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Analysis of the Effectiveness of Using Augmented Reality (AR) on Science Learning in Elementary Schools: A Systematic Literature Review

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ABSTRAK

Penelitian ini berfokus pada kurangnya pemahaman mengenai efektivitas penggunaan Augmented Reality (AR) dalam pembelajaran IPA di sekolah dasar. Augmented Reality dinilai mampu meningkatkan interaktivitas dan motivasi siswa dalam memahami konsep ilmiah. Penelitian ini menggunakan pendekatan Systematic Literature Review (SLR) dengan menganalisis artikel dari database Scopus yang diterbitkan antara tahun 2019 hingga 2023. Subyek penelitian adalah 8 artikel yang dipilih dari total 27.520 dokumen awal berdasarkan kriteria kelayakan, seperti sitasi lebih dari 10 dan aksesibilitas. Hasil penelitian menunjukkan bahwa penerapan AR dalam pembelajaran IPA efektif meningkatkan pemahaman, motivasi, dan hasil belajar siswa di sekolah dasar. Implikasi dari penelitian ini adalah AR dapat menjadi alat yang berguna bagi guru untuk memperkaya pengalaman belajar siswa dan meningkatkan kualitas pendidikan sains di tingkat dasar, serta menjadi dasar pengembangan teknologi pembelajaran yang lebih inovatif.

ABSTRACT

This research focuses on the lack of understanding regarding the effectiveness of using Augmented Reality (AR) in science learning in elementary schools. Augmented Reality is considered capable of increasing student interactivity and motivation in understanding scientific concepts. This research uses a Systematic Literature Review (SLR) approach by analyzing articles from the Scopus database published between 2019 and 2023. The research subjects were 8 articles selected from a total of 27,520 initial documents based on eligibility criteria, such as citations more than 10 and accessibility. The results showed that the application of AR in science learning was effective in improving students' understanding, motivation, and learning outcomes in elementary school. The implication of this research is that AR can be a useful tool for teachers to enrich students' learning experience and improve the quality of science education at the primary level, as well as a basis for the development of more innovative learning technologies.

1. INTRODUCTION

Augmented Reality (AR) has brought a revolution in the world of learning by incorporating digital elements into real environments, creating a more interactive and immersive learning experience (Salwa et al., 2023; Shonima et al., 2024; Weifeng et al., 2024). By using devices such as smartphones or AR glasses, students can view additional information, 3D visualizations, and simulations that serve to clarify abstract concepts and improve understanding of the subject matter (Babajide et al., 2024; Vu et al., 2024; Zulfadli et al., 2023). For example, in science lessons, AR allows students to manipulate models of human organs or explore the solar system virtually, making the learning process more interesting and effective. Not only does this technology increase student engagement, but it also assists teachers in delivering material in a more innovative and understandable way (Ayesha et al., 2022; B. et al., 2024; Ivana et al., 2023).

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Although Augmented Reality (AR) offers great potential in improving science learning in primary schools, there is still a lack of understanding among teachers regarding the effectiveness of using Augmented Reality (AR) in improving science learning in primary schools (Dhea et al., 2024; N et al., 2019; Ningning et al., 2023). Many teachers do not fully understand how AR can be properly integrated into the curriculum and how this technology can concretely affect student learning outcomes (Tuli et al., 2022; Waskito, 2024). The lack of adequate training and information on AR applications and its impact on the learning process makes many educators hesitant to adopt this technology thoroughly, even though they recognize the innovative potential it offers (Kharisma et al., 2023; Rugaiyah et al., 2024).

Therefore, the main focus of this research is to analyze the effectiveness of using Augmented Reality (AR) in learning science in primary schools using a Systematic Literature Review (SLR) approach, this research specifically evaluates the findings of several selected articles, providing a comprehensive picture of the impact of AR on student learning outcomes in primary schools in the context of science. This research provides more specific insights into how AR can be effectively applied at the primary school level, an area that has not been explored much in depth in previous research.

The implementation of augmented reality in education not only enhances students' learning experience through direct interaction with visual content, but also shows great interest in exploring the potential of the technology to improve learning effectiveness, as demonstrated by the large amount of research conducted in this field (Vasil & Boyana, 2023; Yenioglu et al., 2023). Existing research provides evidence of the efficiency of employing augmented reality in education in relation to achieving specific learning objectives for various subjects. For example, research by (Riko Arrasyid et al., 2024) this research develops an application called Geolab which includes augmented reality technology to support geography education learning in higher education and proves that GeoLab has the potential as an effective mobile learning solution to support blended learning-based geography learning in Indonesian universities.

