



The Effectiveness of Using Augmented Reality-Based Educational Games in Science Learning for Elementary School Students: A Systematic Literature Review

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ABSTRACT

The development of Augmented Reality (AR) technology offers an immersive, interactive, and engaging solution to improve science learning in elementary schools. This study aims to analyze the effectiveness of using Augmented Reality-based educational games in learning science in elementary school students. This research uses Systematic Literature Review (SLR) to analyze the effectiveness of AR-based educational games by reviewing 344 articles from 2019 to 2024, sourced from Google Scholar and Publish or Perish. The findings show that AR games significantly improve students' motivation, learning achievement, enthusiasm, and understanding of science concepts. AR creates an effective and interactive learning environment. However, further research is needed to assess the long-term effectiveness of AR.

INTRODUCTION

Natural Science has an important meaning in the learning process in elementary schools (Bunyamin, 2023a). First, science fosters curiosity and critical thinking skills by encouraging students to explore nature and conduct investigations, and encourages analytical thinking (Abadillah. & Setyawati, 2023). Second, science helps students understand the world around them, from atoms to complex systems such as the solar system, encouraging appreciation and adaptability to the environment (Margunayasa, 2023). In addition, science helps develop 21st century skills such as collaboration, communication and creativity, which are crucial in the digital age. In addition, science also prepares students for future professions by laying a solid foundation in science and technology. Finally, engaging and inspiring science learning can instill positive attitudes towards science, encourage continuous learning, and contribute to the advancement of science (Ana & Ines, 2023).

Low motivation to learn science in primary school students can have significant impacts beyond just low grades. It can inhibit problem-solving abilities, reduce interest in science and technology, limit future career opportunities, negatively impact everyday decision-making, and lead to disappointment and a crisis of confidence (Nuraini et al., 2023). Increasing motivation to learn science is essential to foster critical thinking, nurture interest in science, broaden career prospects, improve decision-making skills, and increase self-confidence (Bunyamin, 2023b). The collaborative efforts of the importance of teachers, parents and communities in creating stimulating and supportive learning environments cannot be underestimated, which spark curiosity, encourage learning and instill a love of science (Putri & El, 2023). By promoting high motivation, Indonesian youth can develop into critical thinkers, proficient problem solvers, and future leaders in science and technology will drive the nation forward.

Implementing Augmented Reality (AR)-based educational games in elementary schools can significantly increase motivation to learn science. By designing interactive games with interesting themes, diverse gameplay, and rewarding challenges, students' curiosity and motivation can be stimulated. Utilizing AR features such as realistic 3D visualization, interaction with virtual objects, and fun effects can make learning more immersive and enjoyable. Integrating AR games with classroom learning as a complement, ensuring relevance to learning topics, and encouraging post-game discussions can deepen understanding. Teacher training, parental guidelines, and open communication are essential for effective implementation and supervision of AR games. By following these strategies, AR-based educational games can effectively increase IPA learning motivation making teaching more interesting and meaningful for elementary school students without violating plagiarism rules (Soumik, 2023).

Previous research has shown the positive impact of educational games on learning outcomes and student motivation. The benefits of integrating augmented reality, gamification, and serious games in computer science education. The results showed that this approach led to increased motivation, engagement, self-efficacy, and immersion among students, which ultimately

improved their achievement in learning and academic performance (Zhang et al., 2023). Similarly, research by Rosida Amalia and Ruli Astuti showed that the use of educational games significantly improved the learning outcomes of natural science students, the effectiveness of such interactive methods in improving student performance (Georgios et al., 2023). Therefore, incorporating AR educational games in biology learning, as suggested by Akbulut (2014), will likely have a positive impact on student motivation and learning outcomes based on existing evidence.

This article This study aims to: (1) assess the extent to which Augmented Reality (AR)-based educational games can increase the motivation to learn science at the elementary school level; (2) present information related to the application of Augmented Reality in Science Learning; and (3) encourage further research on the application and benefits of AR in education.

METHODOLOGY

In this study, the researchers applied the Systematic Literature Review (SLR) method, an approach that aims to identify, evaluate, and interpret all relevant studies related to the research question, topic, or phenomenon under investigation (Lanxin et al., 2021). The focus of the literature search was on the utilization of augmented reality learning media in the context of Indonesian language learning, with the search conducted through the Google Scholar and Publish or Perish database platforms. The research stages carried out include:

First, the Planning stage, where the researcher gets an overview In general, the research begins with reading scientific articles to formulate research questions that become the basis for literature studies. Furthermore, at the Implementation stage, researchers searched for references and sources in the literature study by utilizing the available features." "Searching" on the Google Scholar website. Third, the Reporting stage, where researchers sorted the articles that had been obtained.

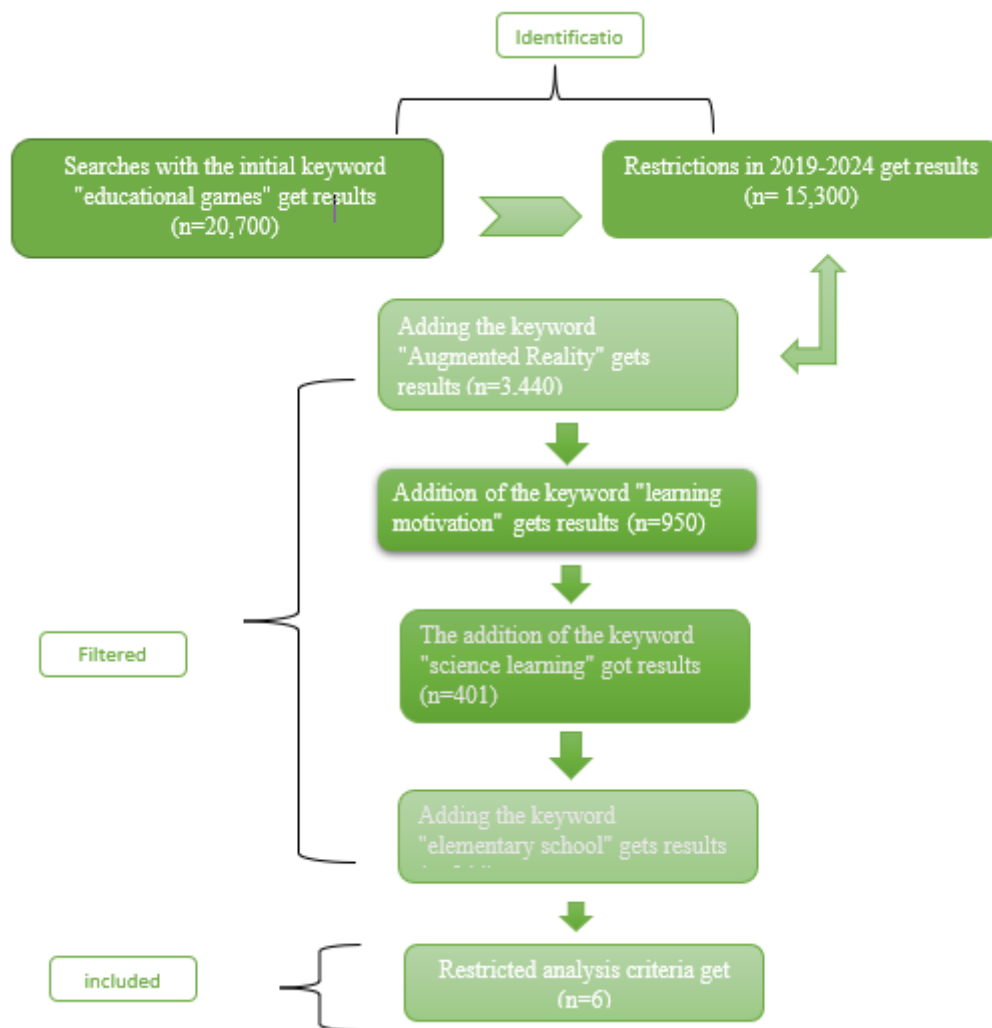


Chart 1. Research Stages Systematic Literature Review Method

INCLUSION CRITERIA

In this study, the journals reviewed were from sources relevant to the research topic and found through the Google Scholar database. The initial focus of the literature search was on the phrase "educational games", which resulted in 20,700 articles. Further filtering was done based on the publication year, 2019-2024, which reduced the number of articles to 15,300. The addition of the phrase "augmented reality" resulted in 3,440 articles. By adding "learning motivation" to the search, the number of articles was reduced to 950. Furthermore, by adding "science learning", the number of articles was reduced to 401. Finally, by adding "elementary school" to the search, the number of articles reduced to 344. From these 344 articles, a data selection process was carried out, including due

diligence, to ensure that the articles selected fit the purpose of this literature review.



RESEARCH RESULT

The purpose of the literature search in the Google Scholar database is to provide clarification of the research results, which can be displayed in the form of graphs, tables, or through discussions and comments. The article entitled "The Effectiveness of Using Augmented Reality-Based Educational Games to Increase Science Learning Motivation in Elementary School Students" shows an increasing publication trend every year from 2019 to 2024. The development of this article publication can be seen in the following diagram:

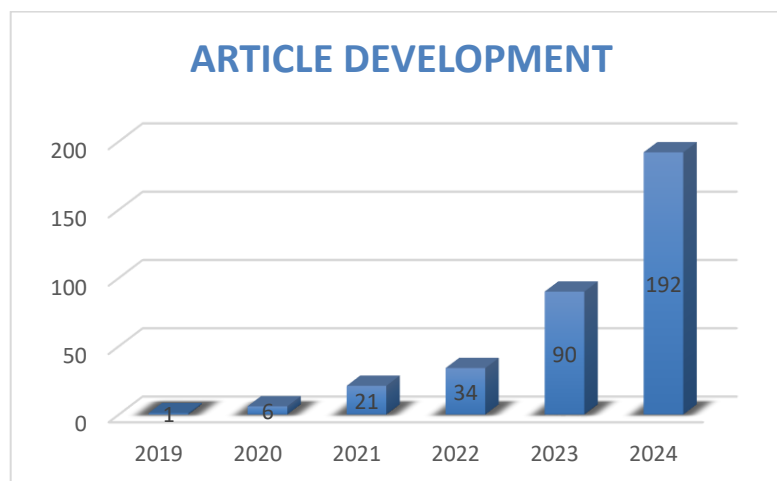


Diagram 1 The development of research on the utilization of state-of-the-art reality-based educational games in increasing the enthusiasm for learning science among elementary school students. as a foundation for improving student learning achievement in elementary schools on google scholar.

Based on the graph displayed above, it can be seen that the publication of an article entitled “The Effectiveness of Using Augmented Reality-Based Educational Games to Increase Science Learning Motivation in Elementary School Students” on Google Scholar has increased throughout the 2019-2024 period. In 2019 and 2020, there were 1 and 6 articles published on Google Scholar. Then in 2021 and 2022, the number of publications increased to 21 and 34 articles. This increase continued in 2023 and 2024, with 90 and 192 articles published in the Google Scholar database on the topic. The year 2024 saw the highest number of publications in Google Scholar, with a total of 90 articles, and this number is expected to continue to grow.

Here are the results of the calculation of the average number of articles published in the Google Scholar database:

$$\tilde{x} = \frac{\text{number of articles}}{\text{number of year}}$$
$$\tilde{x} = \frac{344 \text{ article}}{6 \text{ year}} = 57,3 \text{ Article}$$

So, the average number of articles published on the Google Scholar database per year is rounded up to 57 articles.

Furthermore, based on the results of the author's search in the Google Scholar database, the number of articles cited certainly changes every year. The number of articles cited in the 2019-2024 period was 344 articles. The following is a presentation of the articles cited over the past six years regarding “The Effectiveness of Using Augmented Reality-Based Educational Games to Increase Science Learning Motivation in Elementary School Students” in the context of science learning in elementary schools:

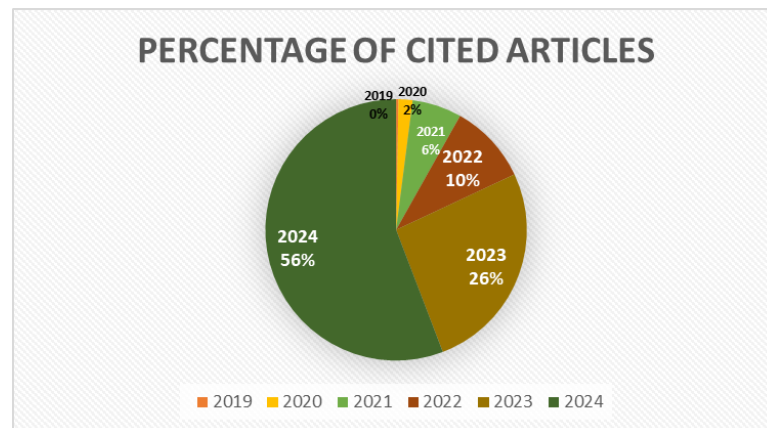


Figure 2 Proportion of articles referring to the use of augmented reality-based educational games in increasing elementary school students' science learning motivation, as documented in Google Scholar.

Based on the graph above, we can see the number of articles cited each year. In 2019, the percentage of articles cited was 0%. Then, in 2020, the percentage of articles cited increased to 2%. In 2021, the percentage of articles cited rose to 6%, and in 2022, the percentage rose again to 10%. In 2023, the percentage of cited articles reached 26%, and in 2024, the percentage jumped to 56%, which is the highest percentage compared to previous years.

The process of searching for articles began by visiting the Google Scholar database. The keyword “Educational Games” was used for the search, and the publication timeframe was limited from 2019 to 2023. This search was conducted on May 6, 2024. The use of these keywords resulted in 15,300 documents of various types. The first search process identified 15,300 documents in various file formats. To find articles relevant to the research objectives, the search was continued by entering additional keywords. “Augmented Reality”, combined with the word ‘AND’ along with the initial keywords. The second stage of searching in the Google Scholar database produced 3,440 results.

In the second stage of the search, 3,440 documents in various file formats had to be filtered to find articles relevant to the research objectives. The third stage included a search by adding the keyword “Learning Motivation”, which was linked to the word “AND”. The third stage search in the Google Scholar database yielded 950 results. In the third stage of the search, 950 Documents with various file formats were found. To find articles that match the research objectives, the search continued in the fourth stage by adding the keyword “Science Learning”, which is linked with the word “AND”.

At the fourth search stage, there were 401 Documents covering various file types. To find relevant articles in accordance with the research objectives, a stage five search was conducted with the addition of the keyword “Elementary School”, linked with the word “AND”. The results of the stage five search led to the research on Using augmented reality-based educational games to increase the enthusiasm of learning natural science among elementary school students. The stage five search in the Google Scholar database produced 344 results.

The sixth stage of data collection was obtained by downloading documents from 344 search results in the fifth stage. At this stage, the selection

focused on journal articles only, while other documents such as proceedings, books, or HTML pages were not taken into account. From this sixth stage, 52 journal articles were obtained. Of these 52 articles, 26 were successfully downloaded and systematically analyzed. Of these 26 articles, 20 were irrelevant in the context of the topic, there are several reasons to note. 1) the articles did not focus specifically on the effectiveness of using augmented reality-based educational games to increase motivation to learn science among elementary school students. 2) the articles only touched on the surface of learning in elementary schools without providing in-depth analysis. and 3) the articles did not provide clear results regarding the effectiveness of using augmented reality-based educational games. The results of the systematic analysis of this review are presented in Table 1 below.

No	Title	Research Method	Research Results
1	Development of Augmented Reality Applications as Learning Media to Recognize the Solar System at Islamic Village Elementary School (Edi Junaedi et al., 2023).	This research method applies the Classroom Action Research (PTK) method	A learning media has been developed in the form of augmented reality-based Android applications that are suitable for use as a tool in learning Natural Sciences, especially to understand the various types of planets in the solar system. Students at Penerus Bangsa Elementary School show high interest in the use of this augmented reality application as a medium for learning natural science.
2	Digital Media in Empowering 21st Century Critical Thinking Skills in Science Learning at Elementary School (Jannah & Atmojo, 2022).	This study adopted a qualitative approach in conducting the literature review as the research methodology.	The results showed that the application of digital media innovation to improve 21st century critical thinking skills in Science learning in elementary schools, especially focusing on augmented reality technology, proved that the use of multimedia such as Augmented Reality (AR) and digital games is very effective. This media is proven to be able to facilitate the understanding of science concepts by students and

			increase their learning motivation. The use of digital game media can be applied in both online and face-to-face learning.
3	Utilization of Augmented Reality to Visualize Changes in Object Forms for Elementary School Students (Wardani et al., 2024)	This research is a development study that uses an R&D approach with the intention of creating effective products or innovations according to a specific context.	The results of this study show that the evaluation by media experts resulted in a score of 77.3%, which indicates a feasible category. Evaluation by material experts gave a score of 88%, falling into the very feasible category, while evaluation by respondents showed a score of 79.5%, which also showed a feasible category. Thus, it can be concluded that the development of this learning environment goes through a systematic process, produces products that meet quality standards, and is proven to be effective in supporting Natural Science learning at the elementary school level.
4	Mobile Application of Animal Recognition for Elementary Students with Augmented Reality (Suratman, 2021)	This research applies the Multimedia Development Life Cycle (MDLC) approach which consists of six phases, namely concept, design, material collection, assembly, testing, and distribution.	Application testing is done using alpha test, beta test, System Usability Scale (SUS), and effectiveness test, which is an evaluation of scripts/programs based on application functions. This research produces software "Mobile Application of Animal Recognition for Elementary Students with Augmented Reality". The results of the alpha test showed 100%, indicating that this application passed without the need for additional improvements. The result of the beta test is

			97%, indicating that this application is suitable for use. While the result of SUS is 82.5%, indicating that this application is also feasible to use. Based on the results of all these tests, it can be concluded that this application is suitable for learning about animal recognition and is expected to be a new method of learning animal recognition.
5	Development of Science Learning Media for Solar System Materials through Augmented Reality Applications to Increase Learning Motivation of State Elementary Students in Adiwerna District, Tegal Regency (Hidayat, 2024)	This study used a Research and Development (R&D) development approach by applying the ADDIE development model as its main framework.	Science learning media on solar system material using Augmented Reality application technology for grade VI elementary school students has been proven appropriate based on evaluations from three validators with material validation reaching 96%. In addition, in the media aspect, this media gets an average score of 93%. The effectiveness of the use of science learning media based on Augmented Reality applications for grade VI students in studying Solar System material can be supported by an increase in student learning outcomes from the initial test (pre-test) to the final test (post-test) in the experimental class, which increased from 20% to 70%.
6	Designing Augmented Reality Applications as Solar System Learning Media in Grade 6	The development method used in this research is the Multimedia	The test results before and after using the Augmented Reality (AR) application in Solar System learning show significant differences. The

Elementary School Development Life Cycle (MDLC). (Matin & Utomo, 2023)	average pre-test score was 57, while in the post-test it increased significantly to 88. This shows that the use of AR applications is effective in improving students' understanding of the material. Thus, AR application is considered as an effective, efficient, and interesting learning media, capable of providing interactive and in-depth learning experiences and increasing students' enthusiasm for Solar System learning.
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DISCUSSION

Based on the results of research (Edi Junaedi et al., 2023) the development of learning media in the form of Android-based applications using augmented reality is considered suitable for use as a learning tool for Natural Sciences in understanding planetary variations in the solar system. With the Android application that uses augmented reality technology, students at Penerus Bangsa Elementary School become more enthusiastic in learning natural science. This application is expected to be an effective learning media. Research results. According to Jannah and Atmojo (2022), the utilization of innovative digital media technologies such as Augmented Reality (AR) and digital games has successfully improved students' critical thinking skills in the learning process of Natural Sciences at the elementary school level. The results showed that the use of AR was effective in helping students understand Natural Science concepts and increasing their learning motivation. This research provides recommendations that the use of digital games can be implemented in both online and in-class learning.

According to (Suratman, 2021), application checks are carried out using the alpha test, beta test, SUS, and effectiveness test methods. These methods are used to test scripts or programs based on the function of the application. The results of the study produced a software with the title "Mobile Augmented Reality Application for Animal Recognition Learning for Elementary School Students". The results of this study provide recommendations that the application of the development results can be a new approach in learning science, especially in animal recognition material.

Based on a study by Hidayat (2024), the evaluation of Natural Science learning media to teach material about the solar system to grade VI elementary school students, using Augmented Reality technology to ensure the accuracy of

understanding of the material. 96% of the three validators, with the average value of media aspects reaching 93%. The effectiveness of using this media in learning Solar System material can be seen from the increase in student learning outcomes between the pre-test and post-test in the experimental class, which rose from 20% to 70%. The results of this study indicate that the use of augmented reality technology in science learning has a positive impact and is able to improve the results of science learners. The same study was conducted by Matin & Utomo (2023) that the use of AR technology in teaching Solar System can substantially improve students' understanding. Thus, AR is considered an effective, efficient, and interesting learning tool, and is able to provide an interactive and in-depth learning experience, as well as increase students' interest and understanding of the Solar System.

Based on existing assessments related to the use of AR technology, it can be seen that the use of educational games based on AR technology has proven effective in increasing motivation to learn science, increasing critical thinking skills and improving learning outcomes for elementary school students. AR-based learning media development has great potential to be developed in order to complement the material that has been developed with AR technology. Innovations in AR-based digital media make it easier for students to understand science concepts and significantly increase their learning motivation. Therefore, the use of AR-based educational games can be considered as an effective strategy to increase the motivation to learn science in elementary school students.

CONCLUSIONS

Based on an in-depth investigation of how effective the use of AR-based educational games is to increase motivation to learn Natural Sciences (IPA) among elementary school students, it can be concluded that the use of AR technology-based educational games has proven effective in increasing motivation to learn science, increasing critical thinking skills and improving learning outcomes for elementary school students. The results of analyzing data searches on the google scholar database show that research related to AR-based educational games has been widely researched at various levels of education. Especially research for elementary school students, AR-related research in the 2019 to 2023 time period obtained data as many as 344 articles with an average publication per year of 57.3 publications. Judging from the development from 2019 to 2023, there is a tendency to increase publications which means that the interest of researchers related to this topic continues to increase and is predicted to continue to grow given the support of technological developments that also continue to grow. The potential for research related to the use of AR technology is still large with various specific study focuses such as increasing interest, motivation, critical thinking skills and so on.

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