A Systematic Study: The Use of Artificial Intelligence and Search Engines in Mathematics Learning

Yuanda Oktrin Lay[1*)], Jailani[2]
[1,2]Universitas Negeri Yogyakarta
*)yuandaoktrin.2024@student.uny.ac.id

Abstract

Mathematics education in the digital age faces new challenges and opportunities with the advent of technology. Artificial Intelligence and Search Engines have become tools that are often used in the process of searching for information and learning. This study aims to identify, map, and synthesize the latest scientific research on the role, impact, and challenges of using artificial intelligence and search engines in the context of mathematics education. The method used is a systematic study of 26 relevant articles from 2016 to 2025, which are included in the Q1, Q2, and Q3 indices, obtained through a selection process similar to the PRISMA guidelines. The results of the thematic analysis revealed several key findings: (1) There was a significant boom in research trends in 2024-2025, dominated by Generative AI research (such as ChatGPT). (2) The role of artificial intelligence has evolved from intelligent tutor systems (ITS) to dialogic personal tutors (chatbots) and adaptive learning platforms. (3) The role of traditional search engines as information retrieval tools is shifting and, in some cases, being replaced by generative AI capable of synthesizing answers. (4) Consistent positive impacts reported include increased motivation, problem solving, and self-efficacy, but these are offset by challenges related to accuracy, bias, and the urgent need for AI literacy among teachers and students. This study concludes that the state of mathematics learning technology is rapidly shifting toward AI-based systems, which requires pedagogical adaptation and further research on their integration in the classroom.

Keywords: artificial intelligence, search engine, mathematics learning, systematic study

Introduction

Mathematics education plays a crucial role in developing logical, analytical, and problem-solving skills that are essential in the 21st century. However, traditionally, mathematics is often considered a difficult and abstract subject, which ultimately triggers mathematical anxiety and hinders students' self-efficacy (Inoferio et al., 2024). The relationship between digital transformation and mathematics education lies in technology's ability to overcome these psychological and cognitive barriers through personalized learning. In this context, digital technologies such as AI act as More Knowledgeable Others (MKOs) that provide real-time scaffolding, helping students navigate their Zone of Proximal Development (ZPD) without the fear of judgment that often arises in face-to-face interactions. Through adaptive platforms and dialogic tutors, digital transformation turns abstract material into a more structured and responsive learning experience (Chau et al., 2025; Chen, 2025; Oppmann et al., 2025). This approach has been proven effective in reducing anxiety levels while increasing student motivation, self-efficacy, and problem-solving competence (Inoferio et al., 2024; Alkhasawneh, 2025; Asare & Boateng, 2025; Chau et al., 2025).

The digital transformation in mathematics education is fundamentally shaped by the evolution of two key technologies: search engines as instruments for independent information retrieval and artificial intelligence (AI) as adaptive learning support systems (Gabriel et al., 2018; Inoferio et al., 2024; Xuan et al., 2025). Search engines such as Google have long been the main gateway for students to independently search for information, find formulas, or view sample questions (Salehi et al., 2018). This tool supports independent learning, although its effectiveness depends on the student's ability to sort out relevant and accurate information. On the other hand, Artificial Intelligence offers a more sophisticated approach. AI in education is no longer limited to science fiction, but has been realized in the form of Intelligent Tutoring Systems (ITS), adaptive learning platforms, and predictive analysis using machine learning (Gabriel et al., 2018; Chen, 2025; Oppmann et al., 2025). AI promises personalized learning, instant feedback, and material that can be adjusted to the student's learning pace (Alkhasawneh, 2025). This mechanism is made possible through the integration of machine learning algorithms and predictive analytics that continuously monitor students' interaction patterns and performance in solving mathematical problems (Gabriel et al., 2018; Chen, 2025).

