Unveiling the potential: A systematic review of ChatGPT in transforming mathematics teaching and learning

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Abstract

The following systematic review strives to explore the mere integration of ChatGPT within mathematics education, analyzing its impact on teacher assistance and student learning. Google Scholar was utilized as the primary database due to its extensive coverage of academic articles and journals in various disciplines. Through the following preferred reporting items for systematic reviews and meta-analysis (PRISMA) framework, thirty-one studies are evaluated through thematic analysis table. The findings revealed that ChatGPT's potential is dynamic and versatile when it comes to improving personalized learning, and student engagement. Specifically, the findings suggest that the incorporation of ChatGPT offers diversified responses, facilitating lesson planning, student support and answering questions. Additional findings indicate that ChatGPT lead to improvements in learning motivations among students, however, it does struggle to answer complicated or difficult mathematical questions which showcase limitations in specific topics such as spatial geometry and derivatives.

Keywords: ChatGPT, mathematics education, artificial intelligence, PRISMA

INTRODUCTION

The emergence of artificial intelligence (AI) in today's dynamic digital environment has prompted worldwide debate among scholars and policymakers over its immense impact on all phases of today's life activities. AI has given businesses, industries and organizations simple ways of speeding up writing tasks, improving customer service, supporting brainstorming and research by mining vast reference sets, opening new labor markets and generating great interest from the education sector. More specifically, ChatGPT, a chat generative pre-trained transformer developed to communicate with users by answering questions from all fields including education (Grimaldi & Ehrler, 2023), was identified as one of the most advanced AI tools available today (OpenAI, 2024). It can respond to follow-up human inquiries in natural, human-like language, and even possesses the capacity to grow and acknowledge its mistakes. Since its public launch in

November 2022, ChatGPT has received tremendous interest, reaching 100 million users within two months (The Guardian, 2023), and over 180 million users worldwide by August (Tong, 2023). AI's massive potential has thus made preparing new generations of students for the new labor markets of the 21st century an urgent challenge that requires a new kind of response.

Indeed, the education sector was not prepared for ChatGPT. Its usage in schools and colleges has been sudden and massive and its impact immediately felt, prompting many questions about how it will change and contribute to education. College faculty and schoolteachers rapidly faced the reality and dilemma of grading papers and tests that were AI written with no policies in place from their institutions which scrambled to come up with some without clear and full knowledge of implications. Should using generative AI to write an essay or solve problems be considered as cheating or as legitimate tools for learning? While some faculty and teachers considered and talked about ChatGPT as a

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Contribution to the literature

- This review contributes to the literature by synthesizing existing studies on the role of ChatGPT in enhancing mathematics education, highlighting its potential to provide personalized learning experiences and foster student engagement.
- This paper identifies key opportunities and challenges, offering insights into how AI can complement traditional instructional methods in mathematics teaching.
- The findings of this review extend the current understanding of AI-driven tools in education, particularly the impact of ChatGPT on mathematical proficiency and pedagogical practices.

dangerous medicine with amazing side effects, others saw it as an amazing medicine with dangerous side effects (Lee, 2022). The ChatGPT's ability to compose academic writings and solve complex problems prompted questions about its usefulness and suitable deployment of these technologies in teaching and learning (Eke, 2023). It could act like a personal tutor, explaining code, generating data samples, writing essays and translating languages, all while sparking open discussions and engaging conversations in the classroom (Halaweh, 2023), leaving no doubt that ChatGPT can change the educational paradigm with such potential to do these several teaching and learning tasks. However, while its benefits seemed multiple, it also generated as many questions as possible drawbacks. For example, while ChatGPT simplifies or resolves the tasks that teachers assign, it may allow students to skip over the learning process and obtain answers without gaining the requisite information, abilities, or competences (Lim et al., 2023).

Indeed, the bigger challenge resides in the teaching of difficult subjects like mathematics that require teachers to choose and develop tasks that promote the development of students' understanding of concepts and procedures in a way that also fosters their ability to solve problems and to reason and communicate mathematically. Given that good tasks are ones that do not separate mathematical thinking from mathematical concepts or skills that capture students' curiosity and invite them to speculate and to pursue hunches, what kinds of tasks do teachers need to develop to lead students to such understanding? More generally, how can we use generative AI to meaningfully improve educational outcomes? How should we change students learning outcomes when we know that it can generate essays and solve mathematical problems for students? What would constitute a use of generative AI that is ethical, equitable, and accountable? What are the underlying elements of generative AI application and usage in different educational areas, levels, and contexts, its effectiveness and impact on academia, teachers' pedagogical knowledge, instructional quality and student learning? Answers to these questions will without a doubt alleviate the ethical, equitable, and accountable issues related to the use of ChatGPT in education.

