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SYSTEMATIC LITERATURE REVIEW: AUGMENTED REALITY IN MATH LEARNING

Agustina Sianturi[1], Tika Dwi Nopriyanti[2], Allen Marga Retta[3]
[123]Mathematics Education, PGRI University of Palembang, Indonesia; sianturiagustina77@gmail.com

***Corresponding Author**:**
Agustina Sianturi,
PGRI University of Palembang
Jl. Jend A. Yani Lorong Gotong Royong
No. 9/10 Ulu, 13 Ulu, Seberang Ulu II,
Kota Palembang, Sumatera Utara 30116,
E-Mail: sianturiagustina77@gmail.com
Contact Person: 0812-6235-27026

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ABSTRACT

Augmented Reality (AR) technology has become one of the important innovations in mathematics learning, especially in helping visualize abstract and spatial concepts. This study aims to analyze the application of AR in mathematics learning through a Systematic Literature Review (SLR) approach with a publication time span of 2020-2024. The research method involved eight stages: formulation of research questions, development and validation of the review protocol, literature search using the Publish or Perish application with the keyword "Augmented Reality in Mathematics Learning," screening of articles based on inclusion and exclusion criteria, quality assessment of articles, data extraction, data analysis and synthesis, and reporting of findings. Of the 157 articles screened, 29 accredited articles showed that AR can improve various students' mathematical abilities, such as concept understanding, literacy, numeracy, critical thinking, and problem solving. The results also showed that AR is effective in building space, geometry transformation, and simple fractions. Challenges identified include the need for technological infrastructure and teacher training.

Keywords: Augmented Reality, Math Learning

INTRODUCTION

Mathematics learning is one of the essential areas of education but is considered difficult by students (Sri Mulyati, 2020, p. 65). This is because mathematics is abstract, complex and less connected to everyday experiences. (Masyhud, 2021). Conventional learning methods are often difficult to bridge students' needs to understand mathematical concepts visually and interactively (Pokhrel, 2024). Therefore, teachers need innovative learning methods to increase student motivation and learning outcomes. One of the technologies that can be used to make students active through interesting and effective hands-on experiences is Augmented Reality (AR) technology emerged as a solution to overcome the obstacles of conventional learning. (Purnamira Tania et al., 2023)..

According to Nurliana, (2022) Augmented Reality as a merger of real and virtual objects in a real environment, running interactively in real time, and there is integration between objects in three dimensions, namely virtual objects integrated in the real world. This technology allows visualization of

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abstract concepts in a more concrete, interactive, and interesting way. In mathematics learning, AR can help students visualize three-dimensional shapes, manipulate variables, and understand the relationship between mathematics and the real world. This can increase students' learning motivation, concept understanding, and memory. (Sarkar et al., 2020) & (Poddar et al., 2024).

Several studies have shown that the use of AR in learning can have a positive impact on student engagement. (Shubham Nigam, 2022) revealed that AR technology creates tremendous opportunities in education, allowing students to understand abstract concepts through fun interactive experiences, increasing student engagement and understanding of the material. For example, in geometry learning, students can see and manipulate space objects directly through AR, making it easier for them to understand concepts such as volume, surface area, and angle relationships.

The main benefits of using AR in mathematics education include increased learning motivation and better concept understanding. Students who engage in AR-based learning tend to be more active and enthusiastic as they can see first-hand the application of what they are learning (Arifin et al., 2020). Based on the above background, this study aims to analyze the application of Augmented Reality (AR) technology in mathematics learning, especially in improving mathematical abilities such as concept understanding, literacy, numeracy, critical thinking, and problem solving. This study used a Systematic Literature Review (SLR) approach, which involved eight systematic stages: formulation of research questions, development and validation of the review protocol, literature search with Publish or Perish application, screening of articles based on inclusion and exclusion criteria, quality assessment of articles, data extraction, data analysis and synthesis, and reporting of findings. Data were taken from literature published between 2020-2024 with a focus on accredited journals

Previous studies focused more on presenting the results of previous research descriptively, without providing recommendations for practical implementation. Therefore, this study focuses on a comprehensive mapping of the effectiveness of using AR in mathematics learning based on the latest research findings. This research not only highlights the benefits of AR, but also identifies challenges in implementation such as the need for technological infrastructure and teacher training, and provides recommendations for the use of AR as an interactive and innovative learning medium.

