Exploring the Implementation of Augmented Reality in Indonesia Elementary Schools: A Systematic Literature Review

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Abstract: The swift advancement of technology has not only become an integral part of the reality of the 21st century but has also emerged as the primary catalyst for substantial transformations and disruptions across diverse facets of society, notably within the realm of education. Previous studies indicate that augmented reality, as a result of technological advancements, holds the potential to enhance the quality of the education system by fostering interactive learning. Nevertheless, there is a lack of in-depth and comprehensive research on the application of augmented reality in elementary schools. Hence, this study aims to analyze existing research about integrating augmented reality in elementary school education, assess its impact on learning outcomes, and identify potential implementation challenges. This research followed the PRISMA 2020 guidelines and used Scopus and ERIC as the primary databases for collecting data. Of the 637 data relevant to the search query, only 35 articles fulfilled the inclusion criteria. These articles were further analyzed through meta-synthesis techniques. Based on a systematic literature review conducted on the use of augmented reality technology in Indonesian elementary schools, the study revealed the following key findings: Firstly, the development of augmented reality technology exhibits fluctuations. Secondly, the application of augmented reality utilizes existing media and creates new media. Thirdly, its implementation in the educational context yields various positive learning outcomes. Fourthly, challenges arise in terms of the underdeveloped augmented reality media and limited application in one subject area. as well as the preparedness of teachers and students to adopt augmented reality technology. These findings emphasize the critical considerations for future research endeavours in this issue. Despite the potential benefits, further research is needed to implement augmented reality, specifically cultivating 21st-century skills and addressing identified challenges within Indonesian elementary schools.

Keywords: Augmented reality, Education technology, Elementary school

Introduction

Proficiency in technology has become a crucial element in addressing the complexity of educational challenges in the 21st century. Amidst the rapid development of digital technology, technological advancements continue to expand the scope of learning in school environments. As highlighted by Blackwell et al. (2014), the rapid advancements in information and communication technology have resulted in substantial improvements, in line with the accelerated evolution of the education system. To facilitate students' understanding, various teaching strategies have been implemented with ongoing efforts to improve the quality of education through innovation, including the use of information technology and telecommunications. (Chauhan, 2017; Domingo & Garganté,

2016). In response to these developments, it is important to develop effective learning media to achieve educational goals.

Learning media continues to adapt to technological advancements, ranging from print technology, audiovisual aids, and computers to a combination of print and computer technology (Martin et al., 2011). Research conducted by Martín-Gutiérrez et al. (2015) revealed that Augmented Reality (AR) is the latest breakthrough in learning media. AR is a technology that combines digital elements with the real world, following the existing environmental conditions and accessible through mobile devices (Nincarean et al., 2013). The use of AR has penetrated various aspects of life and is anticipated to continue growing in the future. Augmented Reality (AR) technology has now become commonplace. It has been widely applied in various fields such as entertainment, advertising, healthcare, military, and especially in learning and education (Saidin et al., 2015).

In the context of learning and education, the use of Augmented Reality (AR) has experienced significant growth as it is often chosen as an interactive technology (Nurbekova & Baigusheva, 2020). For example, research by Hamzah et al. (2021) demonstrates that using AR in elementary school mathematics learning can increase student engagement and facilitate understanding of abstract concepts. This aligns with research conducted by Liono et al. (2021), indicating that the use of Augmented Reality as a tool in learning is an effective strategy. The implementation of this technology has been proven to enhance learning motivation and outcomes, expand knowledge (Park & Stangl, 2020), improve analytical skills, and deepen understanding of basic concepts ((Bower et al., 2014; Sural, 2018). Therefore, the use of AR has the potential to enhance the quality of learning in addressing educational challenges in the 21st century.

