use of Augmented Reality technology has a significant impact on increasing student activity, which in turn can encourage an increase in their scientific literacy.

Basically, scientific literacy not only includes an understanding of scientific facts and concepts but also the ability to apply this knowledge in everyday life, as well as critical thinking and problem-solving skills. In this case, student activity is closely related to how much they can be involved in various challenging learning activities and develop their skills. Therefore, AR-based learning media play an important role in creating a more interesting and interactive learning environment, which makes students more active in participating and has a positive impact on their scientific literacy.

Various findings have shown that the use of Augmented Reality in science learning can increase student activity. For example, the findings conducted by Yulia and Putri (2024), who developed AR media based on Assemblr Edu to improve the science literacy of grade 6 students. They found that students became more active

in interacting with learning materials thanks to the interactive features offered by AR technology. By seeing science concepts that are usually abstract visually and in three dimensions, students can more easily understand and apply the knowledge they learn. This activity not only increases their activity but also improves their understanding of science materials.

One of the reasons why AR can increase student engagement is that this technology offers a more immersive learning experience. Through AR applications, students can interact with virtual objects that appear in the real world, making it easier to understand concepts that are difficult to explain with just text or static images. For example, in learning ecosystem material, students can see how various elements of the ecosystem interact in a dynamic visual form. This triggers curiosity and encourages students to be more active in exploring these concepts. For example, Agustin et al. (2025) in their research on the need for AR media in ecosystem material in elementary schools showed that this technology can make students more interested and active in the learning process, which ultimately has an impact on increasing their scientific literacy.

In addition, AR also provides an opportunity for students to learn independently and more freely. When students use AR media, they not only receive information passively, but they can also interact with the material and explore various aspects of the topic being studied. This provides an opportunity for students to develop critical thinking and problem-solving skills, which are important parts of scientific literacy. In the findings by Isnaeni and Sa'diyah (2024), the AR module they developed helped students to be more active in seeking information and trying to understand the material more practically and enjoyably. Thus, the use of AR increases student activity in learning and helps them develop the skills needed to improve their scientific literacy.

The increased student activity through the use of AR is also related to their increased motivation to learn. In many cases, students often feel bored or uninterested in science learning materials that are considered too difficult or boring. However, with the introduction of AR, learning becomes more interesting and enjoyable. This can motivate students to be more active in participating in class and be involved in the discussions or assignments given. For example, in the findings by Nainggolan and Limiansih (2025), the use of AR in solar eclipse material succeeded in making students more motivated to learn and active in participating in learning

activities. This increase in motivation certainly contributes to improving student learning outcomes, which is an important aspect of scientific literacy.

In addition to motivating students, AR also facilitates collaborative learning. In AR-based learning, students often work in groups to explore the material being taught, discuss, and find solutions to problems given. This encourages students to interact with each other, share ideas, and learn together. Students' activeness in working together not only improves their understanding of science material, but also develops social skills and teamwork that are very important in everyday life. Findings by Masriani et al. (2024) show that AR-based learning not only improves individual understanding of science material but also strengthens collaboration between students, which ultimately enriches their learning experience.

The activeness of students that is built through the use of AR can also increase their absorption of information. In traditional learning, students often only receive information verbally or in writing, which can make it difficult for them to visualize the concepts being taught. However, with AR, students can see visual representations of these concepts. For example, in learning work and energy materials, students can see directly how energy moves or changes form in various situations, which greatly helps them to understand the material. Findings by Azzarkasyi and Rizal (2024) show that students who use AR in science learning have a better understanding of the material they are learning because they can see and interact with these concepts in a more concrete form.

The use of Augmented Reality in science learning has a very positive impact on student activity. This technology not only makes students more interested and involved in learning, but also allows them to understand the material more deeply and practically. This increase in student activity, in turn, contributes to improving their scientific literacy. In other words, the more active students are in participating in the learning process, the more likely they are to gain better knowledge and improve their critical thinking and problem-solving skills. Therefore, the use of AR as a learning medium based on scientific literacy can be an effective solution to improve the quality of science education in schools.

The findings indicate that the use of Augmented Reality (AR) in science learning significantly enhances student engagement and scientific literacy. This implies that educators and curriculum developers should consider integrating AR as an interactive learning tool to support 21st-century skill development in students.

This study is limited to literature reviews and findings primarily conducted at the elementary to secondary education levels and on specific science topics. Contextual variables such as school technological readiness and teacher competency were not deeply analyzed. Future studies are recommended to examine the effectiveness of AR in higher education science contexts, explore its integration with other innovative learning models, and assess its long-term impact on students' critical thinking and problem-solving abilities.