A significant research gap has emerged in recent years. First, previous research tended to focus on search engines and artificial intelligence separately (e.g., Borba et al., 2016). Second, the emergence of Generative AI such as ChatGPT in late 2022 has fundamentally blurred the line between artificial intelligence and search engines (Lindemann, 2024). Students are now shifting from ‘searching’ to ‘asking’, where technology no longer simply presents links through traditional search engines such as Google or Bing, but actively synthesizes answers (Salehi et al., 2018; Lindemann, 2024). Specific applications of AI in mathematics education have now rapidly evolved beyond general chatbots. Recent literature shows the use of MatGPT, which is specifically designed to improve students' mathematical proficiency (El-Shara et al., 2025), as well as the evolution of Intelligent Tutoring Systems (ITS) that provide a structured and adaptive learning environment (Chen, 2025). Furthermore, AI is implemented through adaptive learning platforms to personalize content (Alkhasawneh, 2025; Oppmann et al., 2025), as well as the use of computer vision technology to recognize mathematical notation technically (Abdrakhmanov et al., 2024). Although many primary studies have emerged on these specific tools, there has been no comprehensive synthesis mapping how the simultaneous integration of these various technologies affects the mathematics learning ecosystem.

The increasing use of these two technologies is like a double-edged sword, where their transformative potential is balanced by fundamental critical challenges. On the one hand, the integration of artificial intelligence and search engines is highly beneficial because it makes it easier for students to access quality math help at any time, which has been consistently reported to increase learning motivation (Alkhasawneh, 2025), self-efficacy (Asare & Boateng, 2025), and student engagement in the learning process (Mengmeng et al., 2025). Furthermore, the use of tools such as dialogic tutors has been proven effective in improving problem-solving competencies (Chau et al., 2025) and helping students with special needs understand mathematical concepts (Rizos et al., 2024). However, on the other hand, there are significant risks if this technology is used without adequate understanding and literacy. The main challenges include issues of accuracy and reliability of answers, where generative AI has the potential to produce inaccurate or ‘hallucinatory’ outputs (Korkmaz Guler et al., 2024). In addition, there is the threat of ‘knowledge encapsulation’, a condition in which students receive instant answers without going through a critical thinking process, thereby risking mathematics losing its essence as an exercise in logic (Lindemann, 2024). This phenomenon can also create an ‘illusion of competence’, where an increase in students' self-efficacy appears only because of the help of tools, not because of an actual increase in internal abilities.

Therefore, this systematic study aims to identify, evaluate, and synthesize existing research on the role, impact, and challenges of artificial intelligence and search engines in mathematics learning. The research questions in this study are:

1. What are the publication trends and research focus of artificial intelligence and search engines in mathematics learning from 2016 to 2025?
2. What are the roles and types of artificial intelligence identified in the literature?
3. What are the roles and types of search engines identified in the literature?
4. What are the impacts and challenges of implementing artificial intelligence and search engines?

Method

This study uses a a systematic review method as the main research design to identify, evaluate, and interpret relevant literature related to the use of artificial intelligence and search engines in mathematics learning with a systematic study method. This method was chosen for its ability to map and synthesize findings from various primary studies in a transparent and comprehensive manner. By using a systematic review, researchers can strengthen scientific evidence regarding the rapid evolution of technology objectively in order to minimize subjective bias. All research procedures were carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure rigor and transparency in every stage of article selection and analysis.

Table 1. Inclusion and Exclusion Criteria

No	Inclusion Criteria	Exclusion Criteria
1	Journal index: Q1, Q2, and Q3 in Scopus	Journal index: Q4, or not indexed Q
2	Year of publication: 2016–2025	Year of publication: outside the range of 2016–2025
3	Focus: the use of artificial intelligence or search engines or both in mathematics learning	Not focused on the use of artificial intelligence or search engines in the context of mathematics learning
4	In the form of primary research articles	In the form of other reviews, editorials, or book chapters
5	Available in full-text format	Not available in full-text format
6	Written in English	Written in a language other than English
7	Open access	Close access

Research articles were collected from the renowned scientific journal database Scopus, with the index limited to Q1, Q2, and Q3. The determination of keywords in this study was not done randomly but through a measurable validation process. The researchers conducted a pilot search to see which terms were most frequently used by experts in the titles and abstracts of articles related to mathematics education technology. In addition, the selection of terms also referred to keywords used in major studies in the fields of artificial intelligence and information literacy.

