



Augmented Reality in Science Learning

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Abstract

Augmented Reality (AR) is a technology that combines the real world with virtual elements in real time, providing immersive, interactive experiences in various fields, including education. This article examines the application of AR in education, highlighting its advantages in creating seamless interactions between the real and virtual worlds, utilizing physical objects as tangible interfaces, and enabling seamless transitions to fully imaginative virtual environments. AR not only enhances collaboration between students through interactive shared workspaces but also facilitates the understanding of abstract concepts through contextual and intuitive three-dimensional visualizations. Various implementation examples, such as Assemblr Edu, demonstrate that AR can enrich science and technology learning experiences in a fun and effective way. With its significant potential to enhance engagement, understanding, and social interaction in learning, AR deserves wider integration into future education systems. This study used a systematic literature review of 28 scientific journals published between 2021 and 2025 that were relevant to the application of AR in science learning. The analysis was conducted thematically to identify AR's contribution to student engagement, conceptual understanding, and implementation challenges.

1. INTRODUCTION

In the era of globalization and rapid technological development, the world of education faces new challenges that demand changes in the learning process (Handayani, 2024). Therefore, the need for ICT-based learning media in the implementation of science education. This shows that the implementation of technology-based guided inquiry-based learning significantly improves prospective biology teachers' understanding of TPACK (Technological Pedagogical and Content Knowledge). This model also supports the development of skills in designing effective, contextual, and interactive technology-based learning media (Irdalisa et al., 2020). To replace conventional methods that are no longer relevant to the needs of the 21st century (Alqarni, 2021; Starks & Reich, 2023), modern approaches are replacing traditional learning media that are no longer suitable for today's needs. This is considered important so that students can adapt to current developments and be ready to face a future that is increasingly influenced by

technological advances, including technologies such as augmented reality (AR) (Majid et al., 2023).

As we know, the main problem in education is low student interest and motivation to learn. Many students lose interest in subject matter because the teaching methods used by teachers feel monotonous, boring, and irrelevant to their current needs. This demonstrates the crucial role of teachers in the learning process, not only as presenters of material but also as facilitators and innovators in creating engaging and meaningful learning experiences (Ummah, 2019).

Augmented reality is a technology that combines the real world with virtual elements such as images, sound, and video in real time. In an educational context, AR provides a rich learning experience, allowing students to view objects in three dimensions and interact with digital content directly related to the subject matter. This is particularly useful in visualizing abstract concepts that are difficult to grasp through conventional methods (Handayani, 2024).

Numerous studies have shown that AR technology in education can significantly improve student engagement, learning motivation, and learning outcomes (Majid et al., 2023). For example, the use of the AR-based Assemblr Edu application has proven effective in helping students understand descriptive topics in English and science at the elementary school level (Handayani, 2024). Students feel more engaged and engaged when interacting directly with the 3D objects presented in the application (Rosyidah et al., 2023), and this learning medium supports the transformation of learning in schools. With its interactive and immersion-based media design, this application can strengthen conceptual understanding and foster students' enthusiasm for learning (Alqarni, 2021). Therefore, it is crucial for educators to understand the potential of AR and integrate it into daily learning practices.

The application of AR technology in learning is not limited to one level of education or one field of study. AR technology has been successfully used in various disciplines such as biology, physics, history, and languages, and at various levels of education from elementary school to university. This shows the flexibility of AR as a learning medium that can be adapted to different learning contexts and needs (Majid et al., 2023).

Through the use of Assembler Edu, the learning process is expected to be more interactive, engaging, and contextual, thereby increasing student interest and motivation (Handayani, 2024). Furthermore, the implementation of Assembler Edu also serves as an effort to assist teachers in optimizing the use of digital technology in teaching and learning activities (Majid et al., 2023). By presenting visual and three-dimensional learning experiences, Assembler Edu can strengthen students' conceptual understanding, encourage active participation, and create a more enjoyable learning environment. This solution is not only oriented towards improving learning outcomes but also aims to equip students and teachers with adaptive skills to technological developments in the digital era (Ummah, 2019). Therefore, the implementation of Assembler Edu in junior and senior high schools is expected to be a strategic alternative to improve the quality of learning and meet the needs of modern education. Several learning media are now available through smartphone-based applications, such as Assembler Edu (Ulasan et al., 2020).

Specifically, this study examines the effectiveness of the Assembler Edu application, an augmented reality-based tool designed to enhance the learning experience (Handayani, 2024). In the context of teaching and learning, this digital tool has transformed the world of education by providing a more interactive, engaging, and accessible platform for students and teachers (Wanti et al., 2023). Assembler Edu, in particular, stands out due to its use of augmented reality, which provides a more immersive and hands-on learning experience, particularly in the school environment.

This study aims to provide an overview of previous studies that have utilized Augmented Reality (AR) technology in learning contexts. This review covers twenty-eight journals

published over a five-year period, from 2020 to 2025. The literature review questions are as follows:

Q1: What is Augmented Reality (AR)?