METHODS

The method used in this research is to use the Systematic Literature Review (SLR) approach, which is a process that involves the identification, evaluation and synthesis of all available research evidence. The main objective of SLR is to present clear answers to research questions by following established steps. The articles collected are accredited articles published in 2020-2024 through the publish or perish search selected *Google Schoolar* application by summarizing and analyzing. The research method used is *Systematic Literature Review* according to (Prasetya Adhi et al., 2021)

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Figure 1: Process of research stages

Formulating a Research Question

In the initial stage, the researcher first pays attention to the topic raised then the focus of this research is to analyze the impact of using *Augmented Reality* in improving mathematics learning, especially in terms of concept understanding and student motivation.

Develop and Validate the Review Protocol

At this stage, the researcher outlines all elements related to the literature review, including the purpose of the study, the main questions to be answered, inclusion criteria, literature search strategy, quality assessment methods, literature screening procedures, strategies for data extraction, and the approach used in synthesizing and reporting results.

Search the Literature

The literature search was conducted on the Publish or Perish application with a search selected by Google Scholar. By entering the keywords "Augmented Reality in Mathematics Learning"

Screen for Inclusion

At this stage, researchers compiled a reference list to select each article that would be included in the data extraction and analysis process.

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Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	*Exclusion* Criteria
Articles that focus on the use of AR in math learning	Articles without full access or only discussing technical aspects of AR without linking it to education
Studies published in Indonesian within the 2020-2024 timeframe	Published outside scopus and not accredited
Published in sinta accredited journal 2-5	

Assess Quality

At this stage, the researcher performs quality evaluation to filter out full-text articles, which is the last step before proceeding to the data extraction and synthesis process.

Extracting Data

At this stage, articles or information are filtered to get the information needed according to the topic taken by the research, namely Augmented Reality in learning mathematics.

Analyzing and Synthesizing Data

At this stage, the researcher analyzes and synthesizes the data that has been collected to produce textual descriptions that are appropriate to the topic studied.

Report Finding

In this step, researchers compile and report all findings based on the information obtained after completing the previous seven stages.

FINDINGS

The results of the Systematic Literature Review (SLR) research include the process of screening literature, analyzing data, and synthesizing findings relevant to the research questions. The literature search was conducted through a digital library using a predetermined search string, utilizing the *publish or perish* application with *Google Scholar search selected* in the time span of 2020 to 2024. From the search results, 157 literatures related to the topic keywords were found.

From the 157 literatures, further selection was carried out based on the search results through the Sinta site and the relevant titles and topics discussed regarding the abstract and content of the literature. The screening results obtained by Sinta with accreditation 2,3,4 and 5 obtained 29 journals with Sinta 2 as many as 1 axiom journal, Sinta 3 as many as 7 articles, Sinta 4 as many as 10 articles, and Sinta 5 as many as 11 articles. Of the total 29 literature, there are 16 publications that focus on mathematics learning materials with the application of *Augmented Reality* technology in the following table.

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Table 2. Mathematics Learning Materials

Author	Title	Learning Materials
(Azis et al., 2024).	Implementation of Augmented Reality (AR) as a Learning Media for Geometric Transformation Mathematics	Geometric Transformation
(Listiawan & Antoni, 2021)	Development of augmented reality (AR) based math learning media on geometry transformation material	
(Buchori & Dina, 2021)	Development of Interactive Mathematics E-Modules Based on Augmented Reality on the Material of Building Space	Circle
(Mardian et al., 2023)	Implementation of android-based augmented reality as a medium for learning three-dimensional mathematics	Cube, Pyramid, Block
(Nur et al., 2023)	Augmented Reality-Based Mathematics Learning Media for Flat Figures	Flat Buildings
(Rosada & Damayani, 2023)	Development of Learning Media Si Baru (Space Building Application) Based on Augmented Reality in Mathematics Subjects Space Building Material	Build Space
(Rozi et al., 2021)	Learning Media Development Introduction Build Spaces Based on Augmented Reality in Mathematics Subjects	
(Hasni & Zakir, 2022)	Utilization of Augmented Reality Learning Media for Space Buildings in Mathematics Subjects	
(M. R. Saputra et al., 2023)	Implementation of Augmented Reality in Mathematics Learning Media Knowing 3D Space Buildings Using the Markerless Tracking Method	
(N. A. Saputra & Aryanto, 2024a)	Utilization of Augmented Reality Learning Media Building Spaces in Mathematics	
(N. A. Saputra & Aryanto, 2024)	Utilization of Augmented Reality as a Mathematics Learning Media on Spatial Buildings	
(Samijo, 2022)	Implementation of Augmented Reality-Based Interactive Math Learning Media	Cube, Block, Prism, Pyramid
(Pratama et al., 2023)	Introduction of Augmented Reality Technology in Learning Mathematics of Spatial and Flat Buildings	Spatial and Flat Buildings

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(Puspasari et al., 2024)	Development of Assemblr Edup-based Fraction Ar (Augmented Reality) Media in Mathematics Learning Simple Fraction Material	Simple Fractions
(Putra & Sofiana, 2022)	Implementation of 3D Geometric Shapes math learning augmented reality application based on Android	Cubes and Blocks
(Rachmawati et al., 2020)	Development of MAR (Mathematics Augmented Reality) exploration with character strengthening	

Based on the table above, there are 16 publications related to the application of Augmented Reality (AR) in learning mathematics, AR is most often applied to building materials such as cubes, blocks, prisms, and pyramids. In addition, geometry transformation materials, flat shapes, and simple fractions are also the focus of AR application. This shows that AR is effectively used to help visualize spatial and abstract concepts.