The search strategy was based on two main concepts: (1) The concept of AI in mathematics education: ((“artificial intelligence” OR AI OR “machine learning” OR “ChatGPT” OR “generative AI”) AND (“mathematics education” OR “mathematics learning” OR “mathematics teaching” OR “mathematics problem solving”) AND (“impact” OR ‘effect’ OR “analysis”)). (2) The concept of SE in mathematics learning: ((“search engine” OR “internet searching” OR “web search” OR Google OR Bing) AND (“mathematics education” OR “mathematics learning” OR “mathematics teaching” OR “mathematics problem solving”) AND (“impact” OR “effect” OR ‘analysis’ OR “use”)).

Several other technical terms such as ‘natural language processing’ or ‘deep learning’ were deliberately not included as separate keywords because they are automatically represented by the umbrella terms ‘AI’ or ‘machine learning’. The same applies to tools such as calculators or Computer Algebra Systems (CAS), which are excluded from the search. This is to ensure that the research remains focused on the phenomenon of digital transformation involving intelligent systems (AI) and search engines (SE), so that the synthesis results are not mixed with traditional instructional technologies that serve a different function.

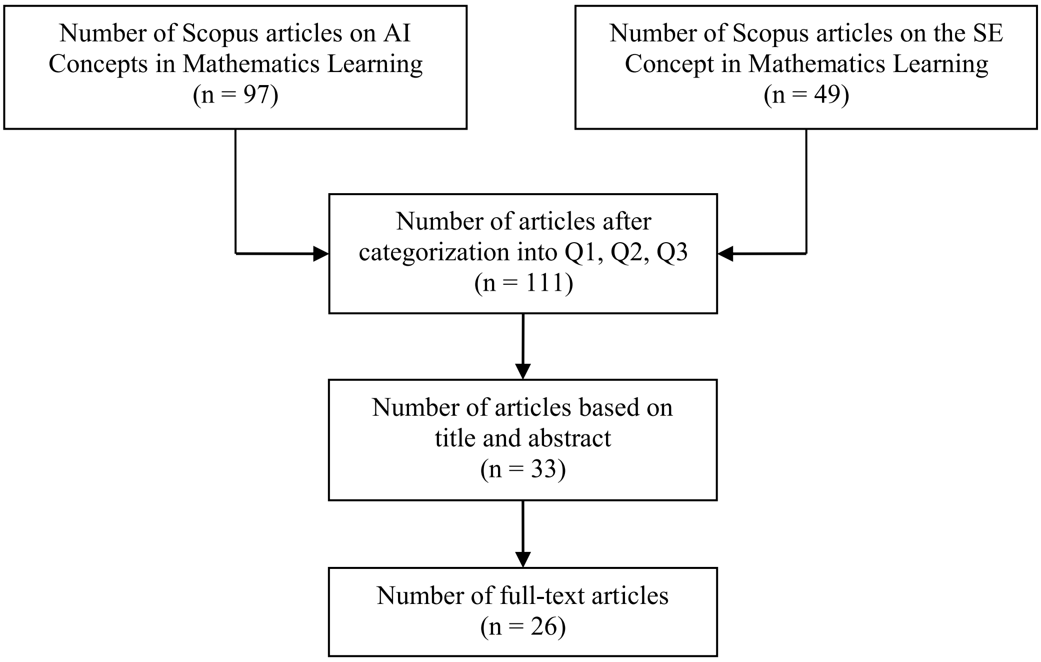

Figure 1. Article Selection Flowchart

Results and Discussion

The following section presents a summary of research studies related to the use of artificial intelligence and search engines in mathematics learning.

Table 2. List of used articles

No	Reference	Title	Type of AI and Search Engine	Research Findings
1	Borba et al. (2016)	Blended learning, e-learning and mobile learning in mathematics education	Digital learning platforms, mobile learning	Improves flexibility, interaction, and access to math content; teacher readiness strongly influences success

