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Research Paper

Artificial Intelligence Integration in Mathematics Education: A SWOT-BWM Analysis

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ABSTRACT

The rapid advancement of artificial intelligence (AI) and its accessibility to almost everyone necessitate a clear definition of its role in education. The primary step in effectively integrating AI into mathematics education (ME) is formulating instructional strategies that consider its advantages and disadvantages. This study aims to develop strategic recommendations for integrating AI into ME by utilizing SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis and the Best-Worst Method (BWM). A SWOT analysis of studies on the use of AI in mathematics education was conducted, and a group of 19 mathematics education experts evaluated these criteria through a paired comparison method. The data was analyzed through BWM to determine the impact level of the criteria, and a SWOT matrix was created to develop key strategies to optimize the role of AI in ME. Strategic recommendations include leveraging AI for personalized learning, integrating AI-driven teaching models, and ensuring that AI complements rather than replaces teacher-student interactions. The findings emphasize the necessity of AI literacy for both educators and students in mitigating its drawbacks. By providing a structured framework for assessing AI's impact and proposing actionable strategies for its effective implementation in ME, this study contributes to the ongoing discourse on AI in education.

INTRODUCTION

The field of artificial intelligence (AI) can be defined as a multidisciplinary approach that utilizes computer and linguistic sciences to perform cognitive tasks requiring human intelligence, such as problem-solving, decision-making, and understanding human communication (McCarthy, 2007). Although AI is defined slightly differently across various fields, it fundamentally aims to improve quality of life across all domains (Sarker, 2022). Consequently, AI applications can be seen in all areas of life. The integration of AI into education, a field with a strong technological component, has been rapid and extensive. Within education, AI is predominantly employed to enhance students' learning experiences and improve the effectiveness of teaching methods (Hwang et al., 2020).Researchers, educators, and students employ AI, particularly Large Language Models (LLMs), to generate ideas, summarize and present information, and even tackle practical applications (Giray et al., 2024).

The utilization of AI in the educational field can be traced back to the 1970s, as evidenced by the development of AI-supported tutoring systems, known as Intelligent Tutoring Systems (ITS). These systems were designed to assess students' learning processes on an individual basis and provide customized feedback (Virvou & Sidiropoulos, 2013). During the 1980s, the application of AI in education underwent a significant expansion, with the development of ITSs grounded in cognitive theory (e.g., Algebra Tutor), which provided guidance tailored to students' problem-solving steps (Anderson et al., 1995).Subsequent years witnessed the emergence of AI-supported teaching models that fostered individualized learning experiences (Alonso et al., 2005). As in many other fields, AI-supported applications have become an integral part of education in the 21st century. Virtual reality applications offering students real-time virtual experiences have become increasingly popular (Antonietti & Cantoia, 2000; Guan et al., 2014). LLMs, such as ChatGPT and Gemini, which generate human-like texts, pose questions, and can be trained on extensive textual data, have recently gained traction in the educational sector (Kasneci et al., 2023). These models have been incorporated into various e-learning programs with the aim of enhancing educational efficiency (Fütterer et al., 2023). In conclusion, considering the historical development of AI, it can be said that it continues to support education with personalized learning environments that contribute to students' learning based on their learning levels and pace (Monroy Andrade, 2024; Virvou & Sidiropoulos, 2013).

The utilization of AI technology in educational settings is driven by the objective of enhancing cognitive processing and reinforcing the learning process (Popenici & Kerr, 2017). When employed judiciously and for its designated purpose, the contribution of AI to education is indisputable. A pivotal role of AI lies in empowering individual learning by facilitating the discovery process and contributing to the structuring of knowledge. In the context of mathematics education (ME), AI is regarded as a potent instrument for facilitating student discovery (see Hwang & Tu, 2021; Mohamed et al., 2022). Specifically, AI has been incorporated into ME through software packages designed for targeted content, often termed "digital tutors." While initially constrained by the objectives and boundaries defined by designers, AI has evolved into a form that is freely accessible and extremely difficult to monitor (even for ordinary users) (Gadanidis, 2017). Consequently, while providing various benefits to users, it also introduces different disadvantages. For instance, in domains aimed at cultivating higher-order thinking skills such as critical thinking, creativity, reasoning, and problem-solving, AI tools have been observed to impede the development of these competencies (Farrokhnia et al., 2023; Kasneci et al., 2023). Despite their accomplishments in knowledge acquisition, AI applications have yet to demonstrate sufficient proficiency in the interpretation and reasoning necessary for complex problem-solving (Farrokhnia et al., 2023). However, it is noteworthy that recent advancements in the field may soon rectify these limitations through rapid technological updates.Nevertheless, unless AI tools are utilized deliberately, their professionalization may persistently impede the development of cognitive skills.