An analysis of 29 articles on *Augmented Reality* in mathematics learning published in 13 sinta-accredited journals shows that AR technology can significantly improve students' mathematical thinking skills. The following is a summary of the use of AR in learning mathematics, with a focus on the skills measured.

Table 3. Skills Measured in Mathematics Learning with Augmented Reality

Penulis	Ability	Description	Learning Media and Methods
(Alisa et al., 2024); (Zulfa et al., 2023)	Mathematical Concept Understanding	AR can improve students' mathematical understanding ability before and after learning	Augmented Reality learning video
(Amrina et al., 2023)	Student Competency	Augmented Reality learning media is effective in improving student competence	AR Book Build Space with vuforia SDK software and Unity 3D.
(Hidayah et al., 2024); (Indrayati et al., 2024); (Ristiana & Widiyono, 2024)	Student Learning Outcomes	Learning using Augmented Reality-based media assisted by Unity 3D is very instrumental and improves student learning outcomes. The utilization of AR technology in learning mathematics has a positive impact on student learning outcomes.	Unity 3D-assisted Augmented Reality, TaRL-Approached Augmented Reality Media

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(Islamiya et al., 2024); (Janawati et al., 2024)	Mathematical Literacy	AR provides an interesting, innovative and easy learning experience for users and can improve students' mathematical literacy skills.	Augmented Reality Pocket Guide using project based learning
(Islamiya et al., 2024); (Janawati et al., 2024)	Student Numeration	AR-assisted LKPD can contribute significantly in improving students' numeracy skills.	AR-assisted LKPD
(Mulianti et al., 2023); (Rihayati et al., 2023); (Umam et al., 2024)	Problem Solving	There is a difference in mathematical problem solving ability between students taught with and conventional after controlling the initial ability of students. In addition, it makes students to understand the concepts in a material quickly, students become more confident in learning, and increase the ability to visualize geometry images.	AR-assisted PBL approach
(Purwati, 2023)	STEAM	Using STEM-based math teaching media using *Augmented Reality* can increase interest in learning, make it easier to solve problems, and interesting learning media, and make it easier to remember math concepts.	STEM-based math teaching media using *Augmented Reality*
(Sari et al., 2024).	Critical Thinking	There is an effect of scientific approach assisted by augmented reality in learning mathematics on mathematical critical thinking skills of elementary school students.	Augmented Scientific Approach Reality

From the analysis table of 13 articles regarding the use of Augmented Reality technology in learning mathematics, it can be concluded that AR has a positive impact on various mathematical abilities of students (Alisa et al., 2024) . AR helps improve students' critical thinking skills before and after learning through interactive visualization (Zulfa et al., 2023) . AR-based media Book Build Space with Vuforia SDK and Unity 3D technology, proven effective in improving student competence

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(Amrina et al., 2023) . The use of AR significantly improves student learning outcomes, especially through the Teaching at the Right Level (TaRL) approach and Unity 3D (Hidayah et al., 2024) , (Indrayati et al., 2024) , (Ristiana & Widiyono, 2024) . AR provides innovative learning experiences that improve students' mathematical literacy and numeracy through AR-based pocket books and AR-assisted LKPD (Islamiya et al., 2024) , (Janawati et al., 2024) . Problem-Based Learning (PBL) based approach with AR support allows students to understand concepts faster, improve geometry visualization, and build confidence in learning (Mulianti et al., 2023) , (Rihayati et al., 2023) , (Umam et al., 2024) . STEM-based learning media using AR can increase learning interest, facilitate problem solving, and help students remember math concepts better (Purwati, 2023) . The AR-assisted scientific approach significantly improves students' mathematical critical thinking skills, especially at the elementary school level (Sari et al., 2024).

CONCLUSION

Based on the analysis of 29 accredited articles on the use of *Augmented Reality* (AR) technology in mathematics learning, it can be concluded that AR contributes significantly to the improvement of students' mathematical abilities. AR allows students to understand abstract concepts through interactive visualization, improves literacy and numeracy, and encourages critical thinking and problem solving.

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