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Education Exploring The Role of Augmented Reality in Enhancing Student Engagement and Learning Outcomes Across Education Levels

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Abstract: This study aims to explore the role of Augmented Reality (AR) in enhancing student engagement and learning outcomes across various educational levels, focusing on its effectiveness compared to traditional teaching methods. A systematic literature review (SLR) was conducted, gathering relevant articles from the Scopus database based on pre-determined eligibility criteria. The review followed the PRISMA approach to ensure transparency, rigor, and a comprehensive examination of existing research. Initially, 166 articles were identified, with 32 meeting the inclusion criteria after a thorough screening process that assessed the title, abstract, and full text. Thematic analysis was employed to synthesize the findings, which revealed that AR significantly improves student engagement and understanding of complex concepts, particularly within physics education. Experimental studies demonstrated that students utilizing AR tools consistently outperformed their peers in traditional learning environments, showcasing higher levels of motivation and improved academic performance. Furthermore, the interactive nature of AR fosters a more engaging learning experience, prompting students to participate actively in their educational journey. However, the review also identified several challenges in implementing AR in educational settings. Issues such as limited access to technology, adequate teacher training, and potential cognitive overload were noted as barriers to effective integration. Despite these challenges, the findings underscore the potential of AR as a transformative educational tool capable of enhancing traditional learning methodologies. In conclusion, integrating AR into educational practices is crucial for fostering interactive and immersive learning experiences that can improve student outcomes. Continued research and investment in AR technologies are recommended to maximize their benefits and address the challenges identified, ultimately enhancing the quality of education across various levels and subjects. This study contributes to the growing body of literature on innovative teaching methods and highlights the importance of adapting educational practices to meet the needs of modern learners.

Keywords: augmented reality in education, student engagement, learning motivation, interactive learning technologies, systematic literatrue review.

▪ INTRODUCTION

Teachers often face difficulties achieving lesson objectives due to inadequate instructional strategies or resources. This can lead to disengagement and a lack of motivation among students, making it challenging to maintain a productive learning environment (Mularsih, 2023) (Parasdya, 2020). Traditional teaching methods that do not incorporate interactive or student-centered approaches can lead to boredom. Lack of stimulation and engagement in the classroom is a significant factor in students' disinterest in reading (Aldridge & Delucia, 1989). Cultural changes have significantly affected students' reading habits. The shift to digital media and the prevalence of gadgets have diverted attention from traditional reading materials, making books less appealing to students (Adelina Br. Sembiring et al., 2023). Emotional factors, such as feeling bored

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with stiff language or not finding reading assignments interesting, also reduce reading interest (Bawawa & Naharawarin, 2019).

Traditional methods are typically teacher-centered, where the teacher is the primary source of knowledge, and students are passive recipients. This approach is structured and controlled, which some students find comforting and familiar, as it aligns with past educational experiences (Maroufi, 1989) Traditional teaching methods often involve passive learning, where students must listen and absorb information. This can lead to a lack of interest and engagement among students, as seen in a study comparing traditional and flipped classroom methods, where the latter showed increased student interest and performance (Dodiya et al., 2019). Traditional methods focus heavily on rote learning and factual knowledge, which may not adequately prepare students for real-world problem-solving and critical thinking. Modern teaching practices emphasizing reasoning and interactive learning are seen as more effective in developing these skills (Bietenbeck, 2014). Challenges educators face include the complexities associated with developing information technology-oriented instructional media, the utilization of such media, the need for more available facilities and infrastructure support, and, significantly, the innovative capabilities of the educators themselves (Winda & Dafit, 2021).

Books incorporating interactive elements, such as augmented reality, have increased student interest and engagement. This approach allows students to visualize and interact with the material, making learning more dynamic and engaging (Novita, 2023). Educational technology is essential in solving learning problems by providing innovative solutions and alternatives. It facilitates the achievement of educational goals by making learning more accessible and engaging (Natalia & Muhtarom, 2024). Information and communication technologies (ICT) have revolutionized education by increasing student motivation and enabling interactive learning methods. Technologies such as blogs, social networks, and scheduling tools are commonly used to enhance learning and engagement (Sani et al., 2024).

