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Augmented Reality and Its Use in Elementary School Education: A Systematic Literature Review

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Abstract: Learning in elementary schools, in this era of information technology development, should ideally utilize existing technology to enhance students' motivation and interest in learning. Ultimately, this can address learning issues and improve students' understanding and thinking abilities. This study aims to determine augmented reality's contribution and practical implications in elementary school education. This research used a Systematic Literature Review (SLR) with a selection of 29 articles related to the use of augmented reality in elementary school education. The PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) method is employed for article searches in this research. The PRISMA method consists of four stages: (1) data search; (2) data screening; (3) data eligibility; (4) identifying similarities and differences from the obtained data. Based on the review results, it is evident that augmented reality positively contributes to various subjects and can be integrated with games and STEM education. Augmented reality also has excellent practical implications in education because it can increase students' motivation, interest, understanding, and critical and creative thinking abilities. Augmented reality is also capable of enhancing students' 21st-century skills.
Keywords: augmented reality, learning media, learning technology.

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Introduction

Learning, especially in elementary schools, currently faces complex challenges that require extra attention. One of the main challenges in elementary school education is the lack of student interest and motivation in learning (Pangestu et al., 2024; Salimi et al., 2024). Several studies reveal that student interest and motivation in learning significantly affect the effectiveness of education (Toding & Wibowo, 2024; Harokah et al., 2024). Fadhli et al. (2022) and Özeren & Top (2023) highlighted that many elementary school students show disinterest in participating in lessons, often attributing this apathy to the conventional and monotonous teaching methods. This observation resonates with the conclusions drawn by Fakhrudin (2018) and Sagan et al. (2022a), who emphasized that conventional learning approaches, coupled with a heavy reliance on textbooks, often fail to meet the diverse learning needs of students. To enhance student motivation and improve learning outcomes, elementary schools must adopt more interactive pedagogical approaches integrating technology as a core teaching medium

(Achmad & Utami, 2023; Destiana & Dewi, 2024; Nurhikmah & Wibowo, 2024). Bistaman et al. (2018a) and Marín et al. (2022) underscored the potential of technology to foster increased engagement among students while injecting a sense of dynamism into the learning environment. Innovations such as Augmented Reality (AR) hold promise in providing students with vivid and immersive learning experiences, enabling them to grasp complex subject matter through visual and interactive means. Key findings from the research by Kravtsov (2020) highlight AR-based media's significant role in reinforcing students' understanding of concepts and boosting their motivation to learn.

Augmented reality has been extensively applied in educational settings, from elementary to secondary levels. Numerous studies on the use of AR in school education indicate that AR media can significantly enhance student motivation, self-efficacy, and active participation (Demircioglu et al., 2022; Elsayed & Al-Najrani, 2021; Kurnianto et al., 2020; Lu et al., 2020; Özeren & Top, 2023; Rahmawati & Wulan, 2022; Ridwan et al., 2023; Silva et al., 2023). It also boosts academic achievement (Abdullah et al., 2022; Demircioglu et al., 2022; Fakhrudin, 2018; Garzón & Acevedo, 2019; Guhl, 2019; Hussein et al., 2023; Lu et al., 2020; Nincarean et al., n.d.; Özeren & Top, 2023; Silva et al., 2023), and critical thinking skills (Angraini et al., 2024a; Dewi & Kuswanto, 2023; Syawaludin et al., 2019a, 2019b). AR media has also been widely combined with various learning models and approaches, such as inquiry-based learning (Wen et al., 2023a; Santoso et al., 2024; Awaliyah et al., 2024), problem-based learning (Rahmasari & Kuswanto, 2023), problem-solving approaches (Guntur & Setyaningrum, 2021), and STEM education (Costa & Domingos, 2019; Ibáñez & Delgado-Kloos, 2018). Furthermore, bibliometric studies have explored how AR is utilized in education and learning (Akhiruyanto & Yudhistira, 2024; Angraini et al., 2024b; Archambault et al., 2009; Hariyanto et al., 2024; Indrawan et al., 2024; Juan & Dewitt, 2024; Li & Li, 2024; Zhang et al., 2024). Systematic literature reviews (SLRs) on AR applications in education are also well documented (Akçayır & Akçayır, 2017; Ekanayake & Gayanika, 2022; Fotaris et al., n.d.; Ibáñez & Delgado-Kloos, 2018; Lampropoulos et al., 2022; Mukhtarkyzy et al., 2023). However, most SLRs focus on broader educational levels, and only one study specifically examines SLRs in elementary schools.

This study focuses on game-based AR, discussing the effectiveness of AR games in elementary learning and the types of AR devices used in game-based learning. There remains a significant gap regarding the contribution and practical implications of AR in elementary education. The identified research problem is the lack of validated findings demonstrating AR utilization's contributions and practical implications in this context. The primary aim of this study is to explore and understand AR media's contributions and practical implications in elementary education.

This problem is formulated into two research questions:

1. What are the contributions of augmented reality in elementary education?
2. What are the practical implications of augmented reality in elementary education?

Methods

The method used in this study is the Systematic Literature Review (SLR). The PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) method is employed for article searches in this research. The PRISMA method consists of four stages: (1) data search; (2) data screening; (3) data eligibility; and (4) identifying similarities and differences from the obtained data (Moher et al., 2009). Thus, the stages of the SLR in this study can be seen in Figure 1.

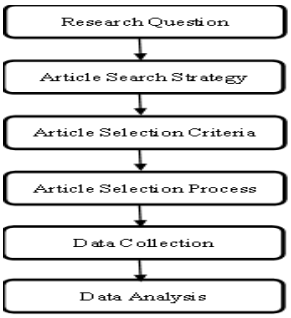

Figure 1. SLR Research Steps

Article searches in this study were conducted on websites such as Google Scholar, ERIC, and Springer from 2018 to 2024. The selected articles are those that are relevant to the research questions. Keywords used to search for articles include "Augmented Reality," "Augmented Reality in Elementary Education," and "How Augmented Reality Can Enhance Learning in Elementary Schools." Based on these keywords, articles obtained from the databases are related to the use of Augmented Reality in elementary school education.

a. To obtain articles suitable for SLR study materials, the selection criteria for this research are as follows: Inclusion Criteria (Acceptance)
   1. Articles relevant to the keywords.
   2. Articles published from 2018 to 2024.
   3. Selected articles are in the form of articles and/or journals.
   4. Articles discussing the use of augmented reality in elementary schools.

b. Exclusion Criteria (Rejection)
   1. Articles not relevant to the keywords.
   2. Articles published before 2018.
   3. Selected articles are not in the form of articles and/or journals.
   4. Articles not discussing the use of augmented reality in elementary schools.

The article search process used the PRISMA method. Article searches used the established criteria, including keyword relevance, publication year, article and/or journal format, and discussion of augmented reality use in elementary schools. The article search flow can be seen in Figure 2.

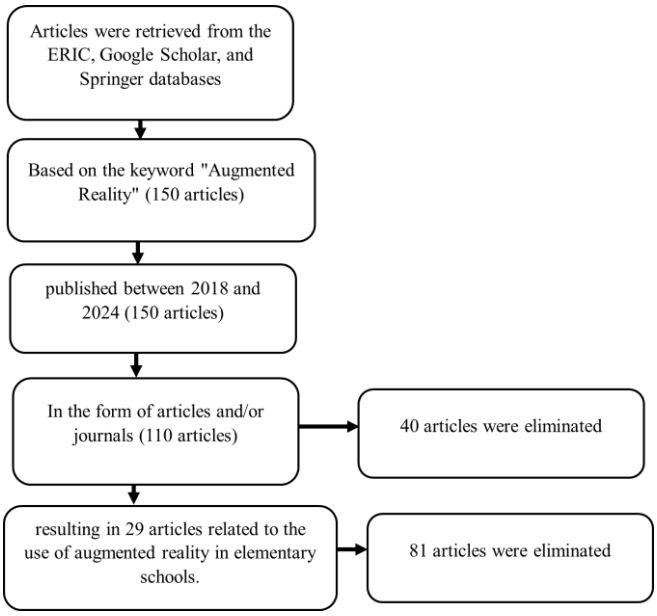

Figure 2. The Process Flow of Article Search

Based on the data collection results and selected articles that met the criteria, 26 articles were obtained from the ERIC, Google Scholar, and Springer databases. During the data analysis phase, analysis criteria were established for each research question. The collected data was organized into a spreadsheet with columns for criteria, including title, authors, year of publication, publisher, research contributions, and practical implications of the studies. The data analysis in this study was aligned with the objectives and research questions, specifically focusing on the contributions and practical implications of augmented reality in primary education. The selected articles were reviewed and analyzed for their research findings to determine the contributions of AR to primary education. Researchers also examined the practical implications of each selected research article, such as the abilities that could be enhanced and/or developed through the use of AR in primary education. Each category was descriptively analyzed, classified into similar categories, and elaborated upon in the discussion section.

Results and Discussion

Results

Based on the literature search results matching the keywords and publication years (2018 - 2024) for research articles on the use of augmented reality in elementary education, 54 relevant articles were obtained and can be seen in Table 1.

Table 1. Augmented Reality Articles in Elementary Schools Year 2018 - 2024

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
1	Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. 2019. *Virtual Reality.* Nikolaos Pellas, Panagiotis Fotaris, Ioannis Kazanidis, David Wells. DOI:10.1007/S10055-018-0347-2. https://cris.brighton.ac.uk/ws/files/505178/VR-paper-PF.pdf	Systematic review of literature on ARGBL in compulsory education. Analysis of 21 studies published between 2012 and 2017 in 11 indexed journals.	ARGBL can increase student motivation and improve learning outcomes. Incorporating ARGBL into teaching can enhance the learning experience.
2	Development of Augmented Reality-Based Interactive Multimedia to Improve Critical Thinking Skills in Science Learning. 2019. *International Journal of Instruction.* Ahmad Syawaludin, Gunarhadi Gunarhadi, Peduk Rintayati. DOI:10.29333/IJI.2019.12421A. https://files.eric.ed.gov/fulltext/EJ1230077.pdf	Development of augmented reality-based interactive multimedia for science learning. Improvement of critical thinking skills in elementary school teacher education students.	Augmented reality-based interactive multimedia can improve critical thinking skills in science learning. The developed multimedia is feasible to use according to experts and users.
3	Integrating augmented reality into inquiry-based learning approach in primary science classrooms. 2023. *Educational Technology Research and Development.* Yun Wen, Longkai Wu, Sujin He, Beng Chong Teo, Chee-Kit Looi, Yiyu Cai. DOI:10.1007/s11423-023-10235-y. https://link.springer.com/content/pdf/10.1007/s11423-023-10235-y.pdf	.Investigates integration of AR and IBL in science learning. Examines impact on academic performance and 21st century skills.	QIMS framework can guide AR learning activities for primary school students. AR with QIMS can improve academic performance and soft skills.
4	The Effect of Augmented Reality on Students' Learning Performance in Stem Education. 2020. Information-an *International Interdisciplinary Journal.* Plamen Petrov, Tatiana Atanasova.	Analyzed effect of augmented reality on students' learning performance in STEM.	AR enhances STEM learning performance in secondary school. Case study shows positive impact of AR in STEM education.

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
	DOI:10.3390/INFO11040209. https://www.mdpi.com/2078-2489/11/4/209/pdf	Presented case study of delivering STEM content using augmented reality.	
5	The effect of using augmented reality applications on social studies education. 2020. *Research and Experience Journal.* Yasin Gümbür, Muhammet Avaroğullari. DOI:10.47214/ADEDER.835927. https://dergipark.org.tr/en/download/article-file/1431195	Technology era with continuous and rapid developments. Innovations aiming to improve human life.	Use of AR applications in social studies courses. Students need mobile devices for AR applications.
6	Augmented reality: effect on conceptual change of scientific. 2019. *Bulletin of Electrical Engineering and Informatics.* Danakorn Nincarean Eh Phon, Ahmad Firdaus Zainal Abidin, Mohd Faizal Ab Razak, Shahreen Kasim, Ahmad Hoirul Basori, Tole Sutikno. DOI:10.11591/EEI.V8I4.1625. https://www.beei.org/index.php/EEI/article/download/1625/1242	Investigated the effect of integrating AR on conceptual change in scientific concepts. Found that most students were able to correct their misconceptions and have a scientific conceptual understanding after learning through AR.	AR can be integrated into education for conceptual change. AR can correct misconceptions about scientific concepts.
7	*Ngelmu*: augmented reality-based P*anji* story learning application in game-based learning as an effort to revitalize culture and character education in elementary school. 2023. *Linguistik, Terjemahan, Sastra (Lingtersa).* Raselly Elfa Putri, Fikry Prastya Syahputra. DOI:10.32734/lingtersa.v4i1.10714. https://talenta.usu.ac.id/lingtersa/article/download/10714/5841	*Ngelmu* is an augmented reality-based Panji story-learning application. It aims to revitalize culture and character education in elementary schools.	*Ngelmu* application can increase students' interest in learning Panji stories. *Ngelmu* application can introduce and preserve the Panji story to younger generations.
8	Virtual Reality Education In Era 5.0. 2022. *Journal Research of Social Science, Economics, and Management.* Hendrik Legi, Yoel Giban, Prima Hermanugerah. DOI:10.36418/jrssem.v2i04.303. https://jrssem.publikasiindonesia.id/index.php/jrssem/article/download/303/772	Virtual reality model improves students' understanding and learning outcomes. Quality of human resources emphasized prosperity in era 5.0.	Virtual reality improves student understanding and learning outcomes significantly. Encourages teachers to enhance quality and creativity in education.
9	Generative learning strategies do not diminish primary students' attitudes towards augmented reality. 2021. *Education and*	Positive attitudes towards AR maintained with generative learning strategies.	Positive attitudes towards AR maintained with generative learning strategies.

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
	Information Technologies. Josef Buchner. 10.1007/S10639-021-10445-Y. https://link.springer.com/content/pdf/10.1007/s10639-021-10445-y.pdf	Gender differences in accessibility factor were observed, which are related to computer skills.	Gender differences in accessibility factor observed, especially with boys.
10	Enhancing pupil engagement and learning through augmented reality-based interactive phonetics education. 2023. *World Journal of Advanced Engineering Technology and Sciences.* DOI:10.30574/wjaets.2023.9.1.0131. https://wjaets.com/sites/default/files/WJAETS-2023-0131.pdf	Augmented reality for interactive phonetics education for young students. Bridging gap between traditional teaching and engaging educational experiences.	Augmented reality (AR) technology can enhance the educational experience for students. Implementing AR-based interactive learning projects can revolutionize phonetics education.
11	The use of augmented reality technology in primary education. 2022. *Revista Amazonia Investiga*. Olena Sagan, Valeriia Blakh, Ondřej Los, O.M. Liba, Olena Kazannikova. 10.34069/ai/2022.49.01.3. https://doi.org/10.34069/ai/2022.49.01.3	Positive impact on cognitive activity and studying results of pupils. Immersive technologies in education enhance didactic means.	AR tech enhances cognitive activity and study success in primary education. Challenges include technical and pedagogical difficulties, digital skills, and organization.
12	Enhancing social science learning with augmented reality for primary students in a CLIL context. 2023. *European journal of educational research.* Amaia Aguirregoitia Martínez, Irene Núñez García. DOI:10.54745/ejerv4n1-002. https://ojs.europubpublications.com/ojs/index.php/ejer/article/download/738/716	AR technology improved student learning outcomes significantly. Positive opinions from both students and teachers towards AR technology.	AR positively impacts Social Science learning outcomes for primary students. Teachers find technology beneficial if properly planned and resourced.
13	Game edukasi pengenalan tumbuhan untuk anak sekolah dasar kelas 3 berbasis augmented reality. 2022. *JIKA (Jurnal Informatika).* Anggi Pratiwi Puspitasari, Biktra Rudianto, Muhammad Aldi Prasetya. 10.31000/jika.v6i1.5155. http://jurnal.umt.ac.id/index.php/jika/article/download/5155/3103	Augmented reality app for interactive and fun learning medium. Implementation of educational game for exploring through augmented reality.	Interactive and fun learning medium for elementary school students. Augmented reality app enhances exploration through camera for educational purposes.

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
14	Improving learning in physical education: Augmented reality mobile app-based for fundamental motor skill. 2022. *Jurnal Sportif: Jurnal Penelitian Pembelajaran*. Budiman Agung Pratama, Sucipto Sucipto, Yulingga Nanda Hanief. DOI:10.29407/js_unpgri.v8i2.18508. https://ojs.unpkediri.ac.id/index.php/pjk/article/download/18508/2875	Impact of COVID-19 on education, especially elementary school students. Testing augmented reality interactive media for fundamental motor skills.	AR enhances fundamental motor skills in 9-10-year-old children. AR can be an alternative teaching media in physical education.
15	Gender Equality in Elementary Education: A Dream or Reality. 2022. *IARS International Research Journal*. Parvaiz Ahmad Dar. DOI:10.51611/iars.irj.v12i01.2022.187. https://researth.iars.info/index.php/curie/article/download/187/150	Special scholarship schemes for low-income families to promote education. Gender-wise data on out-of-school children provided.	Highlight importance of elementary education, especially for underprivileged girls. Implement new schemes for out-of-school children in rural areas.
16	Design and Validation of an Augmented Reality Teaching System for Primary Logic Programming Education. 2022. *Sensors*. ChingChih Tsai, Yu-Cheng Lai. DOI:10.3390/s22010389. https://www.mdpi.com/1424-8220/22/1/389/pdf?version=1641379213	AR-based teaching system for logic programming. Enhancing learning effectiveness and motivation in primary education.	Early access to logic programming lessens pressure on middle schoolers. AR-based system enhances learning effectiveness and motivation in programming.
17	Revolutionizing elementary disaster prevention education and training via augmented reality-enhanced collaborative learning. 2022. *International Journal of Engineering Business Management.* Su-ju Lu, Yu-Chiao Lin, Kim Hua Tan, Ying-Chieh Liu. DOI:10.1177/18479790211067345. https://journals.sagepub.com/doi/pdf/10.1177/18479790211067345	AR enhances collaborative learning in disaster prevention education. Provides reference for national DE and training improvement.	Enhances disaster prevention education through AR technology. Improves collaborative learning effectiveness and motivation in elementary schools.
18	Active Learning Augmented Reality for STEAM Education--A Case Study. 2020. *Education Sciences.* Joanna Jesionkowska,	Investigating AR for engaging students in learning STEAM subjects.	Active Learning AR enhances STEAM education, developing

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
	Fridolin Wild, Yann Deval. 10.3390/EDUCSCI10080198. https://files.eric.ed.gov/fulltext/EJ1264642.pdf	Enabling students to develop their own AR applications.	21st-century skills. AR technology increases student motivation and engagement in STEAM subjects.
19	Assessing the Influence of Augmented Reality in Mathematics Education: A Systematic Literature Review. 2023. *International Journal of Learning, Teaching and Educational Research.* Samsul Pahmi, Agus Hendriyanto, Sani Sahara, Lukman Hakim Muhaimin, Krida Singgih Kuncoro, Budi Usodo. 10.26803/ijlter.22.5.1. https://ijlter.org/index.php/ijlter/article/download/7227/pdf	Systematic literature review on the effects of AR in mathematics education. AR used as a supporting medium for interactive learning.	AR can be used as a pedagogical tool in mathematics education. AR can help overcome learning barriers and mathematical anxiety.
20	The Use of Augmented Reality Technology for Primary School Education in Perlis, Malaysia. *IOP Science.* Izwan Nurli Mat Bistaman, Syed Zulkarnain Syed Idrus, Salleh Abd Rashid. DOI:10.1088/1742-6596/1019/1/012064. https://iopscience.iop.org/article/10.1088/1742-6596/1019/1/012064/pdf	AR enhances teaching and learning in primary school education. AR fosters collaboration between teachers and students for interactive learning.	AR enhances collaboration, motivation, and engagement in primary education. AR offers unique educational experiences for effective teaching and learning.
21	Augmented Reality-Based Elementary Level Education for Bengali Character Familiarization. *Springer.* Mohammad Jaber Hossain, Towfik Ahmed. DOI:10.1007/S42979-020-00402-W. https://link.springer.com/content/pdf/10.1007/s42979-020-00402-w.pdf	Learn Bengali letters and digits interactively using AR technology. Increase student performance and engagement in learning Bengali characters.	Enhances Bengali character learning for children through interactive AR technology. Increases student engagement and performance in learning Bengali letters and digits.
22	Augmented reality based human digestive organ learning application with multi marker method. 2022. *Jurnal Teknik Informatika.* Ellen Pratama, I. G. Ngurah Suryantara. DOI:10.20884/1.jutif.2022.3.5.260.	Development of an augmented reality learning application called ORCEMAR. Successful implementation of the multimarker method in the application.	Augmented reality aids in visualizing human digestive organs for students. ORCEMAR application enhances interest and

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
	https://doi.org/10.20884/1.jutif.2022.3.5.260		understanding in learning human anatomy.
23	An Augmented Reality Learning Toolkit for Fostering Spatial Ability in Mathematics Lesson: Design and Development. 2021. *European Journal of Science and Mathematics Education*. Bilal Özçakir, Erdinc Cakiroglu. 10.30935/SCIMATH/11204. https://www.scimath.net/download/an-augmented-reality-learning-toolkit-for-fostering-spatial-ability-in-mathematics-lesson-design-and-11204.pdf	Integration of augmented reality in educational settings Designing an augmented reality learning toolkit	Mobile AR interface can improve spatial ability in students AR technology can be used in mathematics education
24	Eddie – 3D Scanning and Augmented Reality in Education. *Sciendo*. Csaba Juhász, Kristóf Muhi, Zsolt Csaba Johanyák. DOI:10.33894/MTK-2019.11.19. https://sciendo.com/pdf/10.33894/mtk-2019.11.19.	Eddie combines smartphone app with school book for interactive learning. Application uses AR to display 3D models, animations, and videos.	Enhances traditional education with interactive AR technology. Visualizes digital content on smartphones or tablets for learning purposes.
25	A Review of Augmented Reality Applications for History Education and Heritage Visualisation. *Sensors*. Jennifer Challenor, Minhua Ma. DOI:10.3390/MTI3020039. https://www.mdpi.com/2414-4088/3/2/39/pdf	Augmented reality applications in history education Lack of research on using AR for Holocaust education	Augmented reality can enhance history education Augmented reality can convey the emotional weight of historical events
26	A Preliminary Study of the Influence of Game Types on the Learning Interests of Primary School Students in Digital Games. 2020. *Education Sciences*. Min-Bin Chen, Siou-Ge Wang, You-Ning Chen, Xiao-Fang Chen, Yi-Zhen Lin. DOI:10.3390/EDUCSCI10040096. https://files.eric.ed.gov/fulltext/EJ1251670.pdf	Developed "Mobile Plant" app combining games and augmented reality. Showed positive results in game difficulty and content absorption.	Designing educational games to balance education and entertainment is crucial. Combining games with real experiences can increase student interest.

No.	Title/Year/Publisher/Author/ DOI/URL	Research Contribution	Practical Implication
27	Augmented Reality Media Development in STEAM Learning in Elementary Schools. 2022. *Ingénierie Des Systèmes D'information*. Rukayah, Joko Daryanto, Idam Ragil Widianto Atmojo, Roy Ardiansyah, Dwi Yuniasih Saputri, Moh Salimi. DOI:10.18280/isi.270313. https://www.iieta.org/download/file/fid/77651	Emphasized seven skills including critical thinking, creativity, and problem-solving. Implemented AR media in various platforms for educational purposes.	Develop AR media in STEAM for immersive learning experiences. Initial design includes Batik, Wayang, Gamelan, Borobudur Temple, etc.
28	The Effect of Augmented Reality Applications in Science Education on Academic Achievement and Retention of 6th Grade Students. 2020. *Journal of Education in Science Environment and Health.* İsmet Yildirim, Munise Seçkin Kapucu. DOI:10.21891/JESEH.744351. https://files.eric.ed.gov/fulltext/EJ1283600.pdf	Technology literacy importance in education for academic achievement and retention. AR applications enhance academic success and knowledge retention in students.	AR applications in science education can increase academic achievement. AR applications can enhance the retention of learned knowledge.
29	Pengembangan Aplikasi Augmented Reality Pada Mata Pelajaran Bahasa Inggris Untuk Kelas 1 Sekolah Dasar. 2023. *Jurnal Teknologi.* Dwi Warti Ratnawati. DOI:10.34151/jurtek.v16i1.4237. https://ejournal.akprind.ac.id/index.php/jurtek/article/download/4237/3063	Technology literacy importance in education for academic achievement and retention. AR applications enhance academic success and knowledge retention in students.	AR applications in science education can increase academic achievement. AR applications can enhance the retention of learned knowledge.

Discussion

Table 1 shows that the use of augmented reality in elementary education, based on several conducted studies, has been proven to provide positive contributions and have good practical implications. The following section will discuss the findings of the review of 29 articles based on the research questions.

Contribution of Augmented Reality in Elementary Education

Based on the review results in Table 1, augmented reality as a learning tool in elementary education has positive contributions. For instance, augmented reality media can be integrated and effectively enhance Science learning (Nincarean et al., 2019; Pratama & Suryantara, 2022; Sari et al., 2022; Syawaludin et al., 2019; Wen et al., 2023; Wibowo, 2020). Additionally, augmented reality also has positive contributions to Mathematics (Ozcakir & Cakiroglu, 2021; Pahmi et al., 2023), Social and Cultural Sciences (Challenor & Ma, 2019; Legi et al., 2022; Lu et al., 2022; Putri & Syahputra, 2023), Language (Daniel A & Suleiman, I.A, 2023; Setiawan et al., 2023; Masfufah & Wibowo, 2024; Wibowo et al., 2023). Augmented reality can also be used in gender-based learning (Buchner, 2022; Dar, n.d.). Furthermore, augmented reality can be integrated into STEM/STEAM learning (Jesionkowska et al.,

2020; Petrov & Atanasova, 2020), and augmented reality can also be combined with game-based learning (Chen et al., 2020; Pellas et al., 2019; Sari et al., 2022). In general, augmented reality has significant contributions to learning and education, especially in elementary schools (Bistaman et al., 2018; Martínez & García, 2023; Pratama et al., 2022; Sagan et al., 2022; Tsai & Lai, 2022; Yildirim & Kapucu, 2020).

The use of AR in elementary education demonstrates a very positive impact on enhancing the quality of learning (Cai et al., 2022; C. H. Chen, 2020; Cheng & Tsai, 2013; Ibáñez & Delgado-Kloos, 2018; Kasinathan et al., 2018). Augmented reality can provide interactive and immersive learning experiences, allowing students to understand abstract concepts more easily through engaging visualizations (Abdullah et al., 2022; Bratitsis et al., 2017; Hendajani et al., 2018, 2019; Lu et al., 2020; Syawaludin et al., 2019d; Umamah et al., 2020). For example, in science learning, augmented reality can visualize molecular structures or photosynthesis processes in three dimensions, which were previously difficult to explain only with two-dimensional images or text. Additionally, augmented reality enhances student engagement in the learning process (Umamah et al., 2020). Augmented reality's interactivity makes students more actively participate and motivated to learn. Literature studies show that the use of augmented reality in classrooms can increase student motivation and interest in learning (Demircioglu et al., 2022; Elsayed & Al-Najrani, 2021; "Influence of Augmented Reality (AR) Technology via Mobile Application for Knowledge Transfer Program in Fourth Industrial Revolution Era," 2021; Lu et al., 2020; Silva et al., 2023). This increased motivation and interest will impact overall student performance improvement. Furthermore, AR also contributes to developing 21st-century skills such as problem-solving (Guntur & Setyaningrum, 2021), collaboration, and creativity. This enhances their understanding of the subject matter and develops important social and cognitive skills for the future (Dilmen & Atalay, 2021).

Practical Implications of Augmented Reality in Elementary Education

Based on the review results of articles in Table 1, besides the positive contributions, augmented reality also has very good practical implications in elementary education. Augmented reality in elementary education has been proven to enhance student motivation and interest in learning (Bistaman et al., 2018b; Chen et al., 2020; Jesionkowska et al., 2020; Lu et al., 2022; Pellas et al., 2019; Pratama & Suryantara, 2022; Putri & Syahputra, 2023; Tsai & Lai, 2022; Brilatin & Wibowo, 2024; Viantorus et al., 2024; Efendi et al., 2024). Augmented reality also improves the learning experience, participation, collaboration, and activeness of students (Bistaman et al., 2018b; Daniel A & Suleiman, I.A, 2023; Juhász et al., 2019; Legi et al., 2022; Setiawan et al., 2023; Pellas et al., 2019; Sari et al., 2022; Rukayah et al., 2022). Additionally, augmented reality enhances 21st-century skills, students' abilities, and understanding (Challenor & Ma, 2019; Jesionkowska et al., 2020; Legi et al., 2022; Lu et al., 2022; Martínez & García, 2023; Ozcakir & Cakiroglu, 2021; B. A. Pratama et al., 2022; Pratama & Suryantara, 2022; Sagan et al., 2022; Syawaludin et al., 2019; Yildirim & Kapucu, 2020). This is because learning using augmented reality can overcome barriers, boredom, and learning difficulties and enhance student learning effectiveness (Setiawan et al., 2023; Pahmi et al., 2023).

Based on the research findings and discussion, it can be concluded that augmented reality significantly enhances elementary school students' motivation, engagement, collaboration, interest, skills, and learning achievement. The practical implication identified from the research findings and discussion is that augmented reality is crucial in improving students' learning outcomes and abilities.

Conclusion

Based on the research results, it can be concluded that augmented reality in elementary education has a very positive contribution as it is highly suitable for several subjects and can also be integrated with games and STEM-based learning. Augmented reality has also been practically proven to enhance students' abilities, understanding, and skills in learning, as its utilization has been shown to address learning problems, difficulties, and barriers by increasing student participation and collaboration in learning. Based on the research findings, the authors can provide some suggestions that should be considered by researchers and teachers who may read this article and aim to improve the quality of

education by utilizing augmented reality media, thus making learning more concrete for students. Ultimately, this article is expected to contribute motivation and insights for anyone involved in education (lecturers and teachers) to become alternative efforts to improve the quality of learning.

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