Since the 1950s, AI has been a subject of study in various fields of research (Frank et al., 2019). However, the advent of the internet has enabled its rapid integration into educational curricula across numerous disciplines. Consequently, while AI is not a novel subject, it remains a field of research that necessitates comprehensive and interdisciplinary examination. In this regard, educational research, specifically, is not progressing as swiftly as the integration of AI into teaching.The United States and select European countries are revising their curricula and emphasizing the development of an AI curriculum tailored to students' age and needs (Su et al., 2022). To ensure the effective integration of AI into ME, it is imperative that educators develop a comprehensive understanding of the application of AI, including its appropriate usage and limitations (Monroy Andrade, 2024). This necessitates a shift in pedagogical practices, emphasizing the importance of AI literacy among educators. Addressing the deficiencies in teachers' knowledge and skills in this field is imperative (bin Mohamed et al., 2022; Egara & Mosimege, 2024; Forsström & Afdal, 2020; Li, 2024). Universities and administrators worldwide have initiated the process of convening researchers and collaborators (i.e., policymakers, software developers, educators) to design curriculum guides, tools, pedagogies, content knowledge, and assessment methods. The objective of this initiative is to equip K-12 students with AI awareness and literacy (e.g., Ng et al., 2021). The identification of the positive and negative features of AI in education, stemming from both internal and external factors, will have a significant impact on designing a high-quality program.In this study, the strengths, weaknesses, opportunities, and threats of using AI in ME will be identified. In addition, the impact levels of the features included in each component will be investigated. Finally, strategic recommendations that should be considered in determining AI literacy policies will be presented.

Artificial Intelligence in Mathematics Education

In the field of education, some researchers, teachers, and students see AI not just as a functional tool for accessing information, but as an entity that performs its tasks and responsibilities, almost as the subject of thinking itself (Engelbrecht & Borba, 2024). One of the reasons for this is that AI applications provide “convincing” answers and “good” solutions (Dąbrowicz-Tlałka, 2023). The fact that users do not have sufficient knowledge and experience regarding how AI should be used in education leads to their inability to approach the information they receive critically. Eliminating this negativity is possible through defining the role of AI in education and ensuring that users become AI literate (Dąbrowicz-Tlałka, 2023). Determining the purpose of using AI in education, its advantages, disadvantages, ethical and unethical situations is the first step to be taken in this regard. Thus, how AI can be integrated into education and the strategies and policies to be considered in a program to be created for AI literacy can be determined. In the literature, as in other fields, it is possible to find many studies investigating the positive and negative aspects and effects of AI in the field of education (e.g., Farrokhnia et al., 2023). Some of these studies focus on AI in general (e.g., Denecke et al., 2023; Yanev et al., 2024), while others are predominantly focused on ChatGPT, one of the most powerful Large Language Models (e.g., Farrokhnia et al., 2023; Giray et al., 2024). Although ChatGPT is an example of AI applications, when the relevant studies are examined, it is observed that the results are parallel to those of AI research. For example, while AI tools offer students personalized learning environments, they increase learning efficiency by creating different learning methods. However, in this process, concerns such as plagiarism, human interaction, and data security are among the issues that need to be considered (Tran et al., 2024). Similarly, ChatGPT applications increase student engagement by offering personalized learning experiences and customized approaches. Alongside these positive aspects, security issues, ethical considerations, and the reduction of human interactions are just a few of the concerns related to the use of these tools (Markos et al., 2024). Therefore, although ChatGPT is just one example of AI, it can be said that generalizable conclusions have been reached for AI about its positive and negative features in educational research.

The advantages and disadvantages of AI for users vary depending on the specific field or application. For instance, in disciplines such as language education and translation, AI applications with advanced grammar and a substantial vocabulary base have a considerable impact due to these characteristics (Bin-Hady et al., 2023). Consequently, in these respective domains, these attributes are regarded as strengths (Giray et al., 2024). Conversely, in disciplines such as mathematics, physics, and engineering, where analytical and critical thinking are paramount, the grammatical capabilities of AI, while significant, may not be considered among its strengths. Conversely, the capabilities of AI applications, such as the ability to perform operations in problem-solving with speed and accuracy, to provide immediate feedback, and to facilitate interactive learning experiences, can be considered among its strengths. As in many areas of education, the integration of AI into ME offers an important opportunity for the development of new teaching approaches (Druzhinina, et al., 2021; Kubsch et al., 2022; Schindler & Lilienthal, 2022). Moreover, it has the potential to enhance the efficacy of technology-supported teaching methods, such as flipped learning (Voskoglou & Salem, 2020). The limitations of AI in ME can be enumerated as the emergence of ethical problems, the provision of incorrect information, and the violation of user privacy (Engelbrecht & Borba, 2024; Nikolova, 2024; Yoon et al., 2024). Another limitation of AIcould be its inability to effectively respond to the specific desires and needs of each student according to their learning style (Druzhinina et al., 2021). This phenomenon can be attributed to a deficiency in the conceptual understanding of AI (Engelbrecht & Borba, 2024; Torres-Peña et al., 2024).The identification and resolution of the shortcomings and limitations of AI applications, in conjunction with the rapid pace of updates aimed at specializing them in nearly every field, suggests that these negativities may be eradicated in a more expeditious manner than anticipated. Spreitzer et al. (2024) examined the solutions that different versions of ChatGPT produced for complex and open-ended mathematical modeling problems. The fact that mathematical modeling problems are real-life based and assumption-based requires the problem solver to create models suitable for real life by using reasoning and connection skills beyond just performing mathematical operations (Blum & Borromeo Ferri, 2009). Spreitzer et al. (2024) underscore that as ChatGPT versions advance, they generate increasingly successful models, yet mathematical and contextual intricacy prove pivotal in establishing challenges. However, the authors of this article do not fully subscribe to this viewpoint. It is posited that regardless of the rapid advancements and "intelligence" of AI, it will always fall short of the sophistication of human reasoning and will be incapable of imparting logical and creative thinking skills to students (Voskoglou & Salem, 2020). In this context, challenges may arise, but by redefining the role of the teacher, AI can be used as an effective tool in developing higher-order thinking skills such as reasoning and critical thinking.

Theoretical Framework

Identifying the significance, advantages, and limitations of AI in ME is crucial for making sound evaluations and ensuring its effective integration into educational practices. Numerous studies in the literature have addressed this issue (e.g., bin Mohamed et al., 2022; Hwang & Tu, 2021). Among the prominent methods used to assess the advantages and disadvantages of AI is the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. Indeed, SWOT analysis serves as a valuable tool for identifying the strengths and weaknesses of AI in mathematics education, as well as for detecting potential opportunities and threats. Moreover, strategies developed by considering both positive and negative aspects go beyond mere diagnosis and serve as a guide for educational policymakers, curriculum developers, and practitioners.

However, it is worth noting that not all SWOT-based studies include strategic recommendations. Additionally, it is often observed that the prioritization of SWOT components and their respective sub-criteria is based on frequency tables or the subjective preferences of researchers (Tajer & Demir, 2022). It is evident that a more effective strategy formulation could be achieved through an evaluation in which each identified feature contributes according to its weighted impact. This can be realized by combining SWOT analysis with multi-criteria decision-making (MCDM) methods (Tajer & Demir, 2022), which have yielded effective outcomes in various domains—including education (Şahin, 2024).

In particular, methods based on pairwise comparisons—such as AHP, ANP, and BWM—are highly suitable for determining the relative importance of identified attributes by comparing them against each other (Ayçin, 2023; Şahin, 2024). Although a person may rate both attributes A and B as “very important” on a Likert-type scale, this method does not reveal whether the individual considers them equally important. In contrast, the pairwise comparison method enables the identification of which attribute—A or B—is perceived as more important by the individual (Galbraith & Haines, 2001). These degrees of importance (impact levels) play a decisive role in the construction of the SWOT matrix.

While there are studies in fields such as tourism, business, and medicine demonstrating the integration of SWOT analysis with MCDM methods for developing effective strategies, research in the field of education remains relatively limited. One of the features that renders the present study original is its application of this integrated approach within the educational context.

The research questions guiding this study, which was conducted to ascertain the strategies for leveraging artificial intelligence more effectively in the domain of mathematics education, are as follows:

(1) What are the internal factors (strengths and weaknesses) and external factors (opportunities and threats) related to the utilization of artificial intelligence in mathematics education?

(2) What are the impact levels of the characteristics in the dimensions of internal and external factors related to the use of artificial intelligence in the field of mathematics education?

(3) What strategies should be considered for more effective use of artificial intelligence in mathematics education?

The results of this study will determine the role of AI in ME, and recommendations will be made regarding the integration of AI in ME.

METHODS

In this study, the strengths and weaknesses of AI in ME, opportunities and threats were analyzed using SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, and the impact levels of these factors were analyzed using BWM (Best Worst Method), a multi-criteria decision-making method. Document review was conducted for SWOT analysis, and content analysis of the studies reached in line with the determined criteria was performed.

SWOT analysis, a method that has been employed since the 1950s, has seen a surge in usage across various research domains, including education, health, tourism, and marketing, particularly since the 1990s, where it has become a staple of strategic planning (Benzaghta et al., 2021). SWOT analysis facilitates the identification of both the strengths and weaknesses of a given situation, as well as the opportunities and threats that will affect it, thereby providing a comprehensive assessment of the appropriateness of the proposed approach, particularly in scenarios where novel practices are required or when integrating a new practice into an existing context.Strengths and weaknesses are classified as internal factors, while opportunities and threats are considered external factors. Internal factors refer to variables that are under the control of the relevant approach, while external factors refer to variables that are not under its control (Hill & Westbrook, 1997).For example, in this study, the strengths and weaknesses of AI in ME are the advantages and disadvantages that AI brings to ME in line with its purpose, while opportunities and threats are the uncontrolled effects of AI on ME outside of its purpose.

The scope of SWOT analysis extends beyond mere identification of strengths and weaknesses in a situation or opportunities and threats. The fundamental objective of this analysis is to formulate effective strategies, and for this purpose, the SWOT matrix is developed. The SWOT matrix facilitates the integration of internal and external factors (Figure 1).

	OPPORTUNITIES	**THREATS**
STRENGHTS	**SO Strategies** SO: Which strengths can be leveraged to capitalize on opportunities and how?	**ST Strategies** ST: How can strengths be leveraged to avoid threats?
WEAKNESSES	**WO Strategies** WO: Which weaknesses can be eliminated by taking advantage of opportunities?	**WT Strategies** WT: What can be done to avoid threats and eliminate weaknesses?

SO: strength-opportunity; WO: weakness-opportunity; ST: strength-threat; WT: weakness-threat

Figure 1. The SWOT Matrix

In SWOT analysis, the data source can be documents, expert opinions, or user (participant) opinions, depending on the purpose of the relevant research. Research articles on the use of AI applications in ME were selected as the data source of this study. The objective was to reach the most appropriate studies for the purpose of the research by imposing certain restrictions on the sources that constitute the data set. The topic was determined as "mathematics education" or "AI" or "artificial intelligence" and the keywords "mathematics education" and "artificial intelligence" which are frequently used in AI studies in mathematics education (69 documents), were searched separately, maintaining the topic criteria constant. Table 1 provides a detailed account of the documents evaluated within the scope of SWOT analysis.

Table 1. Criteria of document selection

Category	**Criteria**	**Number of Documents**
Publication years	2020-2024	59
Document types	Article or Early Access	44
WoS Categories	Education Educational Research	25
Citation Topic Meso	Education & Educational Research	15
WoS Index	Social Sciences Citation Index (SSCI) or Science Citation Index Expanded (SCI-EXPANDED) or Emerging Sources Citation Index (ESCI)	15
Languages	English	13
Research areas	Education Educational Research	13

As seen in the table, the number of documents gradually decreases as the criteria become more specific. After examining all the studies one by one, a total of 11 AI studies remained in the field of mathematics education.

Artificial intelligence is an umbrella concept that has different components as LLM (Large Language Models) or robotics, etc. As the objective of this study is to concentrate on the utilization of AI in ME in general, a literature review on a particular AI application was not conducted.

All documents that met the established criteria were examined separately by the researchers and coded according to the SWOT analysis components (Figure 2). Pairwise comparisons were subsequently conducted to ensure the reliability of the analysis. Additionally, an independent expert was tasked with coding 10% of the randomly selected documents according to the provided analysis framework. Due to the high degree of compatibility among the codes, the SWOT analysis framework was finalized by incorporating the expert opinions.

	INTERNAL COMPENENTS	EXTERNAL COMPENENTS
POSITIVE	**STRENGHTS**	**OPPORTUNITIES**
NEGATIVE	**WEAKNESSES**	**THREATS**

Figure 2. SWOT analysis template

In scientific studies, SWOT analysis can be used in isolation or in conjunction with other methods (see Azeroual et al., 2021; Muzahidul et al., 2020; Wu, 2020). The adaptable nature of SWOT analysis allows for integration with diverse methods, thereby facilitating the development of more robust strategic decisions through the acquisition of more precise results (see Benzaghta et al., 2021). In this study, SWOT analysis was integrated with BWM, a multi-criteria decision-making method (MCDM) developed by Rezaei in 2015. BWM is an important MCDM method that provides reliable and relevant results, which are used for optimal decision-making. Rezaei (2015) developed BWM to overcome the shortcomings of AHP (Analytic Hierarchy Process). In AHP, which requires pairwise comparisons of all subcriteria, the data collection time is longer and the risk of participants making errors in evaluations increases. BWM allows finding the optimal weight coefficient value by reducing the number of comparisons of pairs of criteria. Thus, a small number of comparisons reduces or even eliminates the risk of inconsistency (Pamučar et al., 2020). Consistency is paramount for BWM. Therefore, BWM provides reliable results. In this method, the decision maker identifies the best (most desirable) and worst (least desirable) criteria. Then, the BWM analysis makes connections between each of these criteria (the best and the worst) and the other criteria (Rezaei, 2015).

In the second stage of the study, the impact values of the factors determined as a result of SWOT analysis were determined with BWM.

The following steps are followed for BWM analysis:

1. A set of decision criteria is identified.
2. Decision makers individually identify the most important (best) and the least important (worst) of these criteria.
3. Pairwise comparisons are made between each of these two criteria (most important and least important) and the other criteria (using scores between 1-9).
4. By assigning weights to the various sets of criteria, the final scores are determined and the best alternative is selected.

As is the case with many multi-criteria decision-making methods, consistent expert opinions are important for BWM. In this study, the opinions of 19 faculty members who are experts in the field of mathematics education and who work in different universities in Türkiye were consulted. While determining the participants, it was taken into consideration that they had studies on AI applications in the field of ME or that they were actively using AI in ME. The SWOT components constitute the primary criteria in the data collection instrument developed, with consideration given to the aforementioned BWM steps.Decision makers were tasked with selecting the most and least significant sub-criteria of each component and performing pairwise comparisons between these criteria and other criteria.Additionally, they were instructed to evaluate the SWOT components in a consistent manner. For the electronic data collected, an Excel file template obtained from https://bestworstmethod.com/software was modified and utilized. The data analysis tables within the same template were then utilized for data analysis. The reliability of the analysis is contingent upon the consistency of the individual evaluations of the participants. Therefore, the consistency of the individual evaluations of the participants was examined (Input-based Consistency Ratio(CR)<Associated Threshold), and in cases of inconsistent evaluations, the participants were contacted and asked to revise their evaluations. Subsequently, the impact levels of the SWOT components and the criteria belonging to these components were calculated by averaging the evaluations of all participants. In the final stage of the study, a SWOT matrix was created with the impact values of the factors obtained as a result of BWM analysis. Furthermore, strategies for the use of AI in ME were developed. The method scheme that was followed in accordance with the research questions can be summarized as in Figure 3.

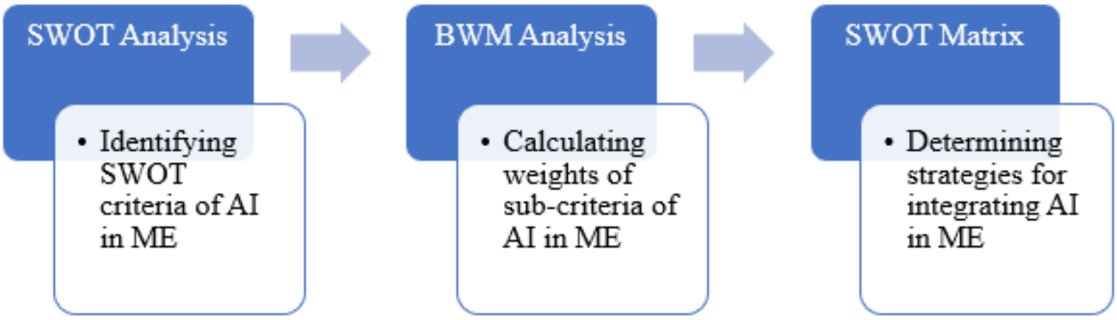

Figure 3. The method scheme

RESULTS

In this study, a content analysis of the studies was first conducted to determine the decision criteria for the use of AI in ME (Table 2).

Table 2. Content analysis results

Coding	Sample Situation
Personalized learning	Digital learning environments enhanced with artificial intelligence hold the promise to address this issue by providing individualized instruction and support for students at scale (Kubsch et al., 2022)
Fast feedback	AI provide fast feedback, allowing students to quickly fix their mistakes and consolidate their information (Nikolova, 2024)
Interactive learning experience	Both AR and VR can contribute to enhancing mathematics education by providing students with engaging and interactive learning experiences, through e.g. visualisation of concepts, interactive problem-solving and addressing real-world applications (Engelbrecht & Borba, 2024)
Scientific and inquiry-based learning opportunity	Adaptive AI-driven learning platforms nurture important skills, such as critical thinking and problem-solving (Engelbrecht & Borba, 2024)
Limitations in error detection	AI failed to identify the error in their procedure, even when specifically asked to accomplish a task (Torres-Peña, et al., 2024)
Failure to encourage students to think	Student uses of AI often involves an individual student working alone with a bot that will “get you instant answers” and does not compel students to think through or retain knowledge (Engelbrecht & Borba, 2024)
Lack of conceptual understanding	In some cases, the integration of ChatGPT might lead to challenges in adapting to diverse learning styles. If not properly customised, it may not effectively address the specific needs of every student (Druzhinina, et al., 2021)
Ease of access	Artificial intelligence tools are frequently available online and on mobile devices, allowing students to learn whenever and wherever they want, with access to a wealth of resources such as video tutorials, articles, and interactive exercises (Nikolova, 2024)
Equality in education	ITSs could be a competitive and suitable option, given their good cost–benefit ratio and considering that they are practically as effective as human tutoring (del Olmo-Muñoz, et al., 2023)
Widespread use of technology in education	ChatGPT can save time for both teachers and students by automating tasks like generating quizzes, creating lesson plans, and providing instant feedback (Druzhinina, et al., 2021)
Developing new teaching approaches	Maths teachers can use ChatGPT to explore various teaching strategies, select relevant resources, and adapt their instruction to the specific learning styles of their students (Druzhinina, et al., 2021)
Increasing learning motivation	Incorporating AI into calculus course activities has created more dynamic and engaging learning experiences through simulations, interactive visualizations, and intelligent tutoring systems (Torres-Peña, et al., 2024)
Saving time	AI tools may also automatically grade coursework, saving educators time and assuring objectivity (Nikolova, 2024)
Ethical issues (plagiarism or cheating)	In addition to concerns about the accuracy of the information provided by genAI, researchers have raised ethical issues such as plagiarism or cheating (Yoon, et al., 2024)

Data security issues (inaccurate information, potential bias, and user privacy	GenAI systems may occasionally provide inaccurate information, potential bias, and user privacy concerns (Yoon, et al., 2024)
Reducing teacher-student interaction	Over-reliance on ChatGPT could lead to a lack of human connection in teaching. While it offers efficient solutions, the personal touch and nuanced understanding that educators bring to the classroom might be compromised (Druzhinina, et al., 2021)

As a result of the content analysis based on the literature, a total of 16 codes were identified. The codes in Table 2 were first classified as positive and negative, and then these characteristics were evaluated as internal and external factors. Thus, as a result of the SWOT analysis, strengths (4 sub-criteria), weaknesses (3 sub-criteria), opportunities (6 sub-criteria) and threats (3 sub-criteria) were identified (Figure 4).