CONCLUSION

The influence of Augmented Reality (AR) on student activity and learning outcomes in science learning is that AR technology has a very significant impact on increasing student engagement, as well as the quality of their learning. The use of AR media provides a more interactive and immersive learning experience, allowing students to participate more actively in learning and visualize science concepts that are often difficult to understand only through conventional learning methods. Various findings show that by utilizing AR, students not only become more active but also gain a deeper understanding of the material being taught, both in theory and in its practical applications. This contributes directly to improving students' scientific literacy because AR supports the development of critical thinking skills, problem-solving, and the application of knowledge in real situations. In addition, AR can also increase student motivation because learning materials become more interesting and fun, which in turn encourages students to be more involved in the learning process. AR-based learning also facilitates collaboration between students, enriches their learning experience, and helps them develop very important social skills. Therefore, AR is not only a sophisticated learning medium, but also a very effective tool to improve the quality of science education in a comprehensive manner, optimize student activeness, and ultimately support better scientific literacy in future education.

REFERENCES

Abdullah, A. A., Richardo, R., Rochmadi, T., Wijaya, A., & Nurkhamid, N. (2022). The Use of Ethnomathematics Learning Media based on augmented reality for madrasah students. *Al-Ishlah: Jurnal Pendidikan*, *14*(1), 877–886.

Abdullah, N., Baskaran, V. L., Mustafa, Z., Ali, S. R., & Zaini, S. H. (2022). Augmented Reality: The Effect on Students' Achievement, Satisfaction and Interest in Science Education. *International Journal of Learning, Teaching and Educational Research*, *21*(5), 326–350.

Afnan, R., Munasir, M., Budiyanto, M., & Aulia, M. I. R. (2023). The Role of Scientific Literacy Instruments for Measuring Science Problem Solving Ability. *IJORER: International Journal of Recent Educational Research*, *4*(1), 45–58.

Agustin, D. I., Hamdu, G., & Muharram, M. R. W. (2025). Analysis of Augmented Reality Media Needs Based on Science Literacy on Ecosystem Material in Elementary Schools. *Pendas: Scientific Journal of Elementary Education*, *10*(01), 112–124.

Ardiansyah, A. & Rahayu, S. (2023). Development and Implementation of Augmented Reality-Based Card Game Learning Media with Environmental Literacy in Improving Students' Understanding of Carbon Compounds. Orbital - Vol. 15 No. 2. https://doi.org/10.17807/orbital.v15i2.17617 .

Ati, S., Aprillya, M. R., & Bianto, M. A. (2022). Science Augmented Reality Media Program for Elementary School Students. *JPI (Indonesian Education Journal)*, *11*(3), 457–465.

Azzarkasyi, M., & Rizal, S. (2024). Improving Science Literacy Using Augmented Reality-Based Media on Work and Energy Material for Students of SMPN 17 Banda Aceh. *Journal of Technology and Literacy in Education*, *3*(3), 132–140.

Balestra, C. and R. Tonkin (2018), "Inequalities in household wealth across OECD countries: Evidence from the OECD Wealth Distribution Database", OECD Statistics Working Papers, 2018/01, OECD Publishing, Paris. http://dx.doi.org/10.1787/7e1bf673-en

Bybee, Rodger W. 1997. Achieving Scientific Literacy: From Purposes to Practices. Books; Opinion Paper, 256.

Cahyana, U., Luhukay, J. R., Lestari, I., Irwanto, I., & Suroso, J. S. (2023). Improving Students' Literacy and Numeracy Using Mobile Game-Based Learning with Augmented Reality in Chemistry and Biology. *International Journal of Interactive Mobile Technologies*, *17*(16).

Candra Sari, R., Rika Fatimah, P. L., Ilyana, S., & Dwi Hermawan, H. (2022). Augmented Reality (AR)-Based Sharia Financial Literacy System (AR-SFLS): A New Approach to Virtual Sharia Financial Socialization for Young Learners. *International Journal of Islamic and Middle Eastern Finance and Management*, *15*(1), 48–65.

Chang, R.-C., Chung, L.-Y., & Huang, Y.-M. (2016). Developing an interactive augmented reality system as a complement to plant education and comparing its effectiveness with video learning. Interactive Learning Environments, 24(6), 1245–1264. https://doi.org/10.1080/10494820.2014.982131

Demircioglu, T., Karakus, M., & Ucar, S. (2022). The Impact of Augmented Reality-Based Argumentation Activities on Middle School Students' Academic Achievement and Motivation in Science Classes. *Educational Quarterly Reviews*, *5*(2), 22–34.

Erwis, F., Jixiong, C., Rahayu, N., Raharja, A. R., & Zebua, R. S. Y. (2024). Use of Augmented Reality (AR) in Mobile Learning for Natural Science Lessons. *Journal of Social Science Utilizing Technology*, *2*(1), 116–126.

Faridi, H., Tuli, N., Mantri, A., Singh, G., & Gargrish, S. (2021). A Framework Using Augmented Reality to Improve Critical Thinking Abilities and Learning Gains of the Students in Physics. *Computer Applications in Engineering Education*, *29*(1), 258–273.