Although there have been many studies on the application of Augmented Reality in elementary schools, there has not yet been specific research focusing on a comprehensive review of findings from previous studies. However, such research is highly significant as it can provide in-depth insights into existing findings, forming a comprehensive understanding of various previous studies exploring the benefits and challenges of adopting Augmented Reality in the primary education environment. This understanding is essential as a guide for academics and practitioners in determining new concepts, providing a basis for further research development and filling the knowledge gaps from previous studies. Therefore, this research aims to provide a more comprehensive understanding of the implementation of Augmented Reality in elementary schools and is directed to answer four main research questions: (1) What is the current status of Augmented Reality development at the elementary school level? (2) How is AR utilized in learning? (3) What are the benefits of implementing AR in elementary school? (4) What are the challenges encountered in implementing Augmented Reality?

Method

This research applies the Systematic Literature Review (SLR) method to all studies exploring the application of AR in Elementary schools. The objective of SLR is to identify, find, and evaluate previous research in a structured manner relevant to a particular topic (Calderón & Ruiz, 2015). To ensure a structured research process, this study refers to the PRISMA 2020 guidelines developed by Page et al. (2021). Articles included in the analysis were collected through Scopus and ERIC databases. The Scopus search utilized the query TITLE-ABS-KEY ("augmented reality" OR "AR" AND "elementary school" OR "elementary school"). In contrast, the ERIC search used the query ("augmented reality" OR "AR" AND "elementary school" OR "elementary school"). A total of 637 articles (598 from Scopus and 39 from ERIC) were identified, and then a selection process was conducted to ensure only articles meeting the considered research criteria were included. This step was taken to ensure that selected articles have optimal relevance to the research focus. The process refers to the assessment criteria outlined in Table 1.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Published between 2013 and 2023	The research outside these dates or times
Articles must involve AR and Elementary School Students as the main components	Article content is not related to AR and elementary school students
Articles are the result of a peer-review process	Articles do not include empirical research results
The research was conducted in Indonesia	The research was conducted in Indonesia
Articles are written in English	Articles are not written in English

A total of 64 relevant articles were identified, but only 47 articles were available openly for full paper analysis. These articles were then selected for analysis based on the established criteria. After the selection process, 35 articles met the specified criteria. The complete selection process can be observed in Figure 1.
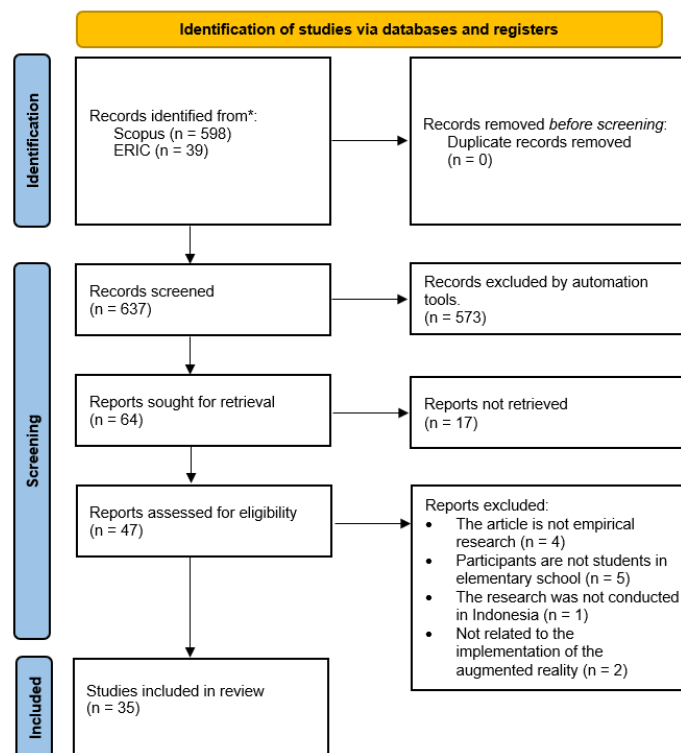
*Not relevant with inclusion criteria

Figure 1. Identify studies through database and register

Results and Discussion

After a structured article selection, 35 articles that met the criteria were identified and documented in Table 2. These articles were comprehensively analysed to consolidate information centred on the application of Augmented Reality (AR) in Indonesia, particularly in elementary school education.