Technology has shifted the role of educators from mere information providers to facilitators and supporters of student learning. This shift allows educators to utilize various learning tools and resources, enriching the classroom experience and increasing the effectiveness of instruction (Mubaroq & Ilham, 2023). One of the technologies present in the 21st century is Augmented Reality (AR). AR transforms the learning environment by providing interactive simulations and immersive experiences that increase student engagement and understanding of complex concepts. It revolutionizes traditional teaching methodologies, making learning more interactive and practical (Shonima & Sowmya, 2024). AR technology creates an immersive learning environment that captures students' attention and increases their learning motivation. This technology allows students to interact with learning materials more engagingly, which can lead to better learning outcomes (Gaikwad & Mulay, 2024).

AR facilitates better information retention by allowing students to visualize and interact with complex concepts. This hands-on approach helps students understand and remember the material more effectively (Meriyati et al., 2024). AR can overlay digital information onto the real world, allowing students to interact with virtual objects in a real-world context. This can enhance learning in chemistry, where students can visualize molecular structures in 3D (Dhaas, 2024). Integrating AR into education can help develop new competencies in students, such as creativity, teamwork, and problem-solving skills.

The technology encourages students to engage in independent educational activities and fosters personal and professional growth (Zheleva et al., 2021). While AR offers significant benefits in educational settings, it is important to consider potential challenges and limitations. Critics of AR in education point to issues such as cognitive overload, the high cost of the technology, and the need for teacher training and buy-in (Larson & Chambers, 2020).

Additionally, there are concerns about data privacy and security and a digital divide that may limit access to AR technology for some students (Panda & Kaur, 2023). Despite these challenges, the potential for AR to transform education and enhance the learning experience is enormous, and continued research and development is essential to address these issues and maximize the benefits of AR in education. This systematic review is intended to find the possibilities and capabilities of AR as a learning tool for students. We have designed the following research questions:

1. RQ1 In which subjects and classes are Augmented Reality suitable as a learning tool?
2. RQ2 Is using Augmented Reality by students proven to be more effective than traditional learning?
3. RQ3 Can Augmented Reality improve students' learning performance compared to traditional teaching materials?

▪ METHOD

Research Design

A systematic literature review (SLR) collects all relevant and evidence-based data based on pre-determined eligibility criteria to answer a specific research question. This method examines qualitative research findings to minimize bias in identifying, selecting, and summarizing studies. SLR is appropriate for this study because it helps identify articles that find aspects of learning that promote Augmented Reality. This review follows the PRISMA approach to increase transparency and accuracy, emphasizing the importance of basing systematic reviews on structured protocols. The SLR method was chosen for this study to ensure a rigorous and comprehensive examination of the use of Augmented Reality with traditional school students' learning. This method systematically synthesizes information and concludes using thematic coding. Thematic analysis helps identify key patterns and themes in the data that influence Augmented Reality, allowing researchers to draw more in-depth and structured conclusions.

Search Startegy

The search process is carried out using the Scopus database. The keywords must be in the article to determine the search. In addition, the keywords of Augmented Reality patterns. To anticipate synonyms that are not found, the Boolean operator is used, namely: "Augmented Reality" OR "AR" AND "Physics, Chemistry, Biology" OR "Science Education".

A total of 166 articles were identified through the Scopus search, of which 78 were not included in the articles to be automatically screened through the Scopus filter. After title screening, 70 articles had their abstracts read, from which 43 articles met all ten inclusion criteria. The flowchart for the selection process is shown in Figure 1.

