



THE ROLE OF ARTIFICIAL INTELLIGENCE IN ENHANCING STUDENTS' MATHEMATICAL COGNITIVE ABILITIES: A LITERATURE REVIEW

Gharitza Zahira Shofa^{1*}, Tian Abdul Aziz², Lukman El Hakim³
^{1,3,3} Jakarta State University

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ABSTRACT

Artificial Intelligence (AI) in education is not only used to provide personalized feedback, but can also be used to build learning systems that can adapt and be tailored to the needs of each student. This study investigates the role of AI in enhancing students' mathematical cognitive abilities. The method used to obtain data is a Systematic Literature Review. Relevant scholarly articles were collected from databases including Google Scholar, Science Direct, DOAJ, and Eric. The novelty of this study lies in mapping the relationship between mathematical cognitive abilities and the role of AI at various levels of education, from elementary school to college. The results of the article search were screened based on predetermined criteria. The final screening resulted in 10 articles from national and international journals being used as literature review material. The analysis indicates that AI has been utilized across all educational levels to support the development of mathematical cognitive skills. The role of AI in mathematical cognitive abilities includes analyzing, evaluating, organizing, and providing space for discussion and reflection. Specifically, AI contribute to strengthening critical thinking, creative reasoning, problem solving, and computational competencies. The practical implication of this research is that educators can utilize AI to develop innovative learning models that integrate AI to improve students' mathematical cognitive abilities.

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Corresponding Author:

Gharitza Zahira Shofa,

Jakarta State University

Email: gharitza_1309825007@mhs.unj.ac.id

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1. INTRODUCTION

The increasing development of digital technology has led to its integration into various aspects of life, such as education and daily life. One of the most significant advances is the emergence of Artificial Intelligence (AI) (Muthmainnah et al., 2024) . The digital era has brought changes to the world of education, with technology having a broad impact on Artificial Intelligence (AI). AI refers to the ability of machines to perform tasks that normally require human intelligence, such as voice recognition, decision making, and problem solving (Faisal, 2024) .

AI has been used in higher education in various forms, such as adaptive learning systems that can tailor learning materials to each student's learning style and needs, virtual assistants that help complete assignments, and automated assessment tools that speed up the evaluation process (Ratnasari et al., 2024). Although the field of Artificial Intelligence in Education (AIEd) has been around for 30 years, many educators still do not clearly understand how to utilize it pedagogically and make a significant impact on the learning process (Zawacki-Richter et al., 2019). The use of AI in education has a significant positive effect.

Although the use of AI in education has grown significantly, research examining its specific influence on mathematical cognitive processes remains limited. Existing studies generally discuss AI in broad educational contexts without providing a focused synthesis of how AI supports distinct mathematical abilities such as critical thinking, creative reasoning, problem solving, and computational skills. This gap indicates a lack of comprehensive understanding regarding the mechanisms through which AI contributes to mathematical cognition across different educational levels.

The AI literacy program implemented in secondary schools has successfully empowered students, helping them not only understand difficult concepts, but also increase their ethical awareness and digital literacy. This program is designed to build students' understanding of how AI works, while developing their critical thinking skills regarding this technology (Kong et al., 2023). Artificial Intelligence allows students to receive feedback and adjust their learning process directly. These tools help teachers identify specific learning needs and provide appropriate guidance (Nujum & Hadi, 2025).

New technologies, particularly artificial intelligence, machine learning, chatbots, and personal virtual assistants, offer numerous benefits (easy access to information, ease of measurement and evaluation, innovation in teaching and learning practices, etc.) and risks (plagiarism, ethics, privacy issues, over-reliance on technology, etc.) in the world of education. Emphasizing the advantages while addressing the risks can have a significant impact on the future of humanity (UNESCO, 2023). Artificial Intelligence (AI) is increasingly involved in everyday life, especially in facilitating and supporting education. For example, AI helps create various learning models with diverse functions, not only meeting user needs but also benefiting both students and teachers, thereby bringing significant changes to the world of education (Saengsai, 2023). Ratnasari et al. (2024) emphasize that the use of AI in education not only serves to provide personalized feedback but can also be utilized to build learning systems that adapt to students and meet the individual needs of each student.

AI enables more innovative learning applications, such as the use of augmented reality (AR) in higher education (Kaluge, 2024). The implementation of AI in education does not only rely on the use of advanced technology, but also on how that technology can be used wisely to improve the learning experience holistically. The balance between technological innovation and traditional educational values is important so that the use of AI in education truly provides sustainable benefits for the development of education in the future (Ulimaz et al., 2024). One of the advantages of AI in learning is its ability to provide in-depth analytical data on student development (Shatila et al., 2025).