Table 2. List of related articles

Source	Subject Area	Research Method	The Name of Application	Benefits	Challenges
Setiawan et al. (2023)	Science	Quantitative	Not Mention	Learning Outcomes	Not Mention
Rusli et al. (2022)	Science	Qualitative	AR Belajar Bagian Tangan	Analysis Skill	Facilities and infrastructure
Rukayah et al. (2022)	Science	R&D	Not Mention	Not Mention	Not Mention
Safitri et al. (2022)	Science	Quantitative	Web-based AR Ecolabel	Environmental Awareness and Understanding	Not Mention
Marini et al., (2022)	Science	Quantitative	Metaverse	Learning Outcomes	Not Mention
Zuniari et al., (2022)	Science	R&D	ARLOOPA	Critical thinking and curiosity	Technical Problems
Septinaningrum et al., (2022)	Citizenship	ADDIE	Grebeg Pancasila	Cooperative, and Motivation	Technical Problems
Suryani et al., (2021)	Language	R&D	Picture Story Book	Not Mention	Not Mention

Septinaningrum et al. (2021)	Math	R&D	3D Hologram Grebeg Pancasila	Enthusiasm	Not Mention
(Sari et al., 2021)	Math	DnD	Digital Book	Understanding	Not Mention
Firmansyah et al. (2021)	Art and Culture	R&D	Kain Tradisional Indonesia	Not Mention	Not Mention
Sobandi et al., (2021)	Art and Culture	SDLC	Batik AR	Learning Outcomes and Interactive	Not Mention
Yuhana et al., (2020)	Math	Quantitative	AUGGO	Learning Outcomes	Technical Problems
Mambu et al., (2020)	Math	Not Mention	Geomath	Not Mention	Not Mention
Syafitri Chani Saputri & Syahrial (2020)	Language	R&D	Learn English Words	Motivation	Technical Problems
Kholisho et al., (2020)	ICT	R&D	Not Mention	Not Mention	Not Mention
Hidayat & Yulianti (2020)	Language	Quantitative	Flashcard AR	Learning Outcomes	Not Mention
Wahyu et al., (2020)	Science	Quantitative	MAR Assisted STEM-Based	Learning Achievement and Literacy	Not Mention
Amir et al., (2020)	Math	Mix Method	3DMetric	Learning Achievement	Not Mention
Husniah et al., (2020)	Math	Quantitative	GemAR	Interest	Technical Problems
Wangid et al., (2020)	Math	Quantitative	Story Book AR	Interest	Not Mention
Wulan & Rahma (2020)	Art and Culture	R&D	AR Edugame	Learning Outcomes	Not Mention
Sudarmilah et al. (2020)	Language	R&D	Ayo Membaca	Interactive and Learning Outcomes	Not Mention
Kurniawan et al. (2019)	Science	R&D	AR media pembelajaran struktur matahari dan bumi	Not Mention	Not Mention
Muliyati et al., (2019)	Science	R&D	Simulasi Banjir	Not Mention	Not Mention
Tresnawati et al.(2019)	Science	R&D	AR Solar System	Not Mention	Technical Problems
Hendajani et al., (2019)	Science	R&D	Fun School AR	Not Mention	Not Mention
Hasan Lubis & Nur Wangid, (2019)	Science	Qualitative	Multimedia Interaktif	Critical Thinking	Not Mention
Syawaludin et al. (2019)	Science	R&D	Turtle Mobile Learning	Interactive and Literacy	Technical Problems
Winarni & Purwandari, (2019)	Math	Quantitative	Magic Boosed	Learning Outcomes	Not Mention
Andrea et al., (2019)	Citizenship	Quantitative	AR buku cerita bergambar	Dicipline	Not Mention
Hendajani et al., (2018)	Science	R&D	Not Mention	Learning Outcomes	Not Mention
Sudarmilah et al. (2018)	Art and Culture	SDLC	AR Edugame	Not Mention	Facilities and infastructure
Cahyono et al. (2018)	Math	MDLC	Model ruang 3D berbasis AR	Interactive	Not Mention
Setyosari et al. (2016a)	Citizenship	R&D	Character Building AR	Interest	Technical Problems