	INTERNAL COMPENENTS	EXTERNAL COMPENENTS
POSITIVE	**STRENGHTS** Personalized learning (S1) Fast feedback (S2) Interactive learning experience (S3) Scientific and inquiry-based learning opportunity (S4)	**OPPORTUNITIES** Ease of access (O1) Equality in education (O2) Widespread use of technology in education (O3) Developing new teaching approaches (O4) Increasing learning motivation (O5) Saving time (O6)
NEGATIVE	**WEAKNESSES** Limitations in error detection (W1) Failure to encourage students to think (W2) Lack of conceptual understanding (W3)	**THREATS** Ethical issues (plagiarism or cheating) (T1) Data security issues (inaccurate information, potential bias, and user privacy (T2) Reducing teacher-student interaction (T3)

Figure 4. Results of the SWOT analysis

After the SWOT analysis was completed, participants who are experts in the field of mathematics education were asked to evaluate these criteria. Table 3 shows the results of the BWM analysis including the participants' evaluations.

Table 3. Results of the BWM analysis

SWOT	Weights of SWOT	Consistency ratio of SWOT	Sub-Criteria of AI in ME	Weights of Sub-Criteria	Consistency ratio of Sub-Criteria	Local Rank	Global Weights	Rank
Strengths (S)	0,4185	0,128	S1	0,260	0,120	2	0,109	2
			S2	0,202		4	0,084	4
			S3	0,325		1	0,136	1
			S4	0,213		3	0,089	3
Weaknesses (W)	0,1495		W1	0,307	0,138	2	0,046	10
			W2	0,305		3	0,046	11
			W3	0,387		1	0,058	8
Opportunities (O)	0,3143		O1	0,143	0,248	4	0,045	12
			O2	0,095		6	0,030	16
			O3	0,232		1	0,073	5

		O4	0,204		3	0,064	7
		O5	0,118		5	0,037	13
		O6	0,207		2	0,065	6
Threats (T)	0,1178	T1	0,298	0,080	2	0,035	14
		T2	0,436		1	0,051	9
		T3	0,266		3	0,031	15

Table 3 shows the results of the prioritization of internal and external factors concerning using AI in ME. Accordingly, out of four factors of SWOT, strenghts (S) were found to be the first priority, with its weight being 0.419 and the least important factor is identified as threats (T), with its weight being 0.118. Among the four strengths, the S3, that is, "interactive learning experience", was identified as the first priority with a weight of 0.136. According to the experts, it can be argued that "personalized learning" is one of the most significant strengths of integrating AI in ME. On the other hand, out of the three prioritized weaknesses, the lack of conceptional understanding (W3) (with a weight of 0.058) was identified as the most important weakness integrating AI in ME.

According to Table 3, although the opportunities factor (with a weight of 0.314) is in the second place in the weight ranking of SWOT components, equality in education (O2), which is one of the opportunities among all sub-criteria, is in the last place with a weight value of 0.03. On the other hand, the most important opportunity factor, the widespread use of technology in education (O3), is in the fifth place in the ranking of all sub-factors with a weight value of 0.073.

On the other hand, data security issues (T2) was I dentified as the most important threat, with its weight being 0.051.

Table 4. SWOT matrix: Strategies of integrating AI in ME

Strategies	SWOT	Sub-Criteria	Global Weights	Rank
S_1: By empowering students to manage the learning process, reinforcement and assessment activities in mathematics education can take place outside the classroom.	SO	Personalized learning (S1)	0,109	2
		Fast feedback (S2)	0,084	4
		Widespread use of technology in education (O3)	0,073	5
		Saving time (O6)	0,065	6
S_2: In mathematics education, new learning/teaching approaches such as flipped learning, ACE* which provide an interactive learning experience that integrates traditional and online education, can be more effectively used through artificial intelligence.	SO	Interactive learning experience (S3)	0,136	1
		Widespread use of technology in education (O3)	0,073	5
		Developing new teaching approaches (O4)	0,064	7
S_3: AI-supported math platforms where students can access individual learning and feedback data can be created, and students can log in to these platforms by setting a password using their student email addresses with institutional extensions.	ST	Fast feedback (S2)	0,084	4
		Personalized learning (S1)	0,109	2
		Data security issues (inaccurate information, potential bias, and user privacy (T2)	0,051	9
S_4: AI-supported mathematics education should be based on teaching approaches in which the learning	WO	Limitations in error detection (W1)	0,046	10
		Lack of conceptual understanding (W3)	0,058	8