(Sandoval Pérez et al., 2024) showed results that the implementation of AR in electronics practice had a substantial impact on student achievement. Therefore, it can be concluded that gamification-based AR applications are effective for improving student understanding and performance in the topic of half-wave rectifiers. Then the research by (Nurcahyani & Sudarmilah, 2023) this research creates an Android-based AR application designed to display the solar system and its orbiting celestial bodies in an interactive three-dimensional format. The application is intended for use by primary school students on Android smartphones. The findings indicated the augmented reality application is feasible to use and enhances the learning experience.

Furthermore, a study by (Neri et al., 2024) who tested a software called AEducAR based on Augmented Reality (AR) in medical student learning activities which showed the results that there was an escalate in academic performance in human anatomy material using AEducAR based on Augmented Reality (AR). This indicates that augmented reality contributes positively to learning results. (Faiza et al., 2022) in his research, he stated that utilizing learning media in teaching and academic activities can enhance student academic performance, engage students more actively and make students not easily feel bored. Thus, social studies learning at the elementary level can be said to be more effective and meaningful.

Throughout the Covid-19 pandemic, the implementation of augmented reality in learning is also very effective, this is evidenced by the existence of studies correlated to the effectiveness of AR in the pandemic era. Such as a study carried out by (Mooduto et al., 2023) demonstrating that the use of augmented reality technology notably enhances students' attitudes and subjective norms in the context of digital learning. The results confirm that the implementation of augmented reality not only increases students' interest and encouragement to learn, but also enriches their learning experience, thus supporting a more interactive and effective learning process. This research provides evidence that the incorporation of augmented reality in education can bring positive changes to students' perceptions and attitudes towards digital-based learning. Then there is research from (Fitrianingsih et al., 2023) this research shows that the use of Augmented Reality (AR) technology in learning geometry for elementary school students has great potential. With AR, abstract mathematical concepts can be visualized more realistically, thus increasing student motivation and understanding. This research supports the development of AR learning media as a way to improve the quality of education in the digital era, as well as strengthening students' analytical skills in understanding math materials.

There have been many studies related to Augmented Reality (AR) in education (Ahmad & Junaini, 2022) conducting research on the use of realm of mathematics education, this study proves that utilization of card games based on AR can prove to be an effective approach for improving students' math competence. The next research that discusses AR in education is research by (Ibrahim et al., 2024), in this study researchers tested the efficiency of an educational application based on Augmented Reality (AR) in English lessons, testing the effectiveness of proving that this application proves to be an effective tool for increase English vocabulary acquisition. Then there is research by (Di Fuccio et al., 2024) on the use of Augmented

Reality in foreign language learning and cultural knowledge which results in AR showing a positive impact on student learning development. While Augmented Reality (AR) has been extensively studied, but for the use of science lessons in elementary schools is still not widely found. Therefore, this study was conducted with the aim of analyzing the effectiveness regarding the utilization of Augmented Reality (AR) on science learning in elementary schools which will be analyzed using a systematic literature review.

This study aims to analyze the effectiveness of using Augmented Reality (AR) in science learning in primary schools. Through a systematic literature review, this study evaluates the impact of AR on students' learning outcomes, motivation, and understanding in science learning. This research is important because it provides deeper insights into the benefits and effectiveness of AR in science learning in elementary schools. The results can assist teachers in improving teaching methods and provide a basis for educational technology developers to create more effective learning aids. In addition, this research can be a reference for further research.

2. METHOD

The research employs a systematic literature review (SLR) to investigate the efficacy of Augmented Reality (AR) in enhancing science learning at the elementary school level. SLR is a term that refers to a exploration and advancement method used to gather and assess exploration pertinent to a specific subject (Suhaida et al., 2024; Yavuz et al., 2023). This effort was made with the aim of enriching the repertoire of knowledge and complementing the existing collection of literature. According to Parinata & Puspaningtyas in (Rahmadina et al., 2024) the stages of a systematic literature review (SLR) include: 1) clarifying the subject or issue under examination, 2) recognizing relevant sources, 3) selecting results based on predefined standards, 4) constructing a synthesis matrix of the findings, and 5) drawing conclusions from the review outcomes. This research uses data taken from searches on the web https://www.scopus.com/home.uri. The stages of SLR exploration are illustrated in the accompanying diagram