The Distribution of AR Research Studies

In total, there are 35 articles indexed in the Scopus and ERIC databases, published between 2013 and 2023. The distribution was analyzed based on the publication years, as shown in Figure 2.
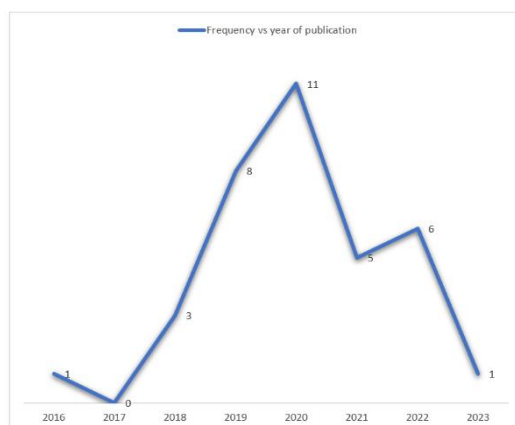

Figure 2. The trend and prevalence of augmented reality

The term "Augmented Reality (AR)" was introduced in 1990 by Thomas Caudell and David Mizell when they described a complex electrical system. However, at that time, many challenges were hindering the adoption of this technology (Elmqaddem, 2019). Figure 2 illustrates the application of AR at the primary school level in Indonesia starting in 2016 when this technology was integrated into citizenship education (Setyosari et al., 2016). The analysis results show an increase in research related to augmented reality in 2018 (n=3) and 2019 (n=8), resulting in a total of 11 articles. According to the data presented in Figure 2, the publication trend regarding the application of AR shows a significant increase in 2020. That year marked the beginning of changes in various sectors of life, including education, in response to the impact of the pandemic (Hendriyanto et al., 2021). This situation prompted individuals to adapt to flexible learning methods by utilizing digital technology. Despite the increase, there was also a decline in the application of AR from 2021 to 2023, indicating fluctuations in the development of AR in primary schools. From these results, it can be concluded that the use of AR in learning is a developing topic, and research on the application of AR in primary education is still in its early stages (Bacca Acosta et al., 2014; Chen et al., 2017; Wu et al., 2013). As predicted by the Horizon report, AR is expected to continue to evolve as a technology that will dominate in the future (Arvidson et al., 2006).
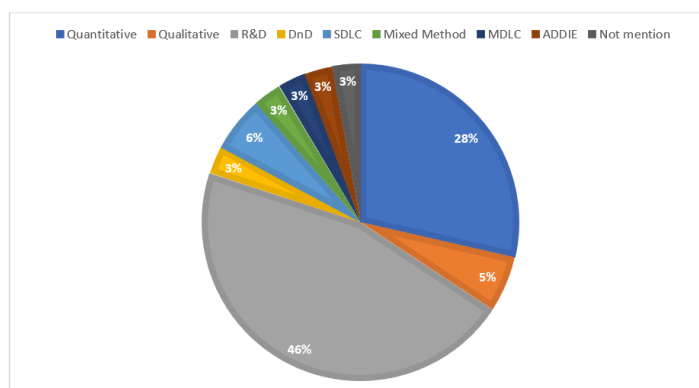

Figure 3. Research method

The most common research method used is the Research and Development (R&D) design, accounting for 46% of the total, followed by quantitative design with 28%. The Software Development Life Cycle (SDLC) accounts for only about 6%, and the use of qualitative design is at 5%, while other methods such as Design and Development (DnD), Mixed Method, ADDIE (Analysis, Design, Development, Implementation, and Evaluation), and MDLC (Multimedia Development Life Cycle) each constitute 3%. Approximately 3% of the articles do not provide specific information about the research methods used. From this data, about 33% of the research using the R&D method has not been utilized in the context of learning. This finding is consistent with