process takes place under the guidance and supervision of the teacher.		Developing new teaching approaches (O4)	0,064	7
S_5: In order for AI to detect errors not only in computational but also in mathematical thinking, databases should be expanded and versions that can make logical connections should be developed.	WO	Limitations in error detection (W1)	0,046	10
		Lack of conceptual understanding (W3)	0,058	8
		Widespread use of technology in education (O3)	0,073	5
		Developing new teaching approaches (O4)	0,064	7
S_6: A more interactive learning environment can be created by expanding the role of AI in answering questions correctly, such as providing hints to the user, asking questions that stimulate thinking, and evaluating the answer given.	WT	Failure to encourage students to think (W2)	0,046	11
		Lack of conceptual understanding (W3)	0,058	8
		Reducing teacher-student interaction (T3)	0,031	15
S_7: The AI can provide feedback to the student to not always accept answers of AI, as correct and sufficient and encourage the student to discuss with friends, or to ask questions of the teacher.	WT	Failure to encourage students to think (W2)	0,046	11
		Lack of conceptual understanding (W3)	0,058	8
		Reducing teacher-student interaction (T3)	0,031	15

*ACE (Activities, Classroom discussion, and Exercises) is a teaching cycle that based on APOS (Action, Process, Object, and Shema) Theory (Arnon et al., 2014).

The strategies identified in Table 4 were formed taking into account the weights of the sub-criteria in each component of the SWOT analysis obtained as a result of the BWM analysis. For this reason, sub-criteria with low weight (local rank) among the sub-criteria (such as O2, O5, W2) were not effective in determining the strategies.

DISCUSSION

In this study, we propose effective strategies for integrating artificial intelligence into mathematics education to enhance learning outcomes. Our findings, which are both consistent with and divergent from existing research, underscore the significance of a multifaceted approach to education. Notably, our study differentiates itself from others by placing particular emphasis on the determination of importance levels of sub-factors derived from SWOT analysis. These levels are weighted using the BWM method, a technique that has been found to be effective in analyzing and prioritizing factors in complex decision-making processes. The objective of this study was to ascertain more effective strategies, and it is believed that this objective has been achieved.

A significant finding of the study is that the strengths of using artificial intelligence in mathematics education (w=0.4185) and the opportunities it offers (w=0.3143) are much more important than its weaknesses (w=0.1495) and threats (w=0.1178). While this comparison has not been explicitly made in other studies, it can be inferred that these results are consistent with the literature, given the number of sub-factors in studies that applied SWOT analysis. Many studies examining the integration of artificial intelligence into education emphasize the positive features more than the negative ones or limitations (e.g., Tran et al., 2024; Zhang & Tur, 2024).

The findings of the present study indicate that the most significant strength of artificial intelligence in mathematics education is the provision of an interactive learning experience (w=0.136). This finding is of particular importance given that many educational studies evaluate the most effective aspect of artificial intelligence as the provision of personalized learning opportunities (Farrokhnia et al., 2023; Li & Wong, 2023). Li and Wong (2023) underscored that the pivotal feature of artificial intelligence in education is its capacity to facilitate individual learning.In this study, personalized learning (w=0.109) and the provision of scientific and inquiry-based learning opportunities (w=0.089) emerged as the second and third most salient sub-factors, respectively, following the interactive learning experience. This finding suggests that the role of artificial intelligence in mathematics education is not merely a source of knowledge, but also a tool for structuring knowledge.

The BWM analysis indicates that the two most salient factors associated with the implementation of artificial intelligence in mathematics education are strengths (w=0.4185) and opportunities (w=0.3143). Consequently, it can be concluded that development strategies (S_1, S_2) should be prioritized. Students who are capable of managing their learning processes can be trained, and particularly in the context of mathematics education, they can be provided with opportunities for independent learning or reinforcement and assessment activities that can be monitored by teachers outside the classroom environment.The use of artificial intelligence-supported learning systems, which offer personalized learning paths and provide rapid feedback, has been shown to enhance students' self-regulation skills (Chang et al., 2023; Jin et al., 2023). Furthermore, the integration of artificial intelligence-supported learning systems (e.g., augmented reality technology) can facilitate the transfer of classroom activities to out-of-class environments that are more relevant to daily life, thereby enhancing the transfer of learning processes from the classroom to real-life settings (Arici, 2024). This pedagogical shift has the potential to positively influence students' critical thinking skills (Terenzini et al., 1995) and mathematical reasoning skills (Jablonski, 2022). Moreover, the incorporation of teacher facilitation approaches in this process can foster students' independent thinking and learning abilities (Song, 2020). Furthermore, the provision of explicit guidelines concerning the utilization of artificial intelligence can serve as an effective method to ensure that students assume responsibility for their academic endeavors (Yoon et al., 2024).