Fitrianingsih, S. E. (2024). *Development of Learning Media Based on Augmented Reality Technology with Unity and Vuforia to Improve Students' Scientific*

Literacy in Optical Instruments Material. UIN Sunan Gunung Djati Bandung.

Gopalan, V., Bakar, J. A. A., & Zulkifli, A. N. (2023). Systematic Literature Review on Critical Success Factors in Implementing Augmented Reality for Science Learning Environments (2006–2021). *Education and Information Technologies*, *28*(9), 11117–11144.

Habiddin, H., Ashar, M., Hamdan, A., & Nasir, K. R. (2022). Digital Comic Media for Teaching Secondary School Science. *International Journal of Interactive Mobile Technologies*, *16*(3), 159–166.

Hakiki, R., Muchson, M., Sulistina, O., & Febriana, A. (2022). The Development of Learning Media Based on Augmented Reality, Hologram, and Ludo Game on the Topic of Molecular Shapes. *International Journal of Interactive Mobile Technologies*, *16*(4), 71.

Isnaeni, N., & Sa'diyah, C. (2024). Optimizing Science Literacy Skills with Earth Exploration: E-Module Based on Augmented Reality Assisted by Assemblr EDU. In *Proceeding of the National Science Seminar* (pp. 521–530).

Juniawan, E. R., Salsabila, V. H., Prasetya, A. T., & Rengga, W. D. P. (2023). Literature Study: Analysis of Science Learning Media to Improve Elementary School Students' Science Literacy. *Cokroaminoto Journal of Primary Education*, *6*(2), 82–94.

Karimah, U., Sunarti, T., & Munasir, M. (2023). Digital Era for Quality Education: Effectiveness of Discovery Learning with Android to Increase Scientific Literacy. *IJORER: International Journal of Recent Educational Research*, *4*(6), 862–876.

Khaerani, N., Nensi, A. I. E., Prasani, T., & Assagaf, S. F. (2023). Steam Learning Innovation Through Traditional Bugis-Makassar Games Based on Augmented Reality as Cultural Preservation and Strengthening of Junior High School Students' Numeracy Literacy. *Advances In Social Humanities Research*, *1*(12), 1–11.

Li, Y., & Guo, M. (2021). Scientific Literacy in Communicating Science and Socio-Scientific Issues: Prospects and Challenges. *Frontiers in Psychology*, *12*, 758000.

Lo, J.-H., Lai, Y.-F., & Hsu, T.-L. (2021). The Study of AR-Based Learning for Natural Science Inquiry Activities in Taiwan's Elementary School from the Perspective of Sustainable Development. *Sustainability*, *13*(11), 6283.

López-Belmonte, J., Moreno-Guerrero, A.-J., López-Núñez, J.-A., & Hinojo-Lucena, F.-J. (2023). Augmented Reality in Education. A Scientific Mapping in Web of Science. *Interactive Learning Environments*, *31*(4), 1860–1874.

Masriani, M., Liana, D., & Susanti, E. (2024). Application of Augmented Reality to Improve Science Literacy of Grade 5 Students of Elementary Madrasah. *Arriyadhah*, *21*(2), 36–43.

Nabil, Z. F., Haris, V., Idrus, H., Ayop, S. K., & Alias, S. N. (2023). Development of a Physics Module Based on Augmented Reality Integrated with Al-Quran Verses on Electricity. *Sainstek: Jurnal Sains Dan Teknologi*, *15*(1), 61–68.

Nainggolan, F. N. A. B., & Limiansih, K. (2025). Development of Augmented Reality Media of Solar Eclipse to Train Science Literacy of Fourth Grade Elementary School Students. *Cokroaminoto Journal of Primary Education*, *8*(1), 141–154.

Ningrum, V. F., Sumarni, W., & Cahyono, E. (2021). Development of Augmented Reality-Based Learning Media on Concept of Hydrocarbon to Improve Multi-Representation Ability. *Journal of Science Education Research*, *7*(Special Issue), 256–265.

Nurroniah, Z., Sani, S., Wulandari, R., Cahya, N., Kusumaningtyas, S. K. S., & Nuraini, L. (2023). Development of Augmented Learning Based on Lahbako Dance Ethnoscience for Science Literacy and Interest in the Concept of Circular Motion. *Edusains*.

Purnama, P., Syahid, M., Ardianto, D., & Arifin, M. Z. (2024). The Effectiveness of Augmented Reality-Based Science Learning in Elementary Schools. *National Seminar & Elementary Education Proceedings*, *1*(1), 163–178.

Rahmi, N. A., Syahmani, S., Mahardika, A. I., Suyidno, S., & Suwandy, F. I. (2025). Trends in Information and Communication Technology (ICT)-Based Science, Technology, Engineering, and Mathematics (STEM) Teaching Materials Development in Science Learning in Indonesia: A Systematic Literature Review. *Indonesian Journal of Multidisciplinary Research*, *5*(1), 115–132.

Rizqillah, I. A., & Kholiq, A. (2023). Validity Analysis of Augmented Reality and Science Literacy Based Modules (ARLISA) on Renewable Energy Material. *Physics Education Innovation*, *12*(3), 35–40.

Rosidah, U. A., Marwoto, P., & Subali, B. (2021). Analysis of the Need for Android Based Mobile Learning Development to Improve Student Science Literacy. *Journal of Science Education Research*, *7*(4), 601–606.

Rozi, I. F., Larasati, E., & Lestari, V. A. (2021). Developing Vocabulary Card Base on Augmented Reality (AR) for Learning English. *IOP Conference Series: Materials Science and Engineering*, *1073*(1), 12061.

Sari, P. A., Fatih, M., & Alfi, C. (2024). Augmented Reality-Based Booklet Through PBL Learning of Ecosystem Balance Material to Improve Science Literacy of Class V SDN Sumberingin 04 Blitar. *MODELING: Journal of PGMI Study Program*, *11*(2), 380–393.

Sesmiarni, Z., Darmawati, G., Yuspita, Y. E., Yeri, S., & Ikhsan, I. (2023). Android-Based Augmented Reality: An Alternative in Mastering Tajweed for Student Learning. *J. Internet Serv. Inf. Secur.*, *13*(2), 30–47.

Setiawan, B., Rachmadtullah, R., Farid, D. A. M., Sugandi, E., & Iasha, V. (2023). Augmented Reality as Learning Media: The Effect on Elementary School Students' Science Processability in Terms of Cognitive Style. *Journal of Higher Education Theory & Practice*, *23*(10).

Setiawan, H., Aji, S. M. W., Oktaviyanti, I., Jiwandono, I. S., Rosyidah, A. N. K., & Gunayasa, I. B. K. (2021). Utilization of Augmented Reality-Based Reading Resources for Literacy Movements in Elementary Schools. *Briliant: Research and Conceptual Journal*, *6*(1), 146–156.

Setiawaty, S., Lukman, I. R., Imanda, R., Sudirman, S., & Rauzatuzzikrina, R. (2024). Integrating of Mobile Augmented Reality Applications Through Inquiry Learning to Improve Students' Science Process Skills and Mastery of Science Concept. *Indonesian Journal of Science Education*, *13*(1).

Shaumiwaty, S., Fatmawati, E., Sari, H. N., Vanda, Y., & Herman, H. (2022). Implementation of Augmented Reality (AR) as a Teaching Media in English Language Learning in Elementary School. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *6*(6), 6332–6339.

Solehatin, S., Aslamiyah, S., Pertiwi, D. A. A., & Santosa, K. (2023). Augmented Reality Development Using Multimedia Development Life Cycle (MDLC) Method in Learning Media. *Journal of Soft Computing Exploration*, *4*(1), 30–38.

Suprapto, N., Tafauliyati, T., & Yanti, V. K. (2022). Development of e-Book with Flip PDF Professional Based on Scientific Literacy. *TEM Journal*, *11*(2), 851–855.

Turan, Z., & Atila, G. (2021). Augmented Reality Technology in Science Education for Students with Specific Learning Difficulties: Its Effect on Students' Learning and Views. *Research in Science & Technological Education*, *39*(4), 506–524.

Twiningsih, A., & Elisanti, E. (2021). Development of STEAM Media to Improve Critical Thinking Skills and Science Literacy. *International Journal of Emerging Issues in Early Childhood Education*, *3*(1), 25–34.

Wahyuni, R., Suwondo, S., Arnentis, A., Putra, R. A., & Febrina, H. (2025). Training of Module Development Based on Augmented Reality Integrated with PBL in Supporting the Implementation of the Independent Curriculum. *JMM (Jurnal Masyarakat Mandiri)*, *9*(1), 436–446.

Yeztiani, O. L., Adrian, Q. J., & Aldino, A. A. (2022). Application of Augmented Reality as a Learning Media of Mollusca Group Animal Recognition and Its Habitat Based on Android. *Technoinfo Journal*, *16*(2), 420.

Yulia, N. M., & Putri, D. D. L. (2024). Development of Interactive Media Assemblr Edu Based On Augmented Reality to Improve Science Literacy of Grade 6 Students. *Flobamorata Elementary Education Journal*, *5*(3), 410–419.

Zumbach, J., von Kotzebue, L., & Pirklbauer, C. (2022). Does Augmented Reality also Augment Knowledge Acquisition? Augmented Reality Compared to Reading in Learning about the Human Digestive System? *Journal of Educational Computing Research*, *60*(5), 1325–1346.