One of the objectives of mathematics learning listed in Permendikbud Number 36 of 2018 is that students are able to convey ideas using symbols, tables, diagrams, or other media to explain situations or problems and have an attitude of appreciating the usefulness of mathematics in life. According to NCTM (2000), mathematical ability is defined as a person's ability to solve problems, both in mathematics and in real life. Mathematical ability consists of mathematical reasoning, mathematical communication, mathematical problem solving, conceptual understanding, mathematical understanding, creative thinking, and critical thinking. Therefore, researchers are interested in synthesizing and reviewing the literature on the role of AI in improving mathematical cognitive abilities in students. This aims to serve as a guideline

for researchers in developing and continuing further research related to AI and mathematical cognitive abilities.

Given the increasing reliance on AI-supported learning environments, it is urgent to understand how AI specifically shapes mathematical reasoning and higher-order thinking skills, particularly as mathematics plays a foundational role in students' overall cognitive development. Therefore, the purpose of this study is to systematically review and synthesize empirical evidence on the role of AI in enhancing students' mathematical cognitive abilities. This study is limited to empirical research articles published in national and international journals, retrieved from major scholarly databases, and focusing on learners at the elementary, secondary, and higher education levels.

The novel contribution of this review lies in its structured mapping of AI functions to key mathematical cognitive domains, providing conceptual clarity and practical insights for educators, policymakers, and future researchers. The findings are expected to support the development of effective AI-assisted instructional designs and to inform further studies on AI integration in mathematics education. This study is limited to a literature review that includes accredited Indonesian journal articles (SINTA 1–4) and international publications indexed in Scopus (Q1–Q3). The data sources consist of secondary scholarly articles retrieved from Google Scholar, ScienceDirect, DOAJ, and ERIC. The reviewed articles are restricted to those published within the period **2017 to 2025** to ensure the relevance and currency of the findings.

2. METHOD

This study employs a *Systematic Literature Review* (SLR) approach to systematically identify, evaluate, and synthesize prior empirical studies related to the role of AI in mathematical cognitive abilities. The search strategy applied multiple keyword combinations and Boolean operators (e.g., “Artificial Intelligence” AND “mathematical cognition”, “AI in mathematics learning”, “machine learning” AND “mathematical reasoning”).

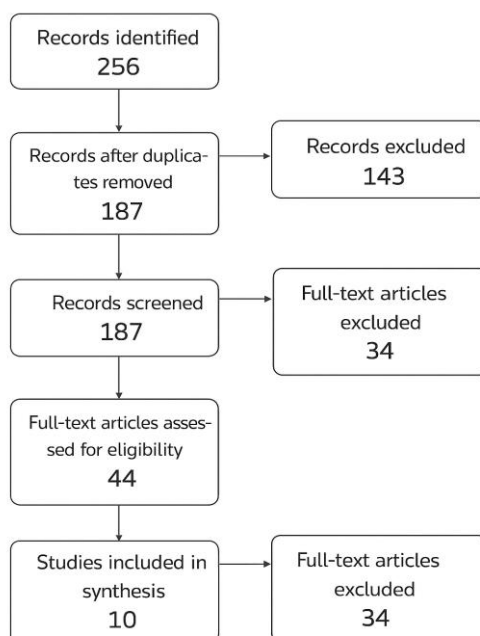


Figure 1. PRISMA Flowchart

Furthermore, the data selection criteria in this study are shown in table 1.

Table 1 . Selection Criteria

Accepted/Rejected	Criteria
Inclusion (Accepted)	<ol style="list-style-type: none"> 1. The article is the result of research in a reputable Indonesian or international journal 2. Discussion of articles in accordance with research topics 3. The scope of schools in Indonesia or outside Indonesia 4. Educational levels: elementary school/equivalent, junior high school/equivalent, senior high school/equivalent, and university
Exclusion (Rejected)	<ol style="list-style-type: none"> 1. The article is not the result of research in reputable Indonesian or international journals 2. Discussion of articles outside the research topic 3. Educational levels below elementary school and above university level

A two-stage screening procedure was implemented, consisting of (a) title and abstract screening and (b) full-text eligibility assessment. The author examined the titles and abstracts of each study to determine whether the research was relevant to the topic being studied. The materials used in this literature review were those that contained data or discussed topics such as the role of *artificial intelligence* and cognitive abilities. The data collected from these study materials was then analyzed and synthesized narratively. This method consisted of six steps, namely 1) formulating the research objectives; 2) collecting study materials in line with the research objectives; 3) evaluating the collected study materials; 4) assessing the quality of the study materials to determine which materials would be used and which would not be used; 5) extracting data in the form of important points contained in the study materials; 6) analyzing and synthesizing the data to obtain coherent and meaningful information or knowledge. A total of ten articles met the inclusion criteria and were selected for final analysis after title, abstract, and full-text screening. The data from these articles are presented in a table that includes the author's name, year of publication, journal name, education level, and research results in the form of the role of AI and cognitive abilities. The research results are then compiled into a comprehensive discussion in this article.