Umamah et al. (2020) research, which stated that although the use of Augmented Reality (AR) in Indonesia has developed over the last five years, its implementation in learning contexts remains scarce.
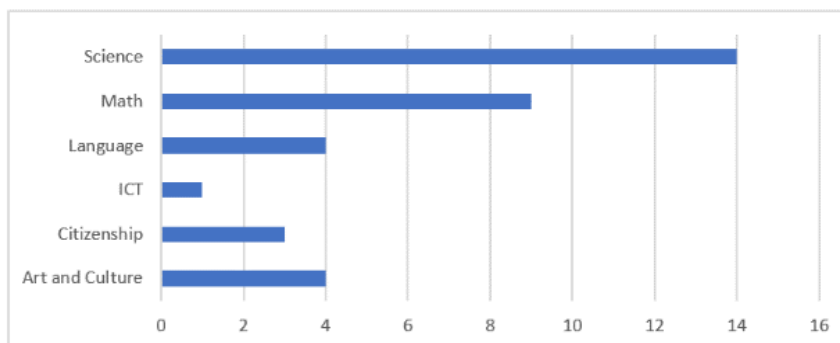

Figure 4. List of subject area

Based on the data provided in Figure 4, it can be concluded that AR can be used in the context of education at the elementary school level in Indonesia across various subjects. This demonstrates the flexibility of AR in the learning context, which is capable of adapting to the specific needs and characteristics of each subject. Although previous research, as reported by Pahmi et al. (2023), indicates that mathematics education is one of the most popular fields in AR implementation, this situation does not align with what happens in AR implementation in primary schools in Indonesia. Here, the use of AR tends to be more focused on science subjects. This finding is consistent with previous research supporting the adoption of AR in various academic fields, including physics (Thees et al., 2020), biology (Weng et al., 2020), and chemistry (Wong et al., 2021).

The AR Application Used in Learning

The application of Augmented Reality (AR) is inherently linked to the use of technology, as highlighted by El El Kouzi et al. (2019), who demonstrated that AR is supported by various mobile devices, making AR applications widely available and easily accessible via smartphones, PCs, and tablets. In Indonesia, the use of AR applications in primary schools can be categorized into two types: utilizing existing media and creating new media. However, the use of AR in the context of primary education in Indonesia generally focuses on the development of new technology, as seen in Figure 5.
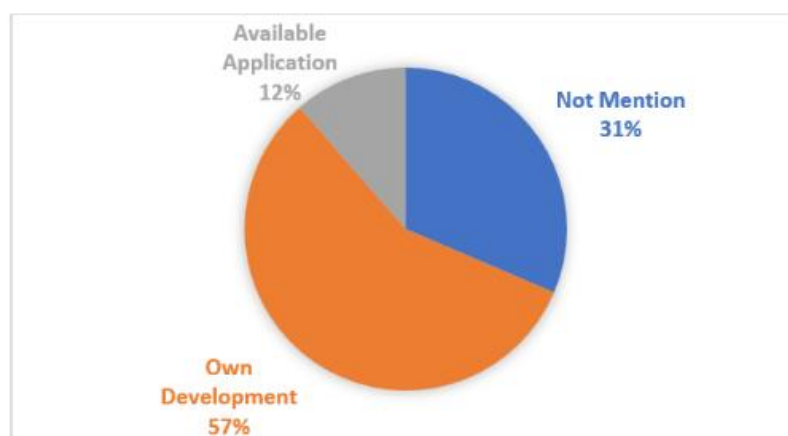