Figure 1. SLR Research Stages

This research focused on the discussion in the Literature Review. The articles analyzed were published in the Scopus database from 2019 to 2023. The process of searching and selecting articles was carried out on the page https://www.scopus.com/home.uri in May 2024. The search was conducted using three selected keywords namely “Augmented Reality” AND “Science” AND “Elementary School”. Searching with the keyword “Augmented Reality” which is limited to 2019-2023 results in 27,520 documents, then added the second keyword “Science” which results in 1,874 documents. After that, finally added the third keyword, namely “Elementary School” getting the results of 51 documents. From 51 documents, data selection was carried out based on eligibility criteria by researchers so that 8 articles were obtained that were suitable for analysis.

The figure below illustrates the stages of research guided by eligibility criteria, which include identification, screening, eligibility, and inclusion.

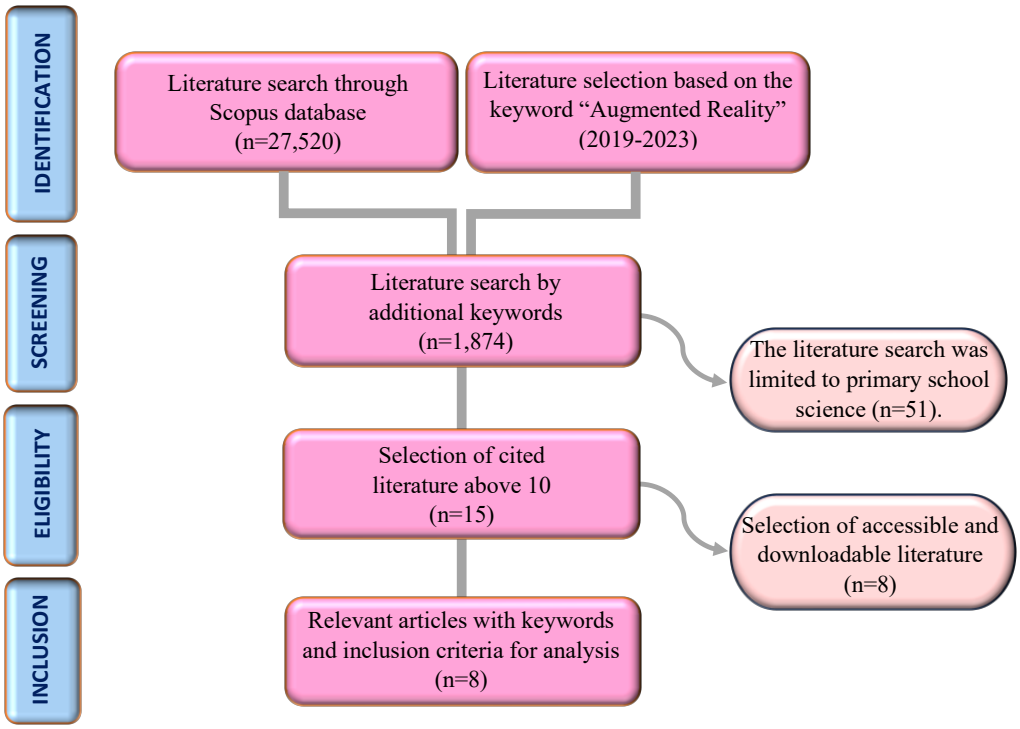

Figure 2. Article Search Process in Scopus Database

3. RESULT AND DISCUSSION

Result

In this study, the outcomes of the literature exploration were performed in accordance with the SLR research stages which went through four stages of research. The last selected article that will be analyzed about the efficiency of employing Augmented Reality (AR) on science learning in elementary schools is obtained as many as 8 articles. The last selected article was obtained through four stages as follows.

Identification

During the identification stage, information regarding articles about Augmented Reality (AR) sourced from Scopus were collected by researchers. The exploration commenced with the key phrases "Augmented Reality" with a time span of the last five years from 2019 to 2023, from the first search results obtained (n = 27,520) documents.

Screening

During the stage of screening, the literature exploration underwent expanded by incorporating supplementary key phrases. The preliminary investigation incorporated the key phrases "Science," yielding a total of (n=1,874) document results then added a third keyword "Elementary School" to obtain (n = 51) documents.

Eligibility

During the eligibility stage, the documents found will be selected again by focusing on "article" type documents with citations above 10 and the results obtained with the number of articles (n = 15). Then from the 15 articles obtained, there are several development articles and articles that cannot be downloaded so that the final search results are collected (n = 8) articles.