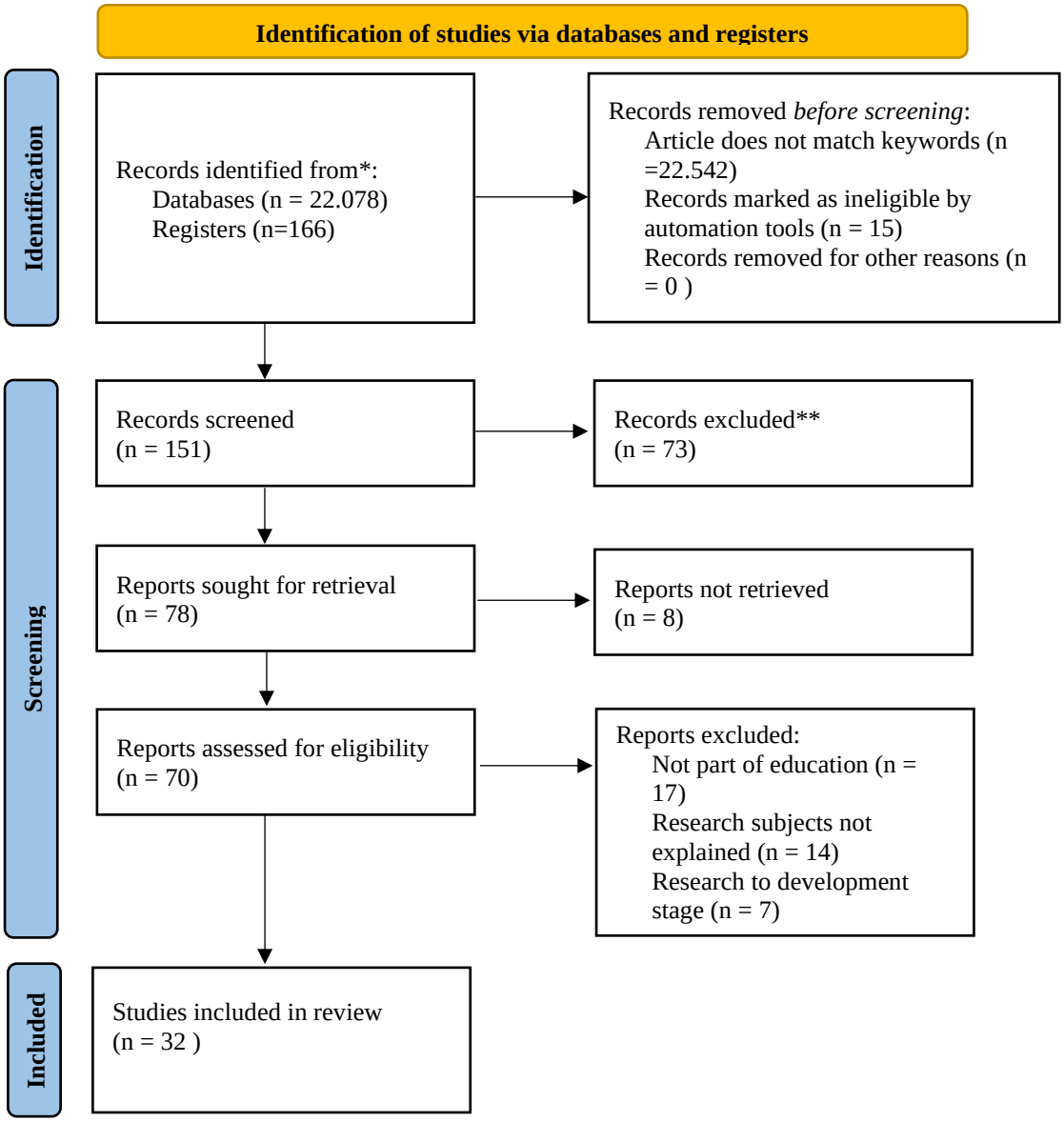

Figure 1. PRISMA flowchart

Inclusion and Exclusion Criteria

The following are the inclusion criteria accepted for selection for the qualitative systematic literature review on learning patterns supporting Augmented Reality in schools:

Table 1. Inclusion criteria

Inclusion Criteria	Description
a. Relevant Topics	Focus on learning that supports using Augmented Reality for students in schools
b. Jenis Penelitian	The research articles are qualitative studies, quantitative studies, and mixed studies.
c. Participants	Students, teachers, or principals

d. Variables	Augmented Reality or its components.
e. Publication Criteria	Articles in Scopus search journals.
f. Language	Articles in accessible English.
g. Publication Date	Published in the last 10 years, namely from 2014 - 2024.
h. Context	Studies from various relevant geographical and cultural contexts.
i. Methodology	Clear methodology and transparent reporting.
j. Implications	Implications Practical implications for education policy and learning practices in schools.

Articles based on the results of the title, abstract, and results review that do not meet the inclusion criteria above are included in the exclusion criteria for articles removed from this literature review.

Data Analysis

Data analysis began with the familiarization phase, where relevant literature on Augmented Reality (AR) in education was thoroughly reviewed. This included reading and re-reading the identified articles to understand the content and context. Following this, the initial coding phase was conducted, where significant features of the data were systematically noted. This involved identifying key themes related to the effectiveness of AR in enhancing student engagement and learning outcomes across various educational levels.

In the subsequent phase of generating themes, the codes were grouped into broader themes, focusing on aspects such as the impact of AR on student motivation and the challenges of implementation. The reviewing phase involved assessing these themes about the dataset to ensure they accurately represented the findings. Finally, defining and naming themes culminated in selecting 32 articles that met the inclusion criteria, providing a comprehensive overview of the current research landscape on AR in education. This thematic analysis thus allowed for a straightforward synthesis of the literature, highlighting both the potential benefits and challenges associated with integrating AR into educational practices.

▪ RESULT AND DISSCUSSION

The researchers have been involved in an exploratory study and will conduct a data extraction process to address the previously articulated research questions. Data extraction aims to obtain findings from a systematic literature review that aligns with the proposed research questions.

RQ1 In which subjects and grades are Augmented Reality appropriate as a learning tool?.

Based on our research findings, no distinct or specific student subject or course is explicitly designed to incorporate Augmented Reality (AR) as a pedagogical tool to enhance learning. Several experimental studies have been conducted by various researchers involving diverse groups of students across different age groups. For clarity, we present a tabular analysis detailing the ages of students who have engaged with AR in their educational activities, as referenced in the literature used for our investigation:

Table 2. School level targets

Group	Subjeck	Article Identification	Total
SD (6-12 years)	Physics	P10	1
	Chemistry		0
	Biology	B4.B5	2
SMP (13-15 years)	Physics	P5	1
	Chemistry	C6	1
	Biology	B2	1
SMA (16-18 years)	Physics	P1.P3.P4. .P6.P7.P8. .P11	7
	Chemistry	C1.C2.C4.C5.C7	5
	Biology	B1.B3.B6.B7	4

Most of the articles related to AR were found at the high school level, with 16 articles indicating that AR implementation is more frequently used or explored in this age group, especially in the Physics subject. Studies have validated the feasibility of AR as a learning medium in the high school environment. In physics education, AR has been very effective in helping students understand abstract concepts. By visualizing these concepts through AR, students can better understand and retain complex information (Fadhiel & Mufit, 2024) (Arymbekov, 2023). The interactive and engaging nature of AR makes learning more enjoyable, which can lead to higher levels of student participation and interest in the subject matter (Swargiary & Roy, 2023). Students also responded positively to AR applications, with the majority considering it an effective and enjoyable learning tool (Elfisa et al., 2023).

Physics subjects received the most excellent attention at all levels, while Biology was less explored at the elementary school level. The articles were relatively small and more evenly distributed among the existing subjects for elementary and junior high school levels. AR applications in chemistry education have also been shown to be beneficial. Students who used an AR system to learn chemical structures and reactions showed better understanding, especially among low-achieving students (Tarng et al., 2022). AR in biology education has been associated with increased learning motivation and improved learning outcomes. Students who used AR applications scored higher in motivation and academic performance (Rini et al., 2024).

RQ2 Is using Augmented Reality by students proven to be more effective than traditional learning?

Table 3. Comparison of experimental group and control group

Tittle	Grade	Experimental Group and Control Group
The Effectiveness Of Problem-Based Learning Physics Pocketbook Integrating Augmented Reality With The Local Wisdom Of Catapults In Improving Mathematical And Graphical Representation Abilities	SMA(P)	This study found that the physics pocket book Problem Based Learning (PBL), which integrates augmented reality with local wisdom, the experimental class catapult is better than the control class.