No	Reference	Title	Type of AI and Search Engine	Research Findings
2	Salehi et al. (2018)	Use of Web search engines and personalisation in information searching for educational purposes	Web search engines (Google, Bing)	Students rely heavily on search engines; personalization shapes search behavior and may introduce bias
3	Gabriel et al. (2018)	A machine learning approach to investigating the effects of mathematics dispositions on mathematical literacy	Machine learning predictive modeling	ML predicts mathematical literacy effectively and highlights role of dispositions and attitudes
4	Jančařík et al. (2023)	Using AI chatbot for math tutoring	AI chatbot	Chatbots support independent math learning; effectiveness depends on students' questioning ability
5	Engelbrecht & Borba (2024)	Recent developments in using digital technology in mathematics education	General digital technologies including AI	Shift from conventional e-learning to AI-based learning ecosystems
6	Lindemann (2024)	Chatbots, search engines, and the sealing of knowledges	Generative AI and search engines	Generative AI may reduce critical engagement by providing ready-made synthesized answers
7	Inoferio et al. (2024)	Coping with math anxiety and lack of confidence through AI-assisted learning	AI-assisted learning system	AI tools lower math anxiety and enhance student confidence
8	Rizos et al. (2024)	Enhancing mathematics education for students with special educational needs through generative AI	Generative AI	Supports individualized explanations and accessibility for students with special educational needs
9	Abdrakhmanov et al. (2024)	Applying computer vision and machine learning techniques in STEM-education self-study	Computer vision and machine learning	AI recognizes mathematical notation and supports automated assessment and feedback
10	Li (2024)	Integrating artificial intelligence in primary mathematics education	AI classroom applications	Teacher attitudes, support, and training significantly affect AI adoption
11	Moral-Sánchez et al. (2023)	Analysis of artificial intelligence chatbots and satisfaction for learning in mathematics education	AI chatbots	Students show high satisfaction due to immediacy of responses and personalization
12	Chen (2025)	Evaluation of the application	Intelligent	Improves performance and

No	Reference	Title	Type of AI and Search Engine	Research Findings
		effect of intelligent teaching systems in mathematics education	Tutoring System (ITS)	engagement using adaptive learning paths
13	Chau et al. (2025)	Personalized mathematics teaching with the support of AI chatbots	AI chatbot tutor	Improves mathematical problem-solving competence and self-regulated learning
14	Li & Lyu (2025)	Motivational and knowledge affordances of conversational AI in math learning	Conversational AI	Increases motivation and conceptual understanding via dialog-based explanations
15	Alkhasawneh (2025)	AI-driven personalized mathematics learning through interactive mobile platforms	AI adaptive mobile platform	Personalized learning increases motivation and academic achievement
16	Asare & Boateng (2025)	ChatGPT usage and pre-service mathematics teachers' self-efficacy	ChatGPT	Increases self-efficacy mediated by self-regulation and self-awareness
17	Lin et al. (2025)	Effects of technology perceptions, teacher beliefs, and AI literacy on AI technology adoption	AI adoption factors	AI literacy is the strongest predictor of teacher adoption of AI in math education
18	Song et al. (2025)	Teachers and learners' perceptions about implementation of AI tools in elementary mathematics classes	AI classroom tools	Positive perceptions overall; concerns relate to ethics, accuracy, and dependency
19	Oppmann et al. (2025)	Stimulating individual learning of fraction equivalence using adaptive features in digital environments	Adaptive AI learning environment	Adaptive support enhances conceptual understanding of fractions
20	Xuan et al. (2025)	Evaluating the impact of generative AI in mathematics education	Generative AI (ChatGPT-like tools)	Students using GenAI show better problem-solving outcomes but reduced reliance on traditional strategies
21	Prahani et al. (2025)	Evaluation of ChatGPT research in STEAM education	ChatGPT	Identifies rapid growth of ChatGPT research and highlights issues of ethics and academic integrity

No	Reference	Title	Type of AI and Search Engine	Research Findings
22	Rezat (2025)	The quality of digital curriculum resources for mathematics in German educational policy	Digital curriculum platforms (AI-integrated)	Quality depends on curriculum alignment and pedagogical design
23	Rajkai et al. (2025)	Artificial intelligence in higher education: Students' AI use and its influencing factors	General AI tools	AI use is influenced by confidence, access, and perceived usefulness
24	Mengmeng et al. (2025)	Effects of AR-based digital mobile game-based learning on student engagement	Augmented reality with intelligent feedback	AR increases engagement and enjoyment in mathematics learning
25	El-Shara et al. (2025)	The effect of using MatGPT on mathematical proficiency among undergraduate students	MatGPT (specialized AI math tutor)	Improves procedural fluency and conceptual mathematical understanding
26	Korkmaz Guler et al. (2024)	Evaluating ChatGPT's academic achievement in a mathematics exam	ChatGPT	Performs well on routine tasks but struggles with complex reasoning and proof-based questions

Based on a systematic analysis of 26 selected articles, several main themes were found that answered the research questions. These findings were grouped into four main aspects.