Inclusion

The final data obtained as many as (n = 8) of these articles were analyzed and discussed by the researcher.

The results of searching for literature related to the research theme on the Scopus database provide a clearer picture of the research results in the form of tables, charts, graphs and diagrams and discussions.

Articles related to this research theme have publication developments every year, starting from 2019 to 2023. The diagram below presents data on the advancement of the article.

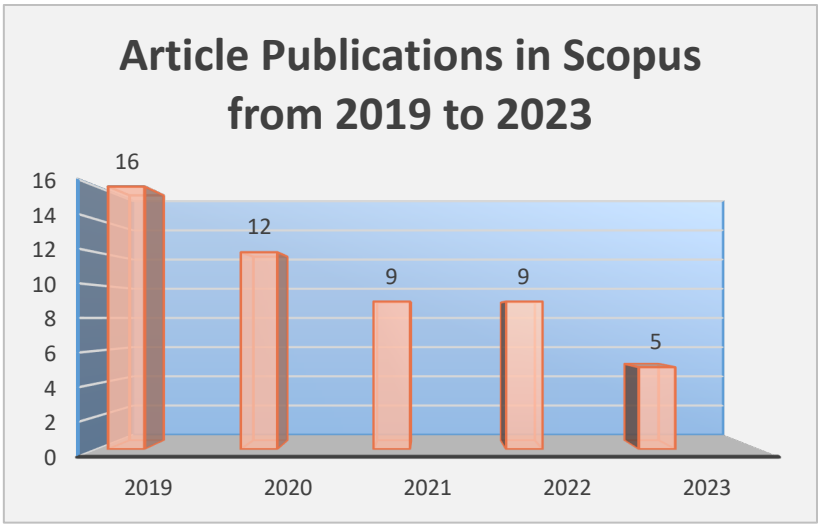

Figure 3. Progress of Article Publication

The number of publications of articles with the key phrases "Augmented Reality" AND "Science" AND "Elementary School" in the Scopus database is shown in the diagram above. In 2019, the number of articles with related keywords was found to be 16 articles, this year is the year with the most publications over the last five years (2019-2023), this number has decreased in the following year, 2020, which has 12 published articles. Publication of articles with related keywords continues to decline in subsequent years. In 2021 there were 9 published articles, the number of publications was also the same as in 2022, namely 9 published articles. Furthermore, in 2023, there were only 5 published articles, this year being the year with the least publications over the last five years (2019-2023). The following is the calculation of the average number of articles per year.

$$\tilde{x} : \frac{number\ of\ articles}{number\ of\ years}$$

$$\tilde{x} : \frac{51\ articles}{5\ years} = \text{ 10,2 articles}$$

So the average number of articles published over the last 5 years is 10 articles.

Through the search and collection process, out of 51 articles, 8 articles were chosen for examination, the table below presents the results of the analysis of these 8 articles.

Table 1. The Results of the Analysis of These 8 Articles

No.	Title of Article & Author	Article Identity	Research Results
1	Effect of Digital Learning Using Augmented Reality with Multidimensional Concept Map in Elementary Science Course (Chou et al., 2022)	The Asia-Pacific Education Researcher, volume 31 number 4 year 2021 page 383-393 (Scopus Q1)	The findings of this research show that learning with ARMCMs (AR Multidimensional Concept Maps) could enhance the promotion of acquisition motivation and enhance acquisition effectiveness, contentment, and reduce cognitive burden
2	Mobile Augmented Reality Learning Media with Metaverse to Improve Student Learning Outcomes in Science Class (Marini et al., 2022)	International Journal of Interactive Mobile Technologies (iJIM), volume 16 number 07 year 2022 page	In general, the findings of this research indicate the utilization of AR media on mobile devices AR positively influences student acquisition achievement in understanding the resource of the human gastrointestinal system in science subjects