Figure 5. AR development and *i*mplementation

Figure 6 outlines the names of applications that can be implemented using Augmented Reality (AR), especially in the elementary school environment. Although the development of new media is an option to consider, it is worth noting that this process takes time, and not all teachers have the skills or sufficient time to do so. This emphasizes the need for attention from practitioners and academics to this issue, to conduct further research to find solutions that can bridge the gap between the need for quality content and the importance of time efficiency in the use of learning media, especially in the context of AR implementation.
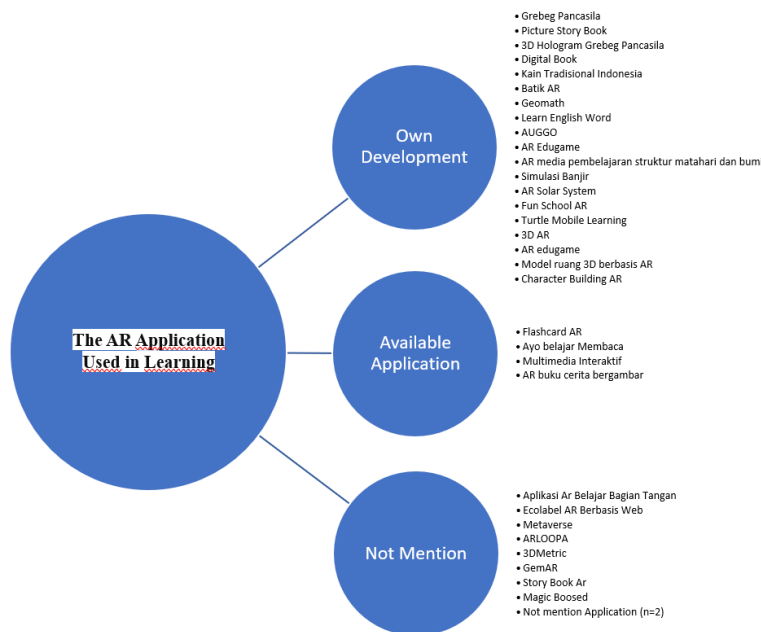
Figure 6. The AR application used in learning

Benefits of Implementing Augmented Reality

A total of 72% of the analyzed articles stated that the implementation of Augmented Reality (AR) has contributed positively to students' learning outcomes and produced other benefits such as interactivity, critical thinking, understanding, and interest that can positively influence learning outcomes. Therefore, these benefits need to be carefully classified to demonstrate how using AR in the learning context can enhance students' academic achievement. Figure 4 visualizes the frequency of positive impacts on learning outcomes caused by the implementation of AR. The two most significant aspects of using AR are improving learning outcomes and interactivity. These findings are consistent with previous research indicating that AR has the potential as an effective tool in the learning context, focusing on improving learning outcomes, enhancing better interactive experiences, and increasing students' knowledge (Liono et al., 2021; Park & Stangl, 2020). This observation confirms the significant correlation between these two aspects, namely learning outcomes and student interaction, which experience the most positive influence from the implementation of AR.
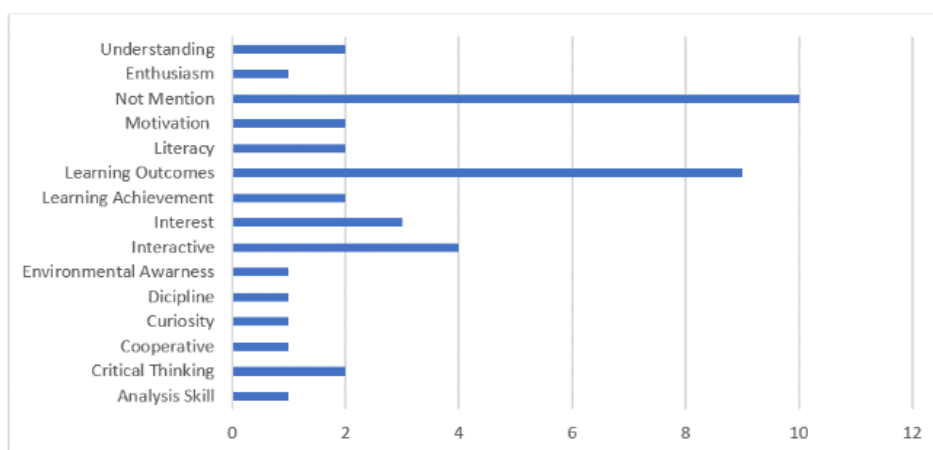

Figure 7. Benefits of ımplementing AR

Although the potential benefits of Augmented Reality (AR) in education have been identified, these benefits have not been conclusively proven, and there may still be barriers. Furthermore, the effectiveness of AR is highly dependent on the learning context and the characteristics of the subject matter. The integration of AR can provide varying benefits depending on the subject or topic of learning. However, research indicates that the implementation of AR is still uncommon at the primary school level in Indonesia. Out of 35 studies, 16 are still

in the development stage. This highlights the gap between efforts to develop AR and its direct application in the educational context in Indonesia. This gap underscores the need for specific attention to the integration of AR into the educational curriculum, as part of efforts to enhance teaching quality (Sulaiman & Ismail, 2020). Therefore, future research should focus on gaining a deeper understanding of the effective implementation of Augmented Reality (AR) in various learning contexts, so that this technology can be more widely accepted and utilized. Considering the potential impact of AR solutions is expected to be reflected in real-world situations, such as in the industrial environment (Fite-Georgel, 2011), further research is needed to explore the use of AR in such contexts.