Integrating Mobile Augmented Reality Applications Through Inquiry Learning To Improve Students' Science Process Skills And Concept Mastery	SMA(C)	The experimental class, which used integrated inquiry-based augmented reality (AR), showed a higher average N-Gain score of 0.57% compared to 0.40% of the control class.
The Application of Mobile Augmented Reality to Improve Learning Outcomes in Senior High Schools	SMA(B)	The experimental class' significant improvement in learning outcomes, indicating the positive impact of AR on student engagement and understanding of abstract concepts.
Development of E-Book Integrated Augmented Reality Based on STEM Approaches to Improve Critical Thinking and Multiple Representation Skills in Learning Physics	SMP(P)	This class uses E-books integrated with Augmented Reality (AR) based on the STEM approach. The results showed that Class X had significant improvements in both critical thinking and multi-representation skills.
Investigating the Role of Augmented Reality in Supporting Collaborative Learning in Science Education: A Case Study	SMP(C)	The experimental group using AR showed significant improvements in science test scores, engagement, and collaboration skills compared to the control group.
An Investigation into whether Applying Augmented Reality (AR) in Teaching Chemistry Enhances Chemical Cognitive Ability	SD(C)	The assessment results showed a significant increase in students' scores after using AR, confirming its effectiveness compared to traditional teaching methods.
Enhancing Education on Aurora Astronomy and Climate Science Awareness through Augmented Reality Technology and Mobile Learning	SD(P)	This study shows that using the Aurora AR System significantly improves student learning outcomes and motivation compared to traditional teaching methods.
Determining the Effect of Science Teaching Using Mobile Augmented Reality Application on the Secondary School Students' Attitudes of toward Science and Technology and Academic Achievement	SD(B)	The experimental group used the Anatomy 4D mobile augmented reality application, while the control group followed the traditional textbook method.

Research shows that students who use AR technology achieve better academic outcomes. In a study comparing traditional and AR-based learning methods, students in the AR group performed better academically, highlighting AR's potential to improve educational outcomes (Amores-Valencia et al., 2023). Science education found that students who used AR showed statistically significant improvements in test scores compared to those taught with traditional methods (Kuanbayeva et al., 2024). The impact of AR on motivation was significant in a study involving students with learning disabilities, where the experimental group using AR technology showed increased levels of motivation compared to the control group (Jdaitawi et al., 2023).

AR fosters collaboration among students and between students and teachers. In the context of mathematics education, AR games encourage students to communicate and work together, improving their collaborative skills and understanding of the subject matter (Stappen et al., 2019). AR provides dynamic, interactive instruction that enhances their understanding of complex engineering concepts and problem-solving skills (Yousif & Noman, 2023). While the evidence strongly supports the effectiveness of AR in experimental classrooms, it is important to consider the context and implementation of AR technology. The success of AR depends on factors such as the subject matter, the design of the AR application, and the readiness of educators to integrate this technology into their teaching practices.

RQ3 Can Augmented Reality improve students' learning performance compared to traditional teaching materials?

Augmented Reality (AR) and Experiential Learning Theory are closely related; AR technology creates an immersive learning environment that engages students by integrating real-world and virtual elements (Meriyati et al., 2024; Rajath et al., 2023). It enhances the learning process by making it more interactive and enjoyable, which are core principles of experiential learning. While AR significantly enhances experiential learning, it is important to consider potential challenges, such as technostress, impacting the learning experience. Technostress can moderate the relationship between AR applications and learning outcomes, indicating the need for careful implementation and support to maximize the benefits of AR in an experiential learning context (Baabdullah, 2022).