1. Trends and Publication Focus

Publication trends show interesting dynamics over the past decade. There is a somewhat irregular distribution of publications between 2018 and 2023, with research still focusing on technology in general or separately (e.g., Borba et al., 2016; Salehi et al., 2018; Gabriel et al., 2018; Jančařík et al., 2023). However, there was a significant surge in publications in 2024 (6 articles) and 2025 (15 articles), with a total of 21 new articles appearing in the last two years. This surge coincided with the popularization of Generative AI. In terms of research focus, there was a clear shift in topics, from conventional e-learning (Borba et al., 2016) to in-depth discussions on Chatbots, GenAI, and ChatGPT (Korkmaz Guler et al., 2024; Chau et al., 2025; El-Shara et al., 2025; Moral-Sanchez et al., 2025; Prahani et al., 2025; Rezat, 2025; Xuan et al., 2025). This indicates that mathematics education researchers are now focusing on the capabilities of AI generative in processing information.

The massive surge in publications during the 2024–2025 period is not merely a statistical anomaly, but rather a sign of fundamental disruption in the mathematics education ecosystem. Whereas in the previous period (2016–2023) technology was positioned as a static tool, the advent of Generative AI has transformed the landscape into one of dynamic interaction. The dominance of GenAI topics confirms that the global academic community is racing to validate the impact of this technology. This shift in focus also implies that traditional e-learning models are considered established, while Generative AI brings new uncertainties, both in terms of potential and risk, which urgently need to be researched. This requires mathematics education curricula to adapt immediately, no longer just teaching the use of calculation tools, but also how to interact with artificial intelligence capable of reasoning. Findings from this systematic study provide a clear picture of the state of technology in mathematics education, which is dominated by a sudden shift towards artificial intelligence.

2. The Role and Types of Artificial Intelligence

In recent literature, artificial intelligence has emerged as the most dominant technology compared to conventional search engines. The role of artificial intelligence in mathematics learning can be classified into three main categories. First, as a dialogic tutor (Chatbot) where artificial intelligence plays an active role in helping students solve math problems (Chau et al., 2025), providing personalized feedback (Li & Lyu, 2025), and helping to overcome math anxiety often experienced by students (Inoferio et al., 2024). Second, as an adaptive learning platform where this technology is manifested in the form of structured Intelligent Tutoring Systems (ITS) (Chen, 2025), Personalized Learning systems (Alkhasawneh, 2025), and adaptive learning environments that adjust the material to the students' abilities (Oppmann et al., 2025). Third, as a specific tool where artificial intelligence technology is also used for specific technical needs, such as the use of computer vision in recognizing mathematical notation or problems (Abdrakhmanov et al., 2024).

The dominance of artificial intelligence as a dialogic tutor and adaptive platform marks a new era of democratization in private learning. In the context of mathematics, the biggest obstacle for students is often not the material itself, but psychological aspects such as embarrassment in asking questions or fear of making mistakes (math anxiety). These findings show that artificial intelligence successfully fills the void left by teachers in large classrooms, such as providing personal attention and real-time feedback without judgment. Theoretically, artificial intelligence acts like a More Knowledgeable Other (MKO) in Vygotsky's concept, guiding students through their respective Zones of Proximal Development (ZPD). However, reliance on this "Tutoring" role also carries risks if artificial intelligence completely replaces students' productive thinking processes, rather than merely serving as a guide (scaffolding).