Challenges in Implementing Augmented Reality

Although the implementation of AR holds great potential, it cannot be overlooked that several challenges arise during the research process. One of the main challenges lies in the research focus, which is still limited to development and has not yet reached the stage of concrete implementation. Although many applications have been developed, there is still a lack of adequate implementation to evaluate the impact of augmented reality in those applications. Furthermore, challenges in implementing AR are divided into facility and infrastructure issues and technical issues. The first aspect related to facility and infrastructure issues is the limited accessibility of AR applications, which can only be installed on smartphones with Android operating system version 11.0 or newer, resulting in not all devices being able to support these applications (Rusli et al., 2022). Additionally, the quality of facilities and infrastructure is also an important factor because if the models created are not attractive, it can reduce the effectiveness and purpose of the application (Sudarmilah et al., 2018). The second aspect regarding technical issues often occurs in the process of capturing 3D animation images. If the room is dark or lacks light reflection, the displayed 3D animations will take a long time to appear or may not appear at all because Light is the essence in operating AR (Muliyati et al., 2019; Septinaningrum et al., 2022; Setyosari et al., 2016a). Additionally, technical issues also arise from the lack of understanding by students and the difficulty for teachers to control learning with AR (Hasan et al., 2019; Zuniari et al., 2022).

Difficulties also arise because the focus of applying augmented reality (AR) tends to be limited to a specific subject, making it challenging to develop AR-based learning media that can be universally applied to all subjects. Findings from research conducted by Setyosari (2016) support this by showing that the use of AR is currently generally limited to Civic Education (PKn) learning only. Therefore, further research is needed to explore the potential benefits of AR comprehensively while addressing various emerging challenges. This is crucial, especially in AR implementation at the primary school level, to ensure that learning objectives can be effectively achieved. Despite the limitations, AR technology is expected to overcome these weaknesses over time, and we believe that the potential benefits of using AR far outweigh its limitations and that this technology is mature enough to be used by educators.

Conclusion

From the conducted analysis, several crucial conclusions can be drawn. The utilization of AR in education, particularly in primary schools in Indonesia, is still in its early developmental stages. Despite increased research on AR in 2018 and 2019, the trend exhibited fluctuations from 2020 to 2023. Implementing AR in education involves leveraging existing media and developing new ones. However, most applications primarily focus on creating new technological solutions, indicating the need to explore existing resources further. AR in Indonesian primary education demonstrates significant potential for enhancing student achievement. Approximately 72% of the analyzed articles reported positive impacts from AR implementation, including improved learning outcomes, interactivity, critical thinking, understanding, and student interest in learning materials. Despite the identified potential benefits of AR, challenges persist in its application. One of these challenges is the continued research focus on AR technology development without reaching a concrete implementation stage. Other challenges include facility and infrastructure issues, technical barriers such as student comprehension levels, and difficulties in utilizing AR technology.

Recommendations

The recommendations derived from this study emphasize the need for further research to comprehensively investigate the potential benefits of AR in the elementary education environment. Subsequent research should focus on concrete and efficient AR implementation across various subjects while addressing emerging

challenges. Education practitioners and academics must consider infrastructure, facilities, and technical problems associated with AR applications. Improvement and enhancement measures should be implemented to broaden and enhance the effectiveness of AR utilization. Strengthening AR integration into the elementary education curriculum and providing training and guidance for teachers to enhance their understanding and skills in using this technology is necessary. Support from government and educational institutions regarding resources and infrastructure is also crucial to facilitate wider and more effective AR usage in primary schools. Therefore, research and development of AR in the context of elementary education in Indonesia must be continuously improved to optimize the potential of this technology in enhancing the quality of learning and academic achievement of students.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Acknowledgements or Notes

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To cite this article: