INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 13, Issue 1, (2024) E-ISSN: 2226-6348

The Usage of Augmented Reality Technology in Mathematics Education: A Systematic Literature Review

Vanessa Ivan, Siti Mistima Maat

Faculty of Education, Universiti Kebangsaan Malaysia

Email: p117123@siswa.ukm.edu.my

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v13-i1/20064 DOI:10.6007/IJARPED/v13-i1/20064

Published Online: 03 January 2024

Abstract

This systematic literature review aims to synthesise the trends in the use of Augmented Reality (AR) in mathematics education from 2019 to May 2023. The researcher selected articles from two databases, namely Scopus and Web of Science (WoS). From these two databases, 11 relevant articles were selected using the PRISMA guide. The findings of this study show an increasing trend in research related to this field since 2019. Indonesian researchers have made the most significant contribution in this field, and quantitative approaches are commonly used. The analysis also found that AR technology is used in three mathematical topics namely Geometry, Algebra, and Statistics and Probability. In addition, this study also examines the impact of the use of AR in mathematics education from the perspective of students' cognitive and affective development.

Keywords: Augmented Reality, Mathematics Education, Systematic Literature Review

Introduction

The rapid development of digital technology has progressed in line with changing times, especially during the Fourth Industrial Revolution era. The increasing use of digital technology has led to the emergence of digital culture, which has become ingrained in human culture (Sugiarni et al., 2022). With the passage of time, the accompanying components have also evolved. The advancement of technology has provided new opportunities in the field of education (Tulgar, 2019).

One of the significant concepts in the field of education is Augmented Reality (AR) technology. AR technology possesses distinctive features that set it apart from other technologies. According to Azuma et al (2001), AR involves the integration of the real and virtual worlds in a seamless environment, real-time interactivity, and three-dimensional (3D) visualisations. This allows users to see and interact with virtual objects that are integrated with the real world and create an immersive and realistic experience. In the present time, AR technology is increasingly popular in the education sector, including the field of mathematics where its use of AR has facilitated the teaching and learning of mathematics (Saundarajan et al., 2020).

In the teaching and learning of mathematics, AR technology offers significant advantages. A study by Rohendi and Wihardi (2020) on secondary school students in Indonesia found that the use of AR enhances students' spatial learning activities in geometry. AR usage can also aid students in better understanding concepts related to three-dimensional shapes. In another study conducted in Turkiye, Poçan et al (2023) discovered that a mobile-supported algebra learning environment had a positive impact on the academic achievement and motivation of secondary school students. The findings of these studies provide valuable insights into understanding how AR can be applied in the field of mathematics education and the extent of its effectiveness for secondary school students. However, the implementation of AR technology in the field of mathematics education is still limited (Lainufar et al., 2021). There is a lack of systematic literature reviews that comprehensively analyse the detailed usage of AR in mathematics learning (Bulut & Ferri, 2023). Therefore, a systematic literature review has been conducted to synthesise articles related to the use of AR in mathematics education for secondary school students. This study aims to address research questions as follows:

i. What are the research trends in terms of publication years, countries, and research approaches used for investigating the use of AR in mathematics education?
ii. What are the mathematical topics that utilise AR technology?
iii. What is the impact of using AR technology in mathematics education?

Methodology

This study employs a qualitative approach and a document analysis method to conduct a systematic literature review. Scopus and Web of Science (WoS) databases are used for searching for relevant articles. Scopus database is the largest abstract and citation database, covering articles from over 25,000 indexed journals (Elsevier, 2021). On the other hand, the WoS database is widely recognised as a highly comprehensive source of information and holds a strong reputation among researchers (Gusenbauer & Haddaway, 2020). The use of both databases allows the researchers to explore diverse sources and gain access to relevant articles in the research field. As a result, this study can provide a comprehensive and detailed understanding of the highlighted topics in the literature.

The PRISMA 2020 guidelines (Page et al., 2021) were chosen for use in this study. These guidelines have been adapted in the context of reporting, which involves the steps of identification, screening, eligibility and included. The guidelines also assist in providing a clear framework for researchers to organise and report the results of the literature review in a systematic and detailed manner.

Identification

The reviewer began the identification phase in May 2023. This phase is the initial step in the systematic search strategy, involving searching all terminologies and variations associated with the key keywords used in the study (Zain & Aiyub, 2021). Using the Boolean operators "OR" and "AND," the reviewer constructed a detailed and effective search string to aid in the identification process while searching for relevant journal articles. Searches were conducted in Scopus and WoS databases using the predetermined keywords listed in Table 1. To align the screening process, these keywords were exclusively used to retrieve results from each database. A total of 116 articles were obtained from Scopus, while 53 articles were obtained from WoS. The overall number of articles to be screened was 169.

Table 1
Database sources and search series

Database	Keyword
Scopus	TITLE-ABS-KEY (("augmented reality") AND ("mathematics education" OR "mathematics" OR "math*") AND ("secondary school" OR "middle school" OR "high school" OR "senior high school"))
Web of Science (WoS)	TS= (("augmented reality") AND ("mathematics education" OR "mathematics" OR "math*") AND ("secondary school" OR "middle school" OR "high school" OR "senior high school"))

Screening

The screening phase involves determining inclusion and exclusion criteria. To achieve the study objectives, the reviewer utilised the automatic filtering functions available in each database. These functions help narrow down the search scope and ensure that only relevant articles are considered (Mengist et al., 2020). Four criteria were established, including publication year, document type, language of writing, and article accessibility. Detailed specifications are provided in the inclusion and exclusion criteria, as outlined in Table 2. Screening the 169 articles using these criteria resulted in only 32 articles meeting the inclusion criteria. The rigorous screening process utilising the inclusion and exclusion criteria ensures that only relevant articles aligned with the research purpose will be considered for further analysis. During the cross-checking process of the 32 articles, the reviewer excluded eight articles identified as duplicates. These duplicate articles were removed to ensure the accuracy of the literature review and to avoid redundancy of information in the study analysis. After the screening, 24 articles in total were selected to proceed to the eligibility phase.

Table 2
Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication year	Publication from 2019 until May 2023	Publication before 2019
Document types	Journals (research articles)	Theses, proceedings, conferences, systematic literature reviews and books
Written language	English	Other than English
Accessibility	Open access (free)	Paid access

Eligibility

The eligibility phase involves a manual article review process to ensure that only articles that are truly suitable and aligned with the accepted objectives proceed to the next stage. According to Kraus et al (2020), reviewers can determine whether an article can address the research questions through abstract reading. Following this phase, only 11 articles were identified as eligible to undergo full-text reading. In this selection, article quality and effectiveness become primary factors to ensure that only the most relevant articles are chosen for further examination.

Included

The included phase is a crucial step that involves an in-depth reading by the reviewer (Kitchenham & Chartes, 2007). In this phase, the reviewer examined and read the 11 selected articles in detail to address the research questions established. This phase is a critical step to ensure that the selected articles are of high quality and contribute to the field of study being investigated. Figure 1 shows the steps of a systematic search strategy using the PRISMA guide adapted from (Page et al., 2021).

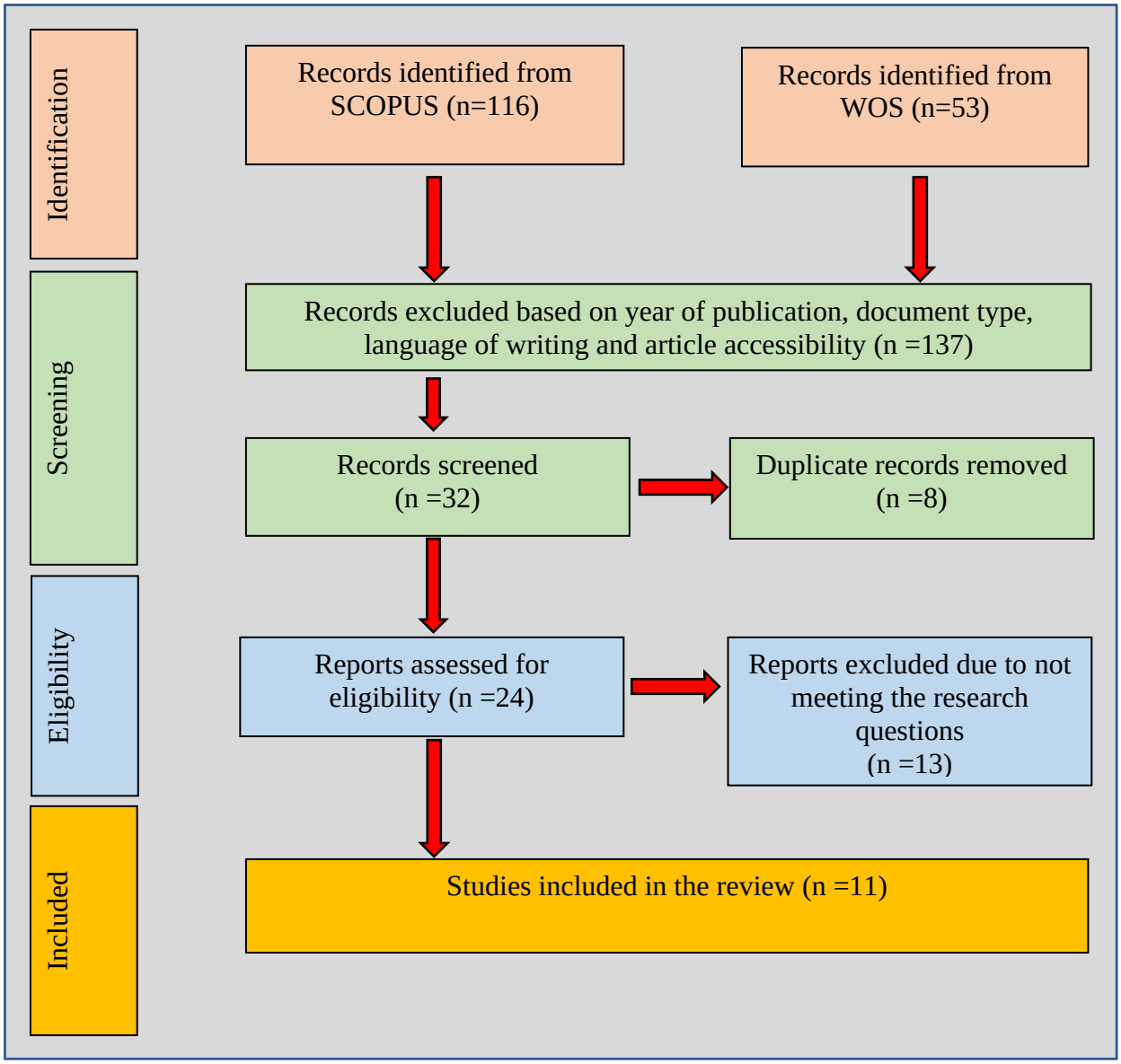

Figure 1: Steps of the PRISMA systematic search strategy (Page et al., 2021)

Research Findings

Article searching was conducted through the Scopus and WoS databases. The results yielded 169 articles based on the predefined keywords. After progressing through the four phases using the PRISMA guidelines, only 11 articles were selected. All the chosen articles have been thoroughly read. Relevant data that support addressing the research questions have also been extracted. This data include publication year, author's country, research approach, mathematical topics utilising AR for learning, and the impact of AR usage in mathematics education.

Research trends in the use of augmented reality in mathematics education

Year of Publication

Based on Figure 2, there are 11 articles published between 2019 and May 2023 that explore the use of AR in secondary school mathematics education. Most studies were conducted in 2021. There were four (4) articles published in 2021 (Elsayed & Al-Najrani, 2021; Kounlaxay et al., 2021; Mailizar & Johar, 2021; Ozcakir & Cakiroglu, 2021). There are three (3) articles published in 2023 (Poçan et al., 2023; Pujiastuti & Haryadi, 2023; Richardo et al., 2023). In 2020, there were two (2) articles published (Rohendi & Wihardi, 2020; Saundarajan et al., 2020). In 2019 and 2020, one (1) article was published (Cai et al., 2019; Majeed & ALRikabi, 2022). The publication year trend shows a consistent increase in the number of articles from 2019 until 2021. There is a decrease in the number of articles in 2022, but it increases again in 2023.

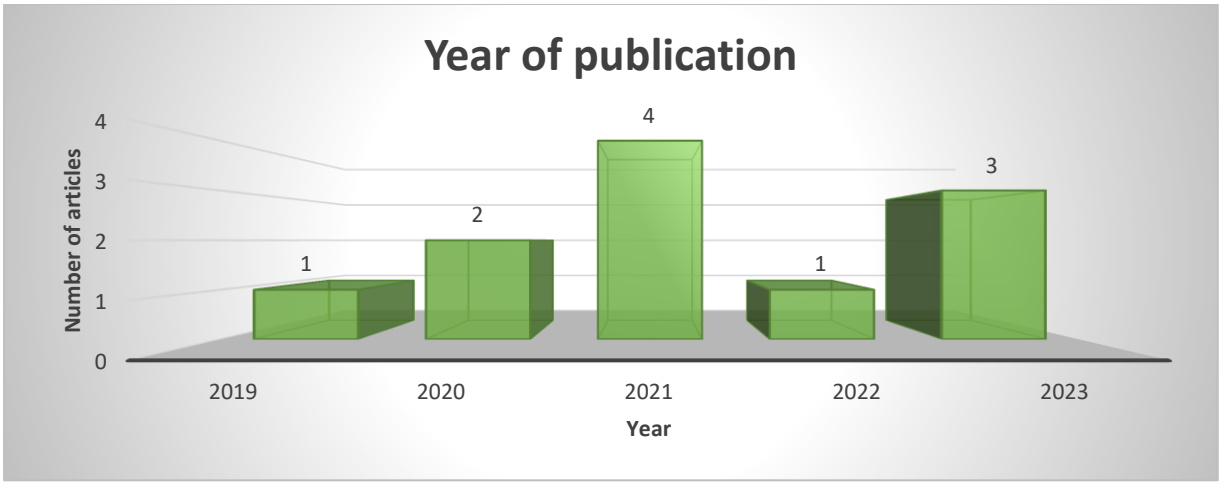

Figure 2: Research trends by year

Researcher Countries

The graph in Figure 3 displays the number of articles published by seven (7) countries. The analysis reveals that researchers from Indonesia have contributed the highest number of studies. has conducted four (4) studies Indonesia Mailizar & Johar (2021); Pujiastuti & Haryadi (2023); Richardo et al (2023); Rohendi & Wihardi (2020); Turkiye conducted two (2) studies (Ozcakir & Cakiroglu, 2021; Poçan et al., 2023). Iraq Majeed & ALRikabi (2022), South Korea Kounlaxay et al (2021), Saudi Arabia Elsayed & Al-Najrani (2021); Malaysia Saundarajan et al (2020), and China Cai et al (2019) each conducted one (1) study.

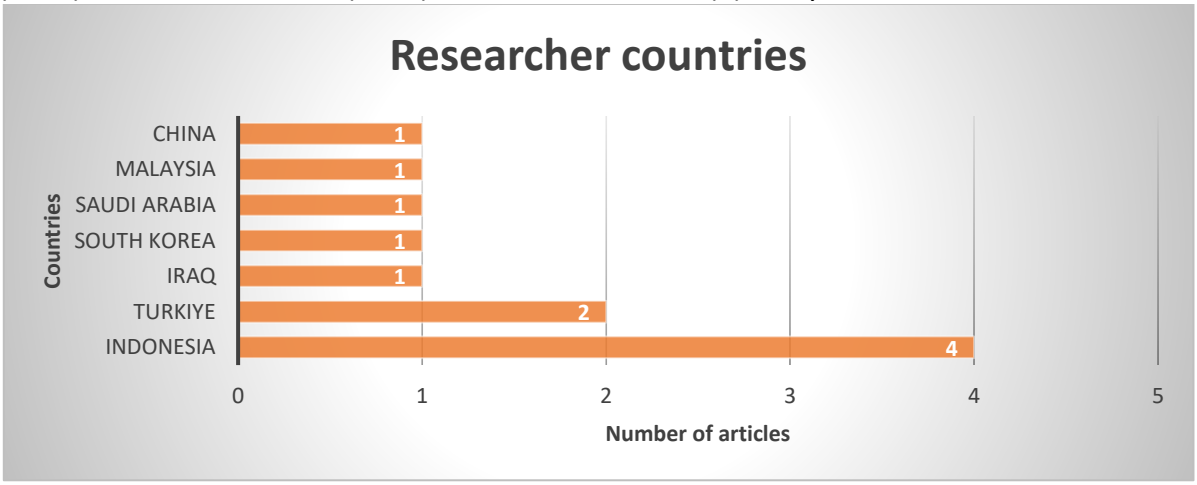

Figure 3: Research trends based on researcher countries

Research Approach

Table 3 displays the research approaches conducted in the selected articles. There are seven (7) studies using a quantitative approach (Cai et al., 2019; Elsayed & Al-Najrani, 2021; Kounlaxay et al., 2021; Mailizar & Johar, 2021; Majeed & ALRikabi, 2022; Pujiastuti & Haryadi, 2023; Saundarajan et al., 2020). Meanwhile, one (1) study utilises a qualitative approach (Rohendi & Wihardi, 2020), and one (1) study employs a mixed-methods approach (Poçan et al., 2023). Additionally, one (1) study uses Research and Development (R&D) (Richardo et al., 2023), while another study employs Educational Design Research (EDR) (Ozcakir & Cakiroglu, 2021).

Table 3
Research Approach

Authors (year)	**Research approach**
Richardo et al. (2023)	Research and Development (R&D)
Pujiastuti and Haryadi (2023)	Quantitative
Poçan et al. (2023)	Mixed method
Majeed and ALRikabi (2022)	Quantitative
Ozcakir and Cakiroglu (2021)	Educational Design Research (EDR)
Mailizar and Johar (2021)	Quantitative
Kounlaxay et al. (2021)	Quantitative
Elsayed and Al-Najrani (2021)	Quantitative
Saundarajan et al. (2020)	Quantitative
Rohendi and Wihardi (2020)	Qualitative
Cai et al. (2019)	Quantitative

Mathematical Topics that Utilize Augmented Reality

Based on Table 4, there are three mathematical topics that utilise AR in secondary mathematics education. Eight (8) studies employ AR in Geometry topics (Elsayed & Al-Najrani, 2021; Kounlaxay et al., 2021; Mailizar & Johar, 2021; Majeed & ALRikabi, 2022; Ozcakir & Cakiroglu, 2021; Pujiastuti & Haryadi, 2023; Richardo et al., 2023; Rohendi & Wihardi, 2020). Two (2) studies utilise AR in Algebra topics (Poçan et al., 2023; Saundarajan et al., 2020). Meanwhile, one (1) study uses AR in Statistics and Probability topics (Cai et al., 2019).

Table 4
Mathematical topics that utilise augmented reality.

Authors (year)	Geometry	Algebra	Statistics & Probability
Richardo et al. (2023)	✓		
Pujiastuti and Haryadi (2023)	✓		
Poçan et al. (2023)		✓	
Majeed and ALRikabi (2022)	✓		
Ozcakir and Cakiroglu (2021)		✓	
Mailizar and Johar (2021)	✓		
Kounlaxay et al. (2021)	✓		
Elsayed and Al-Najrani (2021)	✓		
Saundarajan et al. (2020)		✓	
Rohendi and Wihardi (2020)	✓		
Cai et al. (2019)			✓
Total	8	2	1

The impact of using augmented reality in mathematics education

The impact of using AR in mathematics education is classified based on the cognitive and affective domains. In the context of this study, the cognitive domain refers to the enhancement of understanding mathematical concepts. The affective domain pertains to students' attitudes and motivation towards mathematics.

Table 5 presents a list of selected studies categorised into cognitive and affective domains. The analysis reveals that there are five (5) articles that solely discuss the impact of AR usage within one domain, namely the cognitive domain (4 articles) and the affective domain (1 article). Meanwhile, there are six (6) articles that investigate the impact of AR-based learning in both cognitive and affective domains. The articles that discuss the usage of AR in both cognitive and affective domains provide a more comprehensive understanding of how this technology can enhance the comprehension of mathematical concepts while stimulating positive attitudes and motivation towards the subject.

Table 5
Classification of the impact domains of using augmented reality in mathematics education

Authors (year)	**Impact**	
	Cognitive	Affective
Richardo et al. (2023)	✓	
Pujiastuti and Haryadi (2023)	✓	
Poçan et al. (2023)	✓	✓
Majeed and ALRikabi (2022)	✓	✓
Ozcakir and Cakiroglu (2021)	✓	
Mailizar and Johar (2021)		✓
Kounlaxay et al. (2021)	✓	✓
Elsayed and Al-Najrani (2021)	✓	✓
Saundarajan et al. (2020)	✓	✓
Rohendi and Wihardi (2020)	✓	
Cai et al. (2019)	✓	✓
Total	10	7

Cognitive Impact

The impacts of using AR on students' cognitive development in mathematics include conceptual knowledge, procedural knowledge, and achievement in mathematics. The results of the analysis indicate that the use of AR in secondary mathematics education has the greatest impact on conceptual knowledge, with a total of six (6) studies. For procedural knowledge and achievement, each recorded five (5) studies. Table 6 presents a list of articles categorised according to their cognitive impact.

Table 6
The impact of using augmented reality on students' cognitive development in mathematics

Authors (year)	**Cognitive impact**		
	Conceptual knowledge	Procedural knowledge	Achievement
Richardo et al. (2023)			✓
Pujiastuti and Haryadi (2023)	✓	✓	
Poçan et al. (2023)	✓	✓	✓
Majeed and ALRikabi (2022)	✓		✓
Ozcakir and Cakiroglu (2021)		✓	
Kounlaxay et al. (2021)	✓	✓	
Elsayed and Al-Najrani (2021)		✓	
Saundarajan et al. (2020)			✓
Rohendi and Wihardi (2020)	✓		
Cai et al. (2019)	✓		✓
Total	6	5	5

Aspect of Conceptual Knowledge

The cognitive impact description of the conceptual knowledge aspect is presented in Table 7.

Table 7
Description of conceptual knowledge aspects

Authors (year)	Description
Pujiastuti and Haryadi (2023)	Students can interpret the comparison of quantities, relate it to the concept of circumference, find the concept of breadth, and relate it to the concept of equivalent comparison.
Poçan et al. (2023)	The use of AR enables modelling, visualisation, and the connection of mathematical concepts to real-world applications.
Majeed and ALRikabi (2022)	The use of AR technology has a positive effect on the development of spatial intelligence in mathematics.
Kounlaxay et al. (2021)	Students can enhance their understanding of geometry concepts using AR applications that enable the visualisation of 3D objects.
Rohendi and Wihardi (2020)	The use of AR enhances students' spatial learning activities in understanding three-dimensional shape concepts in Geometry.
Cai et al. (2019)	The use of AR in Statistics and Probability learning enhances the understanding of concepts for students with higher self-efficacy.

Aspect of Procedural Knowledge

The cognitive impact description of the procedural knowledge aspect is presented in Table 8.

Table 8
Description of procedural knowledge aspects

Authors (year)	Description
Pujiastuti and Haryadi (2023)	Students can formulate solution steps, manipulate concrete object models, and utilise procedures to establish connections with the concept of the Pythagorean theorem.
Poçan et al. (2023)	The use of AR technology and WhatsApp applications in a continuous learning environment has helped improve students' success in understanding mathematical concepts and applying their knowledge.
Ozcakir and Cakiroglu (2021)	The use of the SPATIAL-AR toolkit in AR-based learning can enhance students' spatial skills by comprehending and executing the necessary steps.
Kounlaxay et al. (2021)	The use of the GeoGebra application in mathematics learning enables students to master skills in 3D manipulation and modelling, as well as to test the behaviour of models in given situations.
Elsayed and Al-Najrani (2021)	The use of AR technology helps students enhance their visual thinking skills in mathematics. Students can interactively recognise, explain, and describe shapes.

Aspect of Achievement

The cognitive impact description of achievement aspect is presented in Table 9.

Table 9
Description of Achievement Aspects

Authors (year)	Description
Richardo et al. (2023)	The use of multimedia in the form of developed AR is effective in enhancing students' achievement in terms of creative thinking skills.
Poçan et al. (2023)	The test scores of students who used the AR application were higher than those of the control group.
Majeed and ALRikabi (2022)	The performance of students in the group using AR technology is better compared to the group using conventional teaching methods.
Saundarajan et al. (2020)	A significant improvement in post-test scores after the use of the Photomath application.
Cai et al. (2019)	There is an improvement in student learning achievement based on pre and post-test results.

Affective Impact

The impacts of using AR on students' affective development in mathematics include attitudes and motivation. The analysis results revealed that five (5) articles demonstrated the impact of AR learning on student motivation. Meanwhile, three (3) articles highlighted the impact of AR learning on student attitudes. Table 10 presents the list of articles classified by affective impact.

Table 10
The impact of using augmented reality on students' affective development in mathematics

Authors (year)	Affective impact	
	Attitude	Motivational
Poçan et al. (2023)		✓
Majeed and ALRikabi (2022)		✓
Mailizar and Johar (2021)	✓	
Kounlaxay et al. (2021)	✓	✓
Elsayed and Al-Najrani (2021)		✓
Cai et al. (2019)		✓
Saundarajan et al. (2020)	✓	
Total	3	5

Aspect of Attitude

The affective impact description of attitude aspects is presented in Table 11.

Table 11
Description of Attitude Aspects

Authors (year)	Description
Mailizar and Johar (2021)	Students have a positive attitude towards the use of AR in geometry learning using GeoGebra. Students perceive AR as useful and easy to use.
Kounlaxay et al. (2021)	Students' attitudes towards the use of the GeoGebra application tend to be neutral. However, students have a positive perception of using GeoGebra in learning and find it more enjoyable compared to conventional teaching methods.
Saundarajan et al. (2020)	Students exhibit a positive attitude towards the use of the Photomath application in learning algebraic equations. Students find this method interesting and helpful in understanding and solving algebraic equations easily.

Aspect of Motivation

The affective impact description of motivation aspects is presented in Table 12.

Table 12
Description of Motivation Aspects

Authors (year)	Description
Poçan et al. (2023)	The use of AR increases students' motivation levels. Students find the learning experience to be more engaging, enjoyable, and conducive to group learning.
Majeed and ALRikabi (2022)	The use of AR enhances motivation and facilitates students in solving problems smoothly, providing a more interactive learning experience.
Kounlaxay et al. (2021)	The use of the GeoGebra application in 3D geometry learning has increased students' learning motivation. Students can enhance their learning skills and actively participate in the learning process.
Elsayed and Al-Najrani (2021)	The use of AR in learning enhances students' motivation. AR creates a fun and interactive learning environment and encourages students' interest in achieving academic success.
Cai et al. (2019)	The use of AR can enhance the motivation of students with high self-efficacy in mathematics learning. Students show interest and tend to actively engage in the learning process.

Discussion

In this systematic literature review, the reviewer filtered 169 articles from two databases: Scopus and Web of Science (WoS). Eleven studies related to the use of AR in secondary school mathematics education were selected using the PRISMA guidelines. The use of the PRISMA guidelines in this study ensures that the included research aligns with good research standards (Page et al., 2021).

An analysis of the publication trend shows a consistent increase in the number of studies from 2019 to 2021, reflecting a growing interest among researchers in exploring the effects of AR on mathematics learning. However, there is a significant decrease in publications in 2022. This aligns with the findings of Husamah et al (2022), who observed that the COVID-19 pandemic impacted educational activities, including research article publications. Nevertheless, there is an increase in the number of publications in 2023, indicating sustained interest and commitment to studying the use of AR in secondary school mathematics education.

Furthermore, this study also indicates a high level of interest from Indonesian researchers in conducting studies on the use of AR in secondary school mathematics education. These findings are in line with Husamah et al (2022), who found that researchers from Asia, including Indonesia, contributed significantly to educational research even during the COVID-19 pandemic. Manikam and Maat (2023) also noted that Indonesian researchers actively contribute to AR-related research in mathematics education. This highlights the commitment and desire of Indonesian researchers to explore the potential and impact of AR in enhancing mathematics learning among secondary school students, underscoring the important role played by the Indonesian academic community in investigating the potential of AR technology in mathematics education.

The analysis also found that most researchers used quantitative approaches in their studies. Based on the study findings, it can be concluded that most studies employed quantitative methods. This is supported by Ahmad and Junaini (2020), who found that quantitative approaches were the main method used in research articles related to the use of AR in mathematics learning. This approach allows researchers to collect measurable data and analyse it using statistical methods. The diversity in research approaches highlights the need for different research methods to achieve a more comprehensive understanding in this field.

Furthermore, the analysis found that AR has been extensively used in the field of Geometry. The use of AR in geometry learning is reasonable as it can enhance the quality of mathematics teaching and learning in schools (Fitria, 2023). By using AR during geometry learning, students can visualise three-dimensional shapes from various perspectives in real-time (Ibáñez et al., 2020). Apart from Geometry, AR technology is also being applied in other mathematical topics, such as Algebra. Although the use of AR in Algebra and Statistics and Probability is not yet widespread, the studies mentioned in the analysis show interesting potential for the application of AR in mathematics learning for these topics.

The use of AR in mathematics education has been proven to have a positive impact on students' cognitive and affective development. The analysis of studies indicates that the use of AR in mathematics learning has the greatest impact on students' cognitive development in secondary schools. Runisah et al (2022) also showed that the use of AR in mathematics learning can improve various cognitive aspects such as visual thinking skills, learning outcomes and concept understanding. In terms of affective aspects, the use of AR strengthens students' interest and motivation in mathematics. This is consistent with the findings of Runisah et al (2022), who observed that the motivation of secondary school students increased after using AR applications in mathematics learning. The use of AR applications can also reduce mathematics anxiety (Fitria, 2023; Saha et al., 2020). Additionally, AR use enables more effective group learning among students, fostering cooperative learning opportunities

and active discussions. Students find group learning experiences in AR to be more engaging and conducive to building connections with their peers, thereby enhancing their motivation to learn and participate.

Overall, this study demonstrates that the use of AR in mathematics education holds significant potential for enhancing learning among secondary school students. AR provides a deeper, more engaging and interactive learning experience that helps improve the understanding of mathematical concepts and students' interest. With the sustained interest and research on the use of AR in mathematics education, it is expected that further developments and innovations in this field will continue to benefit secondary school students.

Conclusion

This study conducted a systematic literature review that analysed a total of 11 studies pertaining to the use of AR in the context of mathematics learning for secondary school students over the last five years. The year 2021 marked the highest publication year, and Indonesian researchers contributed the most studies. Most studies conducted in this field have employed a quantitative approach. The analysis of studies demonstrates that AR technology has been widely applied in the field of Geometry. AR enables a deeper and more interactive understanding of geometric concepts. The integration of AR technology into mathematics education has shown a favourable influence on student learning, embracing several dimensions, including cognitive and affective domains. The prioritisation of the cognitive domain has had a substantial impact on the efficacy of AR in the context of mathematics learning at the secondary school level. In summary, augmented reality (AR) is a very effective and beneficial technology that has significant potential for widespread application in the field of education, with a particular emphasis on mathematics education. Hence, it is essential to intensify efforts and conduct further study in this domain to optimise the capabilities of AR in delivering a more dynamic and efficacious educational encounter for students.

References

Ahmad, N., & Junaini, S. (2020). Augmented reality for learning mathematics: A systematic literature review. *International Journal of Emerging Technologies in Learning (iJET), 15*(16), 106-122.

Azuma, R. T., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *Journal of Computer Graphics and Application*s, *2*(6), 34-47.

Bulut, M., & Borromeo Ferri, R. (2023). A systematic literature review on augmented reality in mathematics education. *European Journal of Science and Mathematics Education*, *11*(3), 556-572.

Cai, S., Liu, E., Yang, Y., & Liang, J. C. (2019). Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy. *British Journal of Educational Technology*, *50*(1), 248-263.

Elsayed, S. A., & Al-Najrani, H. I. (2021). Effectiveness of the augmented reality on improving the visual thinking in mathematics and academic motivation for middle school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(8), em1991.

Elsevier. (2021). What content is indexed in Scopus?

https://service.elsevier.com/app/answers/detail/a_id/11274/c/10547/supporthub/scopus/

Fitria, T. N. (2023). Augmented reality (AR) and virtual reality (VR) technology in education: Media of Teaching and Learning: A Review. *International Journal of Computer and Information System (IJCIS), 4*(1), 14-25.

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods, 11*, 181–217.

Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022). Global trend of research and development in education in the pandemic era: A systematic literature review. *Research and Development in Education*, *2*(2), 89-101.

Ibáñez, M. B., Portillo, U. A., Cabada, Z. R., & Barrón, M. L. (2020). Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. *Computers & Education*, *145*, 103734.

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering version 2.3. *Engineering*, *45*(4ve), 1051.

Kounlaxay, K., Shim, Y., Kang, S. J., Kwak, H. Y., & Kim, S. K. (2021). Learning media on mathematical education based on augmented reality. *KSII Transactions on Internet and Information Systems (TIIS)*, *15*(3), 1015-1029.

Kraus, S., Breier, M., & Dasí-Rodríguez, S. (2020). The art of crafting a systematic literature review in entrepreneurship research. *International Entrepreneurship and Management Journal, 16*, 1023–1042.

Lainufar, Mailizar, M., & Johar, R. (2021). Exploring the potential use of GeoGebra augmented reality in a project-based learning environment: The case of geometry. In *Journal of Physics: Conference Series* (Vol. 1882, No. 1, p. 012045). IOP Publishing.

Mailizar, M., & Johar, R. (2021). Examining students' intention to use augmented reality in a project-based geometry learning environment. *International Journal of Instruction, 14*(2), 773-790.

Majeed, B. H., & ALRikabi, H. T. (2022). Effect of augmented reality technology on spatial intelligence among high school students. *International Journal of Emerging Technologies in Learning (Online)*, *17*(24), 131.

Manikam, R., & Maat, S. M. (2023). Sorotan Literatur Bersistematik: Trend augmented reality dalam pengajaran dan pembelajaran matematik. *Malaysian Journal of Social Sciences and Humanities (MJSSH)*, *8*(1), e002046-e002046.

Mengist, W., Soromessa, T., & Legese, G. (2020). Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX, 7,* 100777, 1–11.

Ozcakir, B., & Cakiroglu, E. (2021). An augmented reality learning toolkit for fostering spatial ability in mathematics lesson: Design and development. *European Journal of Science and Mathematics Education*, *9*(4), 145-167.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E. and Chou, R. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery*, *88*, p.105906.

Pujiastuti, H., & Haryadi, R. (2023). Enhancing mathematical literacy ability through guided inquiry learning with augmented reality. *Journal of Education and e-Learning Research*, *10*(1), 43-50.

Poçan, S., Altay, B., & Yaşaroğlu, C. (2023). The effects of mobile technology on learning performance and motivation in mathematics education. *Education and Information Technologies*, *28*(1), 683-712.

Richardo, R., Wijaya, A., Rochmadi, T., Abdullah, A., Khamid, N., Astuti, A., & Hidayah, N. (2023). Ethnomathematics augmented reality: Android-based learning multimedia to improve creative thinking skills on geometry. *International Journal of Information and Education Technology*, *13*(4), 731-737.

Rohendi, D., & Wihardi, Y. (2020). Learning three-dimensional shapes in geometry using mobile-based augmented reality. *International Journal of Interactive Mobile Technologies*, *14*(9), 48-60.

Runisah, R., Sudirman, S., Isnawan, M. G., Gunadi, F., Rosyadi, R., Son, A. L., & Assya, L. A. (2022). Impact of using augmented reality on students' cognitive and affective aspects in terms of education level. *International Journal of Science Education and Cultural Studies, 1*(2), 120-128.

Saha, J., Ahmmed, S., Ali, M., Tamal, M., & Rezaul, K. (2020). ICT based mathematics skill development program: An initiative to overcome mathematics anxiety. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(14), 252-261.

Saundarajan, K., Osman, S., Kumar, J., Daud, M., Abu, M., & Pairan, M. (2020). Learning algebra using augmented reality: A preliminary investigation on the application of photomath for lower secondary education. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(16), 123-133.

Sugiarni, R., Inayah, S., Herman, T., Juandi, D., Pahmi, S., Supriyadi, E., ... & Fauzi, A. L. (2022). Sosialisasi penggunaan teknologi virtual reality dan augmented reality dalam pembelajaran untuk menyongsong era metaverse. *Jurnal Abdi Nusa*, *2*(3), 134-140.

Tulgar, A. T. (2019). In between reality and virtuality: Augmented reality in teaching English to young learners. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (41), 356-364.

Zain, N. A. M., & Aiyub, K. (2021). Sorotan literatur bersistematik terhadap kompetensi guru menerapkan konsep pendidikan untuk pembangunan lestari dalam pengajaran. *Geografia: Malaysian Journal of Society & Space*, *17*(4), 74-90.