3. The Role and Types of Search Engines

Unlike artificial intelligence, which dominates discussions, traditional search engines receive far less attention in recent literature. In general, students use search engines for basic needs such as finding mathematical formulas or concepts (Salehi et al., 2018). However, an important finding from this analysis is the threat of disruption to the role of search engines. The ability of AI chatbots to synthesize answers directly is beginning to threaten the relevance of traditional search engines that only provide lists of links, changing students' information search patterns to question-and-answer patterns (Lindemann, 2024).

The decline of search engines in current literature reflects changes in students' cognitive preferences, who desire instant efficiency. Search engines require high-level literacy skills, such as sorting keywords, selecting relevant sources from thousands of links, and synthesizing information independently (cognitively demanding). In contrast, artificial intelligence offers pre-synthesized answers (cognitively undemanding). This shift from a pattern of "searching" to 'prompting' has the potential to erode students' information verification skills. If students become accustomed to receiving "ready-made" answers from artificial intelligence, their ability to trace primary sources and compare references, which is at the core of search engine literacy, could seriously deteriorate.

4. Impact and Challenges of Implementation

Almost all of the articles reviewed reported two sides to the use of this technology, namely positive impacts and challenges. The positive impacts include the consistent implementation of artificial intelligence and search engines, which have been reported to increase learning motivation (Alkhasawneh, 2025), self-efficacy or student confidence (Asare & Boateng, 2025), and student engagement in the learning process (Mengmeng et al., 2025). Furthermore, this technology also has an impact on improving problem-solving skills (Chau et al., 2025) and has been proven effective in helping students with special needs (Rizos et al., 2024). Despite its benefits, there are serious challenges related to the accuracy and reliability of the answers generated by artificial intelligence (Korkmaz Guler et al., 2024). Other issues include the potential for “knowledge sealing” where students receive answers without critical thinking (Lindemann, 2024), as well as the urgency of mastering artificial intelligence literacy for teachers. This includes teachers’ perceptions of technology (Song et al., 2025) and their level of trust in these tools (Lin et al., 2025; Li, 2024).

This finding highlights an educational paradox in the digital age, where increased motivation does not always correlate with increased depth of understanding. The reported increase in self-efficacy may be an “illusion of competence”, where students feel capable because of the help of tools, not because of their increased internal abilities. The challenge of “knowledge encapsulation” becomes a critical issue; if students accept artificial intelligence answers as absolute truth without critical processing, then mathematics loses its essence as an exercise in logic. Therefore, the biggest challenge is no longer technological accessibility, but rather the pedagogical readiness of teachers. Teachers no longer play the role of material deliverers, but must evolve into critical verifiers who teach students how to validate artificial intelligence outputs, ensuring that technology becomes an accelerator of reasoning, not its replacement.

Conclusion and Suggestion

This systematic study concludes that research on technology in mathematics learning is currently dominated and redefined by Artificial Intelligence, particularly Generative AI. The role of artificial intelligence has evolved into that of a dialogic personal tutor, while the role of traditional search engines as information seekers has begun to be disrupted and converged into artificial intelligence. Although positive impacts on student motivation, self-efficacy, and learning outcomes have been widely reported, fundamental challenges related to accuracy, algorithmic bias, and the readiness of the educational ecosystem, especially teachers, remain real and urgent issues to be resolved.

However, the generalization of these findings needs to be understood within the context of the characteristics of the data analyzed. This study specifically limits its focus to high-quality articles indexed by Scopus (Q1, Q2, and Q3) to ensure the credibility of references, so that discussions that may arise in literature outside of this index are not included in this analysis. In addition, variations in educational levels and differences in curricula between countries in the research sample provide diverse global insights, but require readers to exercise caution in adopting these findings into specific local contexts. The rapidly evolving nature of Generative AI technology is also an important context, as the findings of this study capture phenomena at the time the research was conducted and may continue to evolve as technology advances.

Based on the findings and limitations, future research should: (1) Conduct repeated studies to measure the long-term impact of GenAI use on mathematical conceptual understanding; (2) Develop pedagogical models to train teachers and students in AI Literacy, particularly the skills to critically evaluate the output generated by artificial intelligence; (3) Investigate the best ways to integrate the strengths of artificial intelligence (synthesis) with search engines (primary source search) for comprehensive mathematics learning.

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