No.	Title of Article & Author	Article Identity	Research Results
		99-115 (Scopus Q3)	
3	The Effectiveness of Mobile Augmented Reality Assisted STEM-Based Learning on Scientific Literacy and Students' Achievement (Wahyu et al., 2020)	International Journal of Instruction, volume 13 number 3 year 2020 page 343-356 (Scopus Q1)	The application of STEM mobile AR is effective for improving acquisition achievement
4	Impacts of augmented reality and a digital game on students' science learning with reflection prompts in multimedia learning (Chen, 2020)	Educational Technology Research and Development, volume 68 number 6 year 2020 page 3057-3076 (Scopus Q1)	Periodic use of AR-based digital games improves student academic accomplishment and student fow state. This research proves the importance of the fow state in a contextual reflection in multimedia-based learning
5	A Usability and Acceptance Evaluation of the Use of Augmented Reality for Learning Atoms and Molecules Reaction by Primary School Female Students in Palestine (Ewais & Troyer, 2019)	Journal of Educational Computing Research, volume 57 number 7 year 2019 page 1643-1670 (Scopus Q1)	Based on this study, it can be inferred that AR technology offers a distinct advantage over classic learning materials
6	Evaluation of AR embedded physical puzzle game on students' learning achievement and motivation on elementary natural science (Lu et al., 2020)	Interactive Learning Environments, volume 28 number 4 year 2020 page 451-463 (Scopus Q1)	The results showed that both AR-based puzzle games increased knowledge in natural science
7	Enhancing Elementary School Students' Abstract Reasoning in Science Learning through Augmented Reality-Based Interactive Multimedia (Syawaludin et al., 2019)	Jurnal Pendidikan IPA Indonesia, volume 8 number 2 year 2019 page 289-298 (Sinta 1)	The conclusion of this research is that the application of participatory multimedia utilizing AR can improve the capability of fifth grade primary school students in abstract reasoning
8	An augmented reality-based learning approach to enhancing students' science reading performances from the perspective of the cognitive load theory (Lai et al., 2019)	British Journal of Educational Technology, volume 50 number 1 year 2019 page 232-247 (Scopus Q1)	Experiments showed that students who used Augmented Reality had better learning achievement and motivation than those who used conventional science multimedia learning. In addition, their perception of cognitive difficulties decreased significantly during the learning process

Drawing from the analysis and reviewed of the eight articles, the researchers found the following findings : 1) Research related to the efficacy of utilizing of Augmented Reality (AR) on science learning in elementary schools is still not much found starting from 2019-2023, 2) Augmented Reality implementation in learning science in elementary schools has proven effective in increasing student motivation, interest and learning outcomes, 3) Augmented Reality (AR) used in learning media is feasible in elementary schools and can be used in various learning materials, especially science.

Discussion

The study carried out by (Chou et al., 2022) showed that learning with ARMCMs (Augmented Reality Multidimensional Concept Maps) could enhance the promotion of learning motivation and provide a positive influence regarding effectiveness in learning outcomes, satisfaction with the learning process, and cognitive load. Next is research by (Marini et al., 2022) In general, the findings of this study suggest that implementing AR media on mobile devices positively influences student learning outcomes in understanding the material of the human digestive system in science subjects (Wahyu et al., 2020) in his research said that the outcomes from implementing STEM-oriented education with the aid of Mobile Augmented Reality proved successful in enhancing students' academic performance.. According to (Chen, 2020) in his research shows that incorporating Augmented Reality technology into digital gaming significantly improves student learning achievement and student fow conditions.

There is also research by (Ewais & Troyer, 2019; Lu et al., 2020; Syawaludin et al., 2019) which integrating Augmented Reality technology into digital gaming materials and increases knowledge in science and improves the abstract reasoning ability of elementary school students. Last but not least is the research (Lai et al., 2019) which showed that students who used Augmented Reality had better learning achievement and motivation than those who used conventional science multimedia learning. In addition, their perception of cognitive difficulties decreased significantly during the learning process.

4. CONCLUSION

Based on the analysis of 8 articles that meet the criteria of literature review, this study shows that the application of Augmented Reality (AR) as a science learning media in elementary schools has a positive and significant impact on improving learning outcomes, motivation, and student understanding. AR technology is proven to be able to make the learning process more interactive, interesting, and efficient, as well as facilitate students' understanding of abstract concepts that are difficult to understand with traditional methods. The main benefits of using AR include increased learning motivation, material understanding, reduced cognitive load, and improved abstract thinking skills and science literacy. Based on these findings, researchers recommend that educators, especially at the elementary school level, make more use of Augmented Reality technology in science learning. The use of AR can support students in understanding the material better, improve learning outcomes, and hone critical and abstract thinking skills. However, keep in mind that AR is just one of the tools that can be used to improve the quality of science learning. Educators are expected to use this technology creatively and innovatively, and combine it with other learning methods so that teaching can be organized in a way that provides a deeper understanding for students.

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