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Analysis of Augmented Reality Technology Trends in the World of Education

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Abstract: The development of information and communication technology has driven a major transformation in the world of education, one of which is through the use of Augmented Reality (AR) technology. This technology combines virtual objects into the real world in real-time and enables an immersive, contextual, and enjoyable learning experience. This study aims to analyze the trend of AR utilization in Indonesian education over the past five years, and explore its relationship with the potential for utilizing digital technology to support the development of sustainable shopping tourism. This study uses a qualitative approach with a systematic literature study method on 10 relevant national and international scientific articles, published between 2019–2025. Data analysis was carried out using thematic analysis techniques to identify patterns of AR use, media development approaches, and their impact on learning outcomes. The results of the study show that AR has a significant positive impact on increasing learning motivation, understanding of complex concepts, and students' critical thinking skills. In addition, the trend of AR implementation also reflects cross-disciplinary integration, ranging from science education, engineering, health, to environmental literacy. When the reflection of the results of this study is drawn to the context of shopping tourism, it was found that the AR-based approach in education has great potential to be applied in supporting operational efficiency, enriching tourist experiences, and preserving local cultural values. This study suggests the integration of digital technology policies in education and tourism to promote sustainable development.

INTRODUCTION

The development of information and communication technology has driven a major transformation in the world of education, one of which is through the use of Augmented Reality (AR) technology. AR is a technology that combines virtual objects into a real environment in real-time, enabling two-way interaction between users and systems (Agustin et al., 2025). In the context of learning, AR is able to create immersive, contextual, and enjoyable learning

experiences, thereby increasing student participation and retention (Sucitra & Latif, 2025; Zein et al., 2025). This technology is becoming increasingly relevant in supporting 21st-century learning approaches that demand creativity, problem solving, and digital literacy (Wardani et al., 2025).

Augmented Reality (AR) is a technology that combines virtual elements into the real world in real-time, creating an immersive interactive experience. In the context of education and marketing, AR provides tremendous opportunities to improve conceptual understanding and user engagement. For example, the use of AR in science and mathematics learning media has been proven to improve digital literacy and students' critical thinking skills, as shown in various recent studies (Aini & Indrawati, 2024; Sholikhah & Pratiwi, 2025). In addition, AR has been used in product promotion media through interactive packaging, which enriches the consumer experience and strengthens the appeal of digital marketing (Sariyono & Nerisafitra, 2024).

Not only in the world of education and business, AR is also used to preserve culture and history. (Gustiansyah & Fahmi, 2024) developed an AR application for local history learning based on Android, providing a contextual and interesting learning experience for students. The use of AR based on marker-based tracking and the Multimedia Development Life Cycle (MDLC) approach is widely chosen because of its flexibility and ease of implementation. (Susilowati & Mahdiannur, 2024) also stated that the integration of AR with a cooperative learning model can increase student participation and understanding. With innovation that continues to develop, AR is an effective and adaptive solution in various fields, especially in creating active learning and information-rich user experiences.

AR integration in education has been widely applied, especially in science, mathematics, and geography lessons. For example, AR learning media has been used to explain the concept of the solar system, spatial structures, and ecosystems, which have been empirically proven to improve students' conceptual understanding (Putra & Putra, 2025; Sartika et al., 2025). In geometry learning, AR helps visualize 3D objects that are difficult to imagine in the form of static images (Sari et al., 2025). Other studies also show that the use of AR improves students' learning independence and critical thinking (Rini et al., 2025).

On the other hand, the implementation of AR in education also presents challenges, such as the need for compatible devices, technical skills of teachers, and readiness of school infrastructure (Trisnawati, 2025). However, with the right approach, these obstacles can be overcome and the potential of AR can be optimized to support the quality of learning (Febrianto & Widodo, 2025). Therefore, it is important to analyze how the trend of utilizing AR technology has developed in the Indonesian educational environment in recent years, both in terms of pedagogical approaches, content, and its impact on student learning outcomes (Nurfadillah & Da, 2024).

The trend of AR in education is not only seen from the technical aspects of its use, but also from how much this technology is accepted and utilized at various levels of education. Research on the readiness of higher education institutions in integrating AR, for example, shows the need for policy support and training for educators (Ain & Sya, 2025). In the context of inclusive learning, AR is even used to help students with special needs, such as reading difficulties.

The urgency of this research lies in the need to map trends and potential of AR technology in education to support sustainable learning innovation policies. With the increasing

dependence on digital technology post-pandemic, understanding the effective and efficient application of AR is crucial in designing adaptive and transformative education strategies.

Previous studies have revealed various benefits of AR, such as increasing student learning motivation and learning outcomes, but most of them are still case studies and have not presented a comprehensive trend analysis (Bata, 2025; Rini et al., 2025). In addition, there has not been much research linking the dynamics of AR development in education with the needs of national policies and curricula that support systemic technology integration.

The purpose of this study is to analyze the development trends of Augmented Reality technology in the world of Indonesian education over the past five years. This study aims to identify patterns of AR use in various levels of education, its development approaches, and its impact on the learning process and outcomes of students. The findings of this study are expected to be a reference for policy makers and education practitioners in designing innovative and sustainable technology-based teaching programs.

METHOD

This study uses a qualitative approach with a literature review type that aims to examine and analyze the development trends of Augmented Reality (AR) technology in the world of education. This approach was chosen because it is in accordance with the objectives of the study which focus on in-depth exploration of previous scientific works, as well as a systematic review of the development of AR utilization in various levels and contexts of education (Creswell & Poth, 2016; Zed, 2018).

The literature study provides a strong conceptual basis for understanding the phenomena studied, including mapping themes, patterns, and shifts in research focus related to AR in education over the past five years. The data sources in this study come from national and international scientific journal articles published in the period 2019 to 2024. The articles used were obtained from various reputable databases, such as Google Scholar, DOAJ, and national journals accredited by SINTA (Science and Technology Index), including journals from universities such as Surabaya State University (UNESA), Muhammadiyah University of Mataram (UMMAT), and Pasundan University (UNPAS).

The inclusion criteria in selecting articles included: (1) main topics related to the application of AR in education, (2) articles in Indonesian or English, and (3) have gone through a peer review process. Meanwhile, articles that were opinion-based, did not have a clear methodological structure, or were not directly relevant to education were excluded from the analysis.

The data collection technique was carried out through a systematic literature search process using keywords such as "Augmented Reality in education," "AR-based learning," and "innovative learning media assisted by AR technology." This process was carried out by filtering and reading articles carefully, then recording important relevant information such as research methodology, findings, and contributions to educational practice. To ensure data validity, source triangulation and inter-researcher verification were carried out on the selected articles (Moleong, 2022).

The data analysis method in this study used a thematic analysis approach. The analysis

was carried out through the stages of data coding, identifying main themes, and drawing conclusions based on patterns found in the analyzed literature (Braun & Clarke, 2019). Each article is classified based on the year of publication, level of education, learning approach, and the impact of AR implementation on student learning outcomes. Furthermore, trends in AR use in education are analyzed to see the tendency of topics, media development methods, and their integration into the learning curriculum.

RESULT AND DISCUSSION

The following is a table of bibliographic data which is the result of a selection process of 10 current and internationally reputable scientific articles that discuss the trend of using Augmented Reality (AR) in education. These articles were selected from trusted databases such as Elsevier, IEEE, Springer, Wiley, and Taylor & Francis, with a focus on research published between 2019 and 2025. Each article was analyzed based on the research objectives, method approaches, and main results in the context of the world of education.

Table 1. OEE After Experiment (After Implementation of Independent Variables)

No	Author	Title	Findings
1	Soto-Ruiz & Escalada-Hernández (2025)	Augmented reality for intramuscular injection training	AR is effective in improving the accuracy of injection procedures and practical skills.
2	Zhang et al. (2025)	AR Animations for Science Popularization	Perception of ease and enjoyment increases usage intention
3	Yuan et al. (2025)	AR in Higher Engineering Education	AR facilitates understanding of complex concepts and virtual practicals
4	Guo, Ren & Qi (2025)	Sustainable learning intention with AR	AR fosters interest and motivation to learn in creative media
5	Leitão et al. (2025)	AR Game for Ocean Literacy	The use of AR encourages interactive learning and environmental awareness
6	Li et al. (2025)	QoE-Aware Latency Optimization in AR Education	Edge computing technology accelerates data processing for AR learning
7	Hu, Li & Gao (2025)	Coding in Early STEM with AR & VR	Improve children's understanding of logic and teamwork
8	Chandanani, Laidlaw & Brown (2025)	Extended Reality in Health Professions Education	AR supports situational simulation & clinical decision making
9	Morgado & Imperioso (2025)	Gamify the City: XR and the Metaverse in Education	AR helps spatial learning and social engagement
10	Nguyen et al. (2025)	Augmented Education in the Global Age	AR will play a strategic role in AI-based learning space design

From the results of the literature study that was successfully selected and analyzed, it is clear that the trend of implementing Augmented Reality (AR) technology in the world of education has experienced very significant and multi-dimensional developments in the last five years. The ten scientific articles reviewed reflect various perspectives, methodological approaches, and fields of study that show the potential of AR as a disruptive technology in the modern learning process. Each study highlights a different application context but has a strong common thread, namely how AR can enrich the learning experience, increase motivation, and improve the learning outcomes of students and students at various levels of education and scientific fields.

One study by (Soto-Ruiz et al., 2025) proved that the use of AR in nursing training, especially in intramuscular injection procedures, can improve the accuracy and efficiency of nursing student practice. This study is part of an experimental approach with a cluster randomized controlled trial design and concludes that the use of AR in practical training is able to simulate real conditions without direct clinical risk. With realistic and interactive visualizations, students are able to understand medical procedures in depth and measurably. This approach shows that AR is not only effective in delivering theory, but also in mastering high-precision practical skills.

In the study of (Zhang et al., 2025) published by IEEE, the main focus was directed at psychological factors and user behavior in using AR animation for popular science education. The results of the study showed that perceived ease of use and perceived enjoyment were the main determinants of user intention to adopt AR in the learning process. The implications of this study show that AR adoption does not only depend on the sophistication of the technology itself, but also on how comfortable and motivated users feel when interacting with it.

(Yuan et al., 2025) in a systematic review published in Wiley conducted a mapping of AR integration in higher engineering education. In this context, AR functions as a bridge between theory and practice, especially in complex materials such as machines and electronics. They concluded that the use of AR can accelerate the understanding of abstract concepts and enable experimental simulations without the need for a physical laboratory. This is very relevant especially in engineering education in developing countries which are often constrained by infrastructure facilities.

(Guo et al., 2025) explored the factors that influence sustainable learning intention in the context of learning with AR. This study was conducted in the field of media education, specifically in scriptwriting for radio and television broadcasts. The results show that the use of AR can increase student motivation, strengthen the perception of the meaningfulness of the material, and create long-term learning engagement. This study opens up a new discourse on how AR is not only technical-instrumental, but can also shape sustainable learning attitudes and orientations.

(Leitão et al., 2025) took a different approach by developing an augmented board game to improve marine literacy in elementary and middle school students. AR was used as a medium to introduce the concept of marine ecosystems, pollution threats, and the importance of conservation. By inserting gamification elements, learning became more contextual and encouraged students to think critically about global issues. This study shows the effectiveness of

AR in conveying social and environmental values through a fun approach.

Meanwhile, a study conducted by (Li et al., 2025) highlighted the technical aspects of implementing AR in education, especially in terms of latency optimization. They proposed a system that utilizes edge computing technology to reduce latency in data transmission when AR is used in real-time learning. This study shows the importance of technological infrastructure in ensuring the smoothness and comfort of using AR in digital classrooms.

(Hu et al., 2025) studied the integration of coding education in early childhood STEM programs by utilizing AR, VR, and 3D printing technology. In this program, children are invited to build computational logic intuitively through creative activities in a technology laboratory. The results show that the child's role in the learning process changes from being a recipient to a creator, reinforcing the principles of active and constructivist learning.

(Chandanani et al., 2025) examined the use of extended reality, including AR, in situational skills training for medical students. This study demonstrated that AR helps students understand complex clinical contexts, develop situational awareness, and hone decision-making under pressure. These findings strengthen the argument that AR is not just a visual aid, but a cognitive training medium in professional education.

In the article by (Imperioso & Morgado, 2025), the topic of AR is associated with the development of the metaverse and the transformation of urban space as an educational medium. This study highlights how AR can form new learning spaces that are not limited to school buildings, but can be realized in city parks, virtual museums, and location-based community interactions. They call it "digital space pedagogy", a transdisciplinary approach that expands the meaning of space and time in learning.

(Nguyen et al., 2025) in a critical review of the book Augmented Education in the Global Age, discusses how the integration of AR, AI, and data-driven learning will shape the future of the classroom. They highlight the ethical and policy challenges in adopting this technology on a large scale, but also emphasize that AR will be a strategic component in designing adaptive education systems based on personalization.

Overall, the 10 articles analyzed in this literature study illustrate that Augmented Reality has a wide and cross-disciplinary scope of use, ranging from nursing, engineering, environmental education, to early childhood learning. The implementation of AR has been proven to improve the process, effectiveness, and learning outcomes, while also presenting new challenges in terms of technology, policy, and user readiness. These findings reinforce the importance of developing technology-based education policies and teacher training to be able to adapt to the increasingly rapid changes in the digital education landscape.

Discussion

In the era of digital transformation, augmented reality (AR) technology has experienced rapid development, especially in the world of education. However, the basic principles underlying the use of this technology in the realm of education are now starting to spread to other sectors, including tourism. One sector that shows great potential for digital technology integration is shopping tourism, especially in supporting sustainable tourism development. With an adaptive approach, studies on AR technology trends in education can be reflected in the context of how digital technology plays an important role in improving operational efficiency,

enriching tourist experiences, and preserving local culture in shopping tourism activities.

Digital technology has paved the way for operational optimization in shopping tourism destinations. In various countries, digital-based inventory management systems, the use of analytics from consumer behavior data, and AR-based interactive maps have helped MSMEs and shopping centers manage the flow of visits, product stock, and information conveyed to tourists. Tourists no longer rely solely on physical directions, but can use applications that direct them to strategic locations while providing information about the origin and value of the products they encounter.

More than just efficiency, digital technology also plays a big role in creating a more immersive and memorable experience for tourists. In this context, augmented reality is used to create a narrative layer on top of physical reality, allowing tourists to witness a simulation of batik making, virtually try on traditional clothing, or participate in interactive location-based games that increase their engagement while in a shopping area. The shopping experience is no longer passive, but rather becomes an explorative experience that involves educational and entertainment aspects simultaneously.

Equally important, digital technology also supports the preservation of local culture which is the main identity in the sustainable tourism sector. This is where technologies such as AR and VR play a role as a link between the past and the present. By presenting the stories behind the products, the rituals of making, and the symbolic meaning of local cultural elements, tourists not only buy goods, but also take home an understanding and appreciation of the culture they encounter. In several studies, the use of AR has proven effective in reviving historical narratives and cultural values that were previously difficult for tourists to access directly.

From a sustainable development perspective, the integration of digital technology in shopping tourism offers a comprehensive solution: accelerating digital adaptation for local industry players, enriching the visitor experience without adding physical burden to the destination, and strengthening the preservation of cultural values amidst the flow of modernization. What started as a technology trend in education is now showing strong relevance in a broader context, including the dynamic tourism sector that is heavily influenced by global travelers' expectations for authentic yet innovative experiences.

Thus, it can be concluded that digital technologies—rooted in their application in the education sector such as AR—have shown great potential in driving efficiency, interactive experiences, and cultural preservation in shopping tourism. This approach not only enhances the attractiveness of a destination, but also strengthens the foundation for inclusive, adaptive, and sustainable tourism development.

CONCLUSION

This study concludes that the use of Augmented Reality technology in education has experienced significant development in the last five years and has proven to be able to improve the quality of learning comprehensively. Its application not only improves students' understanding of concepts and practical skills, but also creates a more interactive and contextual learning space. Important findings from this study indicate that the patterns and approaches used in implementing AR in education are also very relevant to be applied in the context of

shopping tourism. This technology can improve the operational efficiency of business actors, enrich the experience of tourists through digital interaction, and become an effective medium for preserving local culture.

Practically, the results of this study suggest that educational institutions, governments, and tourism industry players develop strategic collaborations to utilize digital technology sustainably. The development of AR-based interactive media can be applied not only in classrooms, but also in shopping tourism destinations as a means of education and cultural promotion. It is also important to equip educators and MSMEs with digital literacy and technical skills in managing AR-based applications.

For further research, it is recommended to conduct empirical studies with a quantitative or mixed-method approach to directly measure the impact of AR use in the tourism sector, especially on shopping behavior, visit duration, and tourist satisfaction. In addition, further exploration of the integration of AR with artificial intelligence (AI) and big data also needs to be developed to create adaptive personalized experiences in the future.

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