The integration of artificial intelligence in mathematics education has the potential to enhance productivity in the development and implementation of novel teaching methodologies. Specifically, the creation of hybrid teaching approaches, which integrate in-class activities with online components outside the classroom, is a promising avenue for innovation. Technology-supported teaching methods, such as the flipped classroom and the ACE model, which have already gained traction, can be further enhanced by AI-driven support (S_2). The integration of interactive learning experiences, which combine traditional and online education into the learning process, has been shown to increase peer interaction, facilitate the rapid resolution of in-class problems, and support mathematical achievement and cognitive engagement (Lin & Hwang, 2019; Lo & Hew, 2020). This integration has also been demonstrated to improve students' self-regulation skills and attitudes toward mathematics (Cunska & Savicka, 2012). Furthermore, the enhanced utilization of these innovative learning/teaching methodologies through AI can personalize the learning process (Walkington & Bernacki, 2018), provide educators with opportunities for customized feedback and assessment (Zhai et al., 2020), and foster student autonomy by offering the necessary support during the learning process (Dikilitaş et al., 2024).

A considerable body of research has indicated that one of the most significant challenges posed by artificial intelligence, not only in the domain of mathematics education but also across a wide range of other fields, pertains to the legitimization of unethical behaviors such as cheating or plagiarism (e.g. Denecke et al., 2023; Yanev et al., 2024).In this study, however, ethical issues were found to be among the least salient features, ranking at position 14 with a weight of 0.035. From a researcher's perspective, ethical concerns are not perceived as an insurmountable challenge. We posit that the promotion of academic integrity among students (Ngo, 2023) and the cultivation of awareness regarding the potential pitfalls of overreliance on AI (Yoon et al., 2024) will prove highly efficacious in addressing this threat.

Current AI systems often prioritize the provision of correct answers to posed questions, neglecting context or the deeper meanings of words (Bogost, 2022). This can result in conceptual misunderstandings that are mistakenly accepted as correct, thereby encouraging passive learning behaviors in students (Borji, 2023) and hindering critical thinking and inquiry skills, leading to the acceptance of incorrect information as truth (Zhu et al., 2023). Appropriate guidance from teachers can assist students in recognizing that not all solutions and information provided by AI are necessarily accurate (S_1, S_4). This heightened awareness can foster students' capacity to manage their learning processes more adeptly (Yoon et al., 2024). Adopting a more critical stance toward AI-generated arguments mitigates the impact of AI-related threats (e.g., W1, W3). A salient finding of this study, as previously mentioned, is that experts in mathematics education regard AI threats as the least significant factor when compared to other components.

This study yielded several notable results, one of which is the identification of AI pedagogy as the foundation for effectively integrating AI into mathematics instruction. While many studies have previously focused on the importance of AI technology, this study underscores the need to explore the pedagogical foundations more deeply (Li & Wong, 2021; 2023). The identified strategies emphasize personalized learning, interactive learning, and teaching approaches, all of which are directly related to AI pedagogy and the interactions between students, teachers, and AI. While many studies focus on AI-student interaction, the role of teachers in fostering deeper cognitive interactions must be redefined (Costa et al., 2019; Li & Wong, 2023). For instance, strategies S_2 and S_4 suggest that while enhancing students' problem-solving and critical thinking skills, teachers should also develop strategies to leverage AI's capabilities (Li & Wong, 2023; Marín & Castañeda, 2023). Mathematics educators need to consider how to guide students in using AI effectively during the learning process (Yoon et al., 2024). This task presents a significant challenge for educators, underscoring the necessity for the development of comprehensive educational policies that encompass both pre-service and in-service teacher training (Yoon et al., 2024). This imperative has been repeatedly emphasized by researchers in recent years (e.g., Egara & Mosimege, 2024; Marín & Castañeda, 2023). The efficacy of the proposed development, enhancement, and risk mitigation strategies hinges on the presence of AI-literate teachers who possess a robust foundation in AI pedagogical knowledge. Furthermore, it is imperative to emphasize that AI tools should be cultivated and updated in a manner that fosters collaborative learning environments, as underscored in strategy S_7. AI has the potential to provide pertinent insights during problem-solving and can even successfully address complex problems, as evidenced by extant studies (e.g. Joksimovic et al., 2023). While rapid advancements in AI suggest that flawless mathematical solutions may soon be possible, the impact of AI on mathematics education will be greater if it supports interactions among students and between students and teachers.As highlighted in the final strategy, AI can suggest that students discuss their answers with peers or share them with their teachers, ensuring that personalized learning experiences also retain the guiding role of educators.

The findings obtained in this study suggest various strategies for the effective integration of AI into mathematics education (ME). However, these results should be interpreted within the framework of certain limitations. The primary limitation of the present study lies in the selection of research articles used as data sources, which were chosen within specific constraints. In future studies, these constraints can be modified to broaden the scope of the SWOT analysis framework. The strategies developed through systematic analyses such as SWOT and BWM in this study provide a theoretical foundation for the effective use of AI in ME. Nevertheless, experimentally testing the practical validity of these strategies in classroom settings will be a critical next step to strengthen the applicability of the proposed suggestions. Although these limitations affect the generalizability of the current study's findings, they offer valuable guidance for future research.

Future experimental studies can test the suitability of the proposed strategies for enhancing AI use in mathematics education. Furthermore, these strategies can be integrated into programs aimed at enhancing AI literacy among students and teachers.

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