3. RESULTS AND DISCUSSION

3.1 Result

The selection of articles using inclusion and exclusion criteria resulted in 10 articles that were eligible for further analysis. These articles were sourced from accredited national journals and reputable international journals, published between 2017 and 2025.

The data extracted from each article included: researcher name, year of publication, journal name, education level, role of AI in mathematics learning, and type of mathematical cognitive ability studied. A summary of the study data is shown in table 2.

Table 2 . Table Overview of articles

Researcher and Year	Journal	Role of AI	Level	Cognitive Abilities
Ratnasari, Mewa Zabeta, Faza Zikri Sholeha: 2025	Algorithm: Journal of Mathematics, Natural Sciences, Earth Sciences, and Space Sciences	(1) helping access learning resources, (2) tailoring learning to students' styles and needs, (3) supporting cooperative learning, (4) providing quick reinforcement, (5) supporting problem-based learning	-	Critical Thinking Skills

Researcher and Year	Journal	Role of AI	Level	Cognitive Abilities
Katarzyna Szymd; Ewelina Mitera : 2024	European Research Studies Journal	AI assists with data analysis, hypothesis generation, solution exploration, and decision evaluation; and facilitates reflection and discussion.	-	Critical Thinking Skills
Hesti Noviyana; Fitriana Rahmawati; Arinta Rara Kirana; Mareyke Jessy Tanod : 2025	Journal of Integrated Elementary Education	(1) improving learning performance, (2) improving the quality of unteraction, (3) balancing technological innovation and pedagogy	Junior High School	Problem-Solving Skills
Asti Gimma Shatila; Achmad Buchori; FX Didik Purwosetiyono : 2025	Theorem: Theory and Research in Mathematics	(1) making learning enjoyable and interesting, (2) providing motivation to increase student confidence	Senior High School	Problem-Solving Skills
Mochamad Guntur; Amara Salsabilla; Siti Sahronih; Herisa Hardiyanti Sholeha: 2025	Prima Magistra: Journal of Education	The AI feature in Slidesgo can boost students' enthusiasm and motivation in the learning process	Elementary	Problem-Solving Skills
Habibillah Achmad Putra Fauzi, Tatag Yuli Eko Siswono, Novita Vindri Harini: 2025	MATHEdunesa	AI serves as a source of inspiration and confirmation in understanding problem-solving concepts and strategies.	Junior High School	Creative Thinking Skills
George Gadanidis: 2017	International Journal of Information and Learning Technology	AI provides initial knowledge and arguments that can be developed in the context of computational reasoning.	Junior High School	Computational Skills
Maulidah Amalia Putri; Lifa Farida Panduwinata: 2025	JKIP: Journal of Educational Science Studies	AI provides quick and customized feedback; and facilitates active participation and in-depth questions.	Students	Critical Thinking Skills
Xiaodong Huang, Chengche Qiao: 2022	Science and Education	AI is used to analyze, evaluate, and apply critical thinking skills in a computational context.	Senior High School	Computational Skills
Enaz Mahmod: 2025	Journal of Information Systems Engineering and Management	AI provides quality content, system updates, ease of use, technical support, and considers ethical aspects.	Students	Creative Thinking Skills

As shown in table 2, all selected articles demonstrate relevance to the research focus on AI and mathematical cognitive abilities. The results indicate that AI contributes to different facets of mathematical cognitive development across educational levels. Specifically, AI functions both as an instructional tool for teachers and as a cognitive support system for students, facilitating improvements in various mathematical reasoning processes.

3.2 Discussion

Based on the results of the 10 journals above, there are related connections regarding the role of AI in mathematical cognitive abilities at different levels of education. This discussion will present the results of the analysis based on the *overview* table above.

The Role of AI

Across the reviewed studies, both similarities and differences are evident in how Artificial Intelligence (AI) is utilized in mathematics learning. Several studies, including Ratnasari et al. (2025), Szmyd & Mitera (2025), and Putri & Panduwinata (2025), consistently report that AI is used to provide access to learning resources, facilitate data analysis, and deliver immediate feedback. These similarities indicate that AI is commonly positioned as a learning support tool that assists students during the learning process.

In contrast, other studies emphasize different instructional functions of AI. For example, Noviyana et al. (2025) and Guntur et al. (2025) highlight the role of AI in supporting problem-based learning environments, while Shatila et al. (2025) focus more on AI as a medium that increases students' learning motivation. Meanwhile, Gadanidis (2017) and Huang & Qiao (2024) place greater emphasis on the role of AI in developing computational and algorithmic reasoning through the use of digital and computational tools in mathematics learning. These differences demonstrate that although AI is widely adopted, each study prioritizes distinct instructional roles depending on the educational context and learning objectives.

From a theoretical perspective, these findings are consistent with constructivist learning theory, which emphasizes that learners actively construct their own knowledge through interaction, exploration, and feedback. AI-supported learning environments enable students to engage in problem solving, receive immediate feedback, and refine their understanding independently. Furthermore, from the viewpoint of social constructivism, as proposed by Vygotsky, AI facilitates discussion, collaboration, and scaffolding, allowing students to develop cognitive abilities through interaction with digital tools and peers.

Enhanced cognitive abilities

A comparison across studies also reveals variations in the types of mathematical cognitive abilities most affected by AI integration. Several studies, such as those conducted by Ratnasari et al. (2025), Szmyd & Mitera (2025), and Putri & Panduwinata (2025), consistently report the enhancement of critical thinking skills through AI-supported learning activities. In contrast, Noviyana et al. (2025), Guntur et al. (2025), and Shatila et al. (2025) primarily focus on improvements in students' problem-solving skills, particularly through AI-assisted problem-based learning.

Differences are also found in the development of creative thinking skills. Fauzi et al. (2025) report that students' creativity when using AI depends strongly on their conceptual understanding, whereas Mahmoud (2024) emphasizes AI as a tool that provides diverse challenges and idea exploration to stimulate creativity. Meanwhile, computational skills are mainly addressed in studies by Gadanidis (2017) and Huang & Qiao (2024), which demonstrate that AI supports students' algorithmic reasoning and computational thinking, particularly at the secondary education level.

These comparisons indicate that while AI contributes positively to multiple dimensions of mathematical cognition, the dominant cognitive outcomes vary across studies depending on instructional design, educational level, and the type of AI tools employed.

Despite the positive contributions of AI reported in the reviewed articles, several limitations must be acknowledged. First, most studies focus on short-term instructional interventions, which limits conclusions regarding the long-term effects of AI on students' mathematical cognitive development. Second, several studies do not explicitly report detailed participant characteristics or educational contexts, which restricts the generalizability of the findings. Third, many studies rely primarily on quantitative outcome measures, with limited qualitative exploration of students' learning experiences and cognitive processes. In addition, the rapid advancement of AI technology means that some tools discussed in older studies may no longer reflect current technological capabilities.

Based on the findings and limitations, several directions for future research are recommended. Future studies should investigate the long-term impact of AI integration on students' mathematical cognitive development. Research focusing on specific mathematical topics, such as algebra, geometry, and calculus, is also needed to provide more detailed insights into how AI supports learning in different content domains.

Moreover, future research should examine the role of AI in supporting mathematical communication skills, which remain underexplored in the current literature. The use of mixed-method research designs is recommended to obtain a more comprehensive understanding of both learning outcomes and students' learning experiences. Finally, greater attention should be given to ethical issues, data privacy, and students' dependence on AI tools, especially in technology-rich learning environments.

4. CONCLUSION

This systematic literature review confirms that Artificial Intelligence (AI) plays a significant role in supporting students' mathematical cognitive abilities, particularly in critical thinking, problem solving, creative thinking, and computational skills across various educational levels, with the main contribution of this study being the structured mapping of AI functions to specific mathematical cognitive domains that clarifies how AI supports cognitive development in mathematics learning. Practically, the findings indicate that AI can be utilized to support adaptive and problem-based learning, provide immediate feedback, and enhance students' active engagement in mathematical reasoning, offering important implications for teachers in designing more personalized and interactive instruction and for schools and policymakers in integrating AI into mathematics education in a pedagogically meaningful and ethically responsible manner. However, this review is limited to selected databases, publication periods, and predominantly short-term instructional studies, which restricts conclusions about the long-term impact of AI; therefore, future research is recommended to examine the sustained effects of AI on mathematical cognitive development, explore its role in mathematical communication skills, and investigate its application in specific mathematical topics such as algebra, geometry, and calculus.

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