LITERATURE REVIEW

In education, the introduction of new technology has always raised questions about its applications and implications for learning. For example, the effectiveness of online learning massively introduced during COVID-19 has been questioned (Almarashdi & Jarrah, 2021; García-Peñalvo, 2023). Similarly, the swift advancement of AI in today's dynamic digital environment has prompted worldwide debate among scholars over the immense influence AI has on their various domains. However, although reviews of literature on the use of AI in education have been conducted across a wide range of topics, little is known about how AI and more specifically ChatGPT impact mathematics teaching and learning. The use of ChatGPT in mathematics education is still in its early stages and has been the subject of little related peer-reviewed research due to its novelty. This study is an attempt to do a systematic and careful review of how these studies have been conducted, a summary of their findings and implications for the field, and the opportunities the technology offers as well as the drawbacks to avoid. The overarching goal for the review is to enable educators to understand the cognitive and cultural benefits of the use of generative AI, the importance of harnessing this technology so they can appropriately make substantive but meaningful changes to their teaching learning outcomes and modify accordingly their instructional practices. The academic articles used for this purpose deal with the use of AI in mathematics teaching and learning. They have all been found in Google Scholar, considered to be the most complete source of academic articles as it is a convergence of all databases.

Artificial Intelligence in Education

AI is currently being used in education to alleviate traditional educational challenges such as overcrowded classrooms, lack of allocated attention to students, and diverse learning paces and methods (Labadze et al., 2023). For example, AI technologies, like the Internet of things, virtual reality, and augmented reality, can enhance instructional environments (Vincent-Lancrin & van der Vlies, 2020).

Previously, we could find patterns and insights in data sets by using machine learning models for

prediction. More advanced versions of generative AI have emerged recently, capable of more than only content creation and prediction. Numerous disciplines, including education, now have new opportunities and uses thanks to this discovery. That being said, it is yet unclear what generative AI will accomplish and what hazards it poses (Jarrah et al., 2023; McKinsey, 2023).

Despite concerns that AI could replace people in new job creations, the idea of cooperation between humans and AI is becoming more and more significant. Recent developments indicate that human-AI collaborative teams can be successfully formed (Dwivedi et al., 2023). ChatGPT can help the teacher plan lessons and support students, including question answering, assessment, and programming (Rahman & Watanobe, 2023). It is believed that ChatGate will not be a substitute for interaction between the teacher and his students, but rather a way to support the teacher in his tasks (Dwivedi et al., 2023). It will take research to fully realize the educational potential of this joint effort and to lessen the negative effects of AI, which is getting into every part of human life (Dwivedi et al., 2023).

ChatGPT presented teachers with a creative way to integrate technological tool into their teaching, while it could also give students an alternative to search engines, which usually produce millions of search results and take a significant amount of time and effort to sort through (AlAfnan et al., 2023). Teachers can also use ChatGPT to design projects and tasks, as well as educational assessments like semester tests and monthly quizzes (Kasneci et al., 2023).

According to Dergaa et al. (2023), ChatGPT may be able to assist researchers with a variety of tasks, including creating research questions and hypotheses, organizing experiment protocols, evaluating and interpreting results, and writing publications. Thus, it is clear that the intelligent chatbot ChatGPT will have a big impact on research, education, and learning.

ChatGPT can generate text prompts, summarize complex information into clear outlines, and even detect grammatical and stylistic errors. This not only saves time but also improves the overall quality and clarity of writing (Mondal & Mondal, 2023). Moreover, Rudolph et al. (2023) cited various benefits of ChatGPT, including its ability to generate human-like discussions, its speed and efficiency, and its cost-effectiveness because no human labor is needed.

Despite the advantages that ChatGPT offers, earlier research has also brought up some serious issues regarding its use such as the academic honesty and plagiarism issues (Qasem, 2023), excessive reliance on AI that could result in insufficient understanding of the subject matter and unpreparedness for further assignments (Lim et al., 2023). Furthermore, because ChatGPT is an AI tool and can only work with the data set that it was trained on, its responses could be inaccurate and untrustworthy (Lee, 2022).