AR facilitates a deeper understanding of complex scientific concepts by providing an interactive and immersive experience. For example, students exposed to AR showed improved academic performance and motivation compared to those taught through traditional methods (Muñoz et al., 2024). AR in science education has been linked to developing critical skills such as problem-solving, collaboration, and communication. This is especially beneficial where such skills are essential (Ridzuan et al., 2022) (Kularbphettong et al., 2019). AR has been shown to increase students' interest in science subjects by making learning more fun and engaging. This is especially important in addressing students' declining interest in STEM fields (Abdullah et al., 2022). AR provides conceptual and practical experiences, allowing students to visualize and interact with scientific phenomena that are otherwise difficult to observe directly (Sani et al., 2024).

While AR has been particularly effective for physics, it is important to consider its potential applications in biology and chemistry. AR can visualize complex biological processes and structures in biology (Agrawal, 2022). While in chemistry, AR can help students understand molecular interactions and chemical reactions (Ulrich et al., 2021). However, these subjects often rely more on memorization and less on the abstract visualization that AR excels at providing. Therefore, while AR can enhance learning across all science subjects, its impact is most pronounced in physics due to the nature of the content and the learning challenges it presents (Yoon et al., 2017).

Elementary school students showed high levels of engagement and improved learning outcomes when AR was integrated into their curriculum, especially in subjects such as science (Lastari et al., 2023). The cognitive and affective impacts of AR were

significant, with students benefiting from interactive and engaging learning experiences that enhanced their understanding of complex concepts (Runisah et al., 2022). The cognitive load experienced by secondary school students was low, indicating that they can effectively manage and benefit from AR-enhanced learning environments (Bullock, et al., 2024).

Despite its benefits, AR technology faces challenges related to its integration into existing curricula. The need for improved software interfaces and teachers' need to be adequately trained in using AR tools are significant barriers (Yilmaz, 2021). The implementation of AR in the classroom can be hampered by limited resources, such as the availability of AR-compatible devices and the need for technical support (Kularbphettong et al., 2019). Teachers play a critical role in the success of AR implementation. There is a need for professional development programs to equip teachers with the skills necessary to use AR effectively in their teaching practice (Darusman et al., 2024) (Khawaji, 2024). While AR offers many educational benefits, it is important to consider the broader educational context. Successful AR integration requires a supportive infrastructure, including access to technology and training for educators.

Cultural dimensions play an important role in technology adoption. For example, cultures with high uncertainty avoidance may be less open to adopting new technologies such as AR due to perceived risks and uncertainties (Jorgji et al., 2024). Educational technology adoption is often tailored to fit cultural norms and values. These cultural specificities can influence how AR is perceived and used in different educational contexts (Jung & Lee, 2020). Geographic location often determines the availability of the technological infrastructure necessary for AR adoption. Schools in urban areas with better access to high-speed internet and advanced technological resources are likelier to adopt AR than schools in rural or underdeveloped areas where such infrastructure is lacking (Wong et al., 2021).

Integrating Augmented Reality (AR) into classroom settings can significantly enhance collaborative learning by providing interactive and engaging educational experiences. The design process should include content development, AR technology selection, and prototype development, ensuring that the AR experience aligns with curriculum standards and educational objectives (Panwar et al., 2024). Teachers can incorporate AR into science lessons to create interactive simulations and experiments requiring students to work together, enhancing their collaborative learning experiences (Kuanbayeva et al., 2024). Providing teacher training and developing a comprehensive implementation plan is important to ensure AR technology is effectively integrated into the curriculum (Panwar et al., 2024). Further research and development is needed to explore the long-term effects of AR on learning outcomes and to refine methods for its integration into diverse educational contexts (Valluru et al., 2023)

▪ CONCLUSION

This study shows that Augmented Reality (AR) has significant potential in enhancing students' learning experience at various levels of education. A systematic literature review found that AR can improve the understanding of complex concepts and increase student motivation, especially in physics subjects. AR is more effective than traditional teaching methods, positively impacting student engagement and learning outcomes. Although there are challenges in implementing AR, such as cost, training

requirements for teachers, and technology accessibility, its benefits in creating an interactive and immersive learning environment cannot be ignored. Therefore, the development and integration of AR in the educational curriculum needs to be supported by adequate infrastructure and training programs for educators so that the full potential of AR can be utilized to improve the quality of education.

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