Q2: What types of Augmented Reality (AR) technology are used in learning, and how do they differ in their impact on learning?

Q3: How can the use of Augmented Reality (AR) improve the effectiveness of science learning processes?

2. METHOD

This study uses a systematic literature review method (literature study) of 28 scientific journals published between 2021 and 2025 that are relevant to the application of AR in science learning. The study explores specific themes from various reference sources, with the aim of generating recommendations. The literature study approach was conducted by searching for factual and reliable sources of information, such as scientific articles in journals and reference books. Unlike conventional research methods, literature studies do not require prior primary data collection. In this literature study, the author conducted a search and analysis of various references relevant to the discussed theme. Relevant data sources were obtained through a search on Google Scholar using the keyword "Augmented Reality".

Table 1. Data of Augmented Reality

NO	Author Name	Reference Title	Definition of AR	Types and Benefits of AR	Utilization of AR in Science Learning
1	Alzahrani, N. M.	Augmented Reality: A Systematic Review of Its Benefits and Challenges in E-learning Contexts	✓	✓	✓
2	Astuti, et al.	Effects of Task-based Language Teaching (TBLT) Approach and Language Assessment on Students' Competences in Intensive Reading Course	✓	✓	✓
3	Ebrahimi, et al.	The Impact of Writing Self-Assessment and Peer Assessment on Iranian EFL Learners' Autonomy and	X	X	✓

4	Gutiérrez-Santiuste, et al.	Metacognitive Awareness Higher Education Students' Perception of the E-Portfolio as a Tool for Improving Their Employability: Weaknesses and Strengths	X	X	✓
5	Van Gaalen, et al.	Gamification of health professions education: a systematic review	X	X	✓
6	Endah Lestari	Effectiveness of Using Assemblr Edu Learning Media	✓	✓	✓
7	Linda Imamatul Rosyidah	Learning English With Assemblr Edu-based Augmented Reality: Does The Learning Media Matter?	✓	✓	✓
8	Asma sakr	Virtual, Augmented Reality and Learning Analytics Impact on Learners, and Educators	✓	✓	✓
9.	Fauzi Erwiz	Use of Augmented Reality (AR) in Mobile Learning For Natural Science Lessons	✓	✓	✓
10.	Mohamad Fatih	Science Learning Game (SLG) Based on Augmented Reality Enchnaes Sciense Literacy and Critical Thinking Students Skills.	✓	✓	✓
11.	Allison C	“What about special ed?”: Barriers and	✓	X	X

		Enablers for Teaching with Technology in Special Education			
12.	Turki Alqarni	Comparison of Augmented Reality and Conventional Teaching on Special Needs Students' Attitudes Towards Science and Their Learning Outcomes	✓	✓	✓
13.	Irwanto Irwanto, et al.	Trends of Augmented Reality Applications in Science Education: A Systematic Review from 2007 to 2022	✓	✓	✓
14.	Sabrina Syskowski, et al.	Impact and Classification of Augmented Reality in Science Experiments in Teaching	✓	✓	✓
15.	Nurin Fitriana	Chemistry Taught With Augmented Reality And Learning Outcomes	✓	✓	✓
16.	Giorgos Peikos	What Is the Future of Augmented Reality in Science Teaching and Learning? An Exploratory Study on Primary and Pre-School Teacher Students' Views	✓	✓	✓
17.	Loukeri Paraskevi – Ioannna	Special Education Teachers' Gifted Guidance and the	✓	X	X

18.	Khilda Nistrina	role of Digital Technologies Implementing Augmented Reality in Learning Media	✓	✓	✓
19.	Hsin-Lai Wu	Current Status, Opportunities and Challenges of Augmented Reality in Education	✓	✓	X
20.	Mark Billingham	Augmented Reality and Education	✓	✓	X
21.	Mehmet Kesim	Augmented Reality in Education: Current Technologies and the Potential For Education	✓	X	X
22.	Desi Ramadhanti	Literat Literature Review: Technology Development and Utilization of Augmented Reality (AR) in Science Learning	✓	✓	✓
23.	Dini Ashari	"Using Learning Media to Increase Learning Motivation in High School"	✓	✓	✓
24.	Hermawati, R.	The Effectiveness of Augmented Reality (AR) in Science Learning	✓	✓	✓
25.	Vandan et al	A Systematic Literature Review : Pengaruh Media Pembelajaran Augmented Reality Terhadap Pemahaman Konsep dan Minat Belajar Peserta Didik	✓	✓	✓

3. RESULTS AND DISCUSSION

Various studies have shown that the use of technology-based learning media, such as Augmented Reality (AR) and other interactive media, has proven effective in improving student learning outcomes. A study by (Handayani, 2024) revealed that the use of AR media Assemblr Edu significantly increased the average grade of elementary school students from 62.6 to 88.3, with statistical test results showing a significant difference ($p < 0.05$). Similar findings were obtained by (Majid et al., 2023), who concluded that Assemblr Edu offers an engaging and modern learning approach, although its utilization is still hampered by limited devices and technological knowledge among students.

The effectiveness of interactive media is not only proven in public schools, but also in the education of children with special needs. (Wanti et al., 2023) reported that through a community service program at SLB Putra Mandiri Kawunganten, the use of interactive methods such as picture cards and the TPR (Total Physical Response) approach helped students improve their English pronunciation and vocabulary recognition skills. These activities also support the development of children's overall social and cognitive abilities. Research by (Rosyidah et al., 2023) also shows that the use of AR Assemblr Edu media can increase students' interest and enthusiasm in learning English descriptive texts. Visualizing objects in three-dimensional form helps students understand the material more realistically and enjoyably, so that the learning process becomes more active and student-centered.

The Molecule World application, designed with the Assemblr platform within the ADDIE framework, successfully created an immersive and interactive learning experience in chemistry, thereby strengthening student motivation and interest. Overall, the application of AR technology and interactive media in education significantly contributes to improving learning outcomes, motivation, and conceptual understanding. However, its success still depends on the readiness of teaching staff, adequate device support, and relevant training. Therefore, innovations in technology-based learning media need to be continuously developed and adapted to student needs to create an adaptive and inclusive learning process.

The implementation of interactive technology-based learning media has been proven to significantly improve student learning outcomes at various levels of education, including students with special needs. A study by (Handayani, 2024) showed that the use of Augmented Reality (AR) media through the Assemblr Edu platform was able to increase students' average scores from 62.608 to 88.260 in science learning. The results of the paired sample t-test showed a significance value of 0.000, indicating a significant increase in learning outcomes after using the media.

Similarly, research by Wanti and colleagues (2025) conducted at the Putra Mandiri Kawunganten Special Needs School (SLB) showed that the application of interactive media such as picture cards and the Total Physical Response (TPR) method improved the ability of children with special needs to understand and pronounce English vocabulary. Post-activity evaluations showed positive developments in the children's language and general growth.

Research conducted by (Rosyidah et al., 2023) reinforces these findings by showing that the use of the Assemblr Edu application in English learning received a positive response from students. An average score of 3.47 indicates that students found this media enjoyable, facilitated understanding of object shapes in 3D visualizations, and increased their motivation to learn. (Majid et al., 2023) also confirmed the effectiveness of the Assemblr Edu application in supporting student learning activities at school. Although not yet widely used, most respondents stated that this media was beneficial. The main challenges faced were limited supporting devices and students' lack of understanding of AR technology, which resulted in low levels of widespread application adoption.

Another finding comes from Handoyo's research, which introduced the Molecule World application in chemistry learning. Using the ADDIE instructional design approach, this AR-based media helps students understand concepts of molecules and compounds that are difficult to explain conventionally. 3D visualization through AR makes learning more engaging and easier to understand. In general, AR-based media not only strengthens students' cognitive understanding but also provides a more enjoyable learning experience and encourages their active involvement in the learning process. The interactivity and visualization offered by AR allow students to connect subject matter with the real world, thereby strengthening understanding and retention of information. However, challenges remain. Implementing AR media requires adequate technological support and teacher competence in operating digital devices and platforms. Especially for students with special needs, media adaptations must be made to suit the characteristics and individual needs of each student.

The development and utilization of AR media in education needs to be carried out sustainably, adapted to the local context and the capabilities of school infrastructure. Teachers also need to be involved in training on how to use this technology so that the learning process can run optimally and evenly across all educational units. Overall, the use of interactive media such as AR and visual cards has been proven to encourage improved student learning outcomes, both in general and special education settings. These media create a more engaging, participatory, and adaptive learning environment to meet students' needs, which is part of the challenges of education in today's digital age.

4. CONCLUSION

The application of technology in learning media, especially Augmented Reality (AR), has proven effective in improving student learning achievement at various levels of education. Research conducted by Handayani and Asih shows that the use of AR through the Assemblr Edu platform successfully raised students' average scores from 62.608 to 88.260 in science subjects at SDN 3 Sugihan. These results are in line with other studies evaluating the effectiveness of Assemblr Edu in secondary schools. Majid et al. stated that the Assemblr Edu learning application can be a more interesting and modern learning solution in schools, showing that this application is able to attract students' interest in learning and provide a more enjoyable learning experience through three-dimensional interactions. Wanti et al. reported that the use of interactive media such as flashcards in English teaching at the Putra Mandiri Kawunganten Special Needs School (SLB) helped children improve their pronunciation of simple words. They concluded that the growth and development of children with special needs improved after the community service activities were completed. Overall, the use of interactive learning media based on AR or other digital media had a positive impact on improving student motivation, understanding, and learning outcomes. The main challenges faced relate to infrastructure readiness, such as adequate hardware and teacher training to effectively utilize technology. However, as Majid et al. noted, hardware support, such as smartphones, and connection stability also influence the use of these learning applications, underscoring the importance of technical assistance in implementing technology-based learning.

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