According to Halaweh (2023), ChatGPT can help students acquire research skills by offering resources and information on a particular topic, pointing out aspects that have not been explored, and introducing them to new research areas. This allows them to understand and evaluate the topic better. However, although ChatGPT provides an assistant to students in the research process, there is a growing concern about its ability to write an article or essay rather than the students themselves.

Artificial Intelligence in the Field of Mathematics Teaching and Learning

Equipping students with mathematics knowledge and skills is essential for ensuring sustainable development and adjusting to a rapidly changing society (Almarashdi et al., 2023). Mathematics is not only important for student's academic achievement and essential for future employment prospects, but also linked to their civil rights and important for their social skills development (Jarrah, 2020; Moses & Cobb, 2002).

Technology has added many new elements to the world of education. The term "digital generation" applies to children born in this period, who are immersed by technology in their immediate environment. In this regard, the National Council of Teachers of Mathematics (2014) recommends adopting and integrating new technology in the classroom to improve the bar for mathematics instruction and advance equity. ChatGPT is starting to show promise as a teaching and learning method for mathematics (Baidoo-Anu & Ansah, 2023).

It can be seen that there is an increasing trend towards AI in mathematics education research (Hwang et al., 2023). These investigations mainly study how AI tools might improve students' performance in mathematics by providing them with immediate, tailored feedback (Hwang & Tu, 2021).

As per Getenet (2024), development of problem-solving competencies among students is integral across several contexts, facilitating in their application of mathematical concepts. Teachers and educators urge to groom such skills initially at earlier stages of child's education. AI offers promising opportunities in assisting both students and teachers and poses positive impact on the learning outcomes in mathematics (Li et al., 2023), for example, ChatGPT has been enhancing student's performance in algebra (Karjanto, 2023; Matzakos et al., 2023) and geometry (Wardat et al., 2023).

Moreover, they have augmented the content knowledge of the teachers which facilitate in identification and addressing the student's misconception (Pelton & Pelton, 2023). Pre-service teachers also consider AI adoption positively, perceiving

it as an effective tool in facilitating student motivation towards acquiring knowledge (Soygazi & Oguz, 2023). Despite the vast usage of ChatGPT within educational landscape, specifically in mathematics, wide scale empirical, and non-empirical research are lacking (Getenet, 2024). Hence, further studies are required to assess its capabilities in transforming mathematics teaching and learning.

Study Purpose and Research Question

The purpose of the following systematic review is to analyze and synthesize the empirical evidence on the use of ChatGPT and the extent to which ChatGPT has been playing a facilitative and transformative role in mathematics teaching and learning. Specifically, the study aims to provide a comprehensive understanding of the implications, benefits, and drawbacks of integrating ChatGPT into mathematics teaching and learning. By carefully analyzing and synthesizing the existing literature, the findings from this study will provide mathematics teachers, academics, and policymakers with meaningful information to help them with their decisions about the utilization of ChatGPT in mathematics classrooms, and consequently, increase the knowledge and enhance the understanding of ChatGPT's capabilities and impact in educational environments. Additionally, it is expected that the findings from this review may lay a foundation for future investigations on methods for teaching and learning of mathematics. Based on findings from studies included in the systematic review, this research is intended to answer the following research question: How does the integration of ChatGPT in teaching mathematics impact student learning, engagement, and overall educational experiences, considering both potential benefits and drawbacks?

METHODOLOGY

A multi-phase procedure was employed to carry out an exhaustive search for pertinent research. To find studies in peer-reviewed journals, electronic searches of Google Scholar were first conducted. This covers a vast number of studies published in Scopus, EBSCOHost, JSTOR, ProQuest, SAGE Journals, Emerald, and Wiley Online Library databases (Walters, 2007). Since Google Scholar is thought to be the biggest and most complete knowledge source, it was selected as the database. To find articles methodically, every possible combination of the search terms mathematics, teaching, learning, ChatGPT, AI, and math were employed. References from the first set of identified research were searched to find additional papers to make sure we did not overlook any important studies. As per the guidelines discussed by Page et al. (2021), for the present systematic review preferred reporting items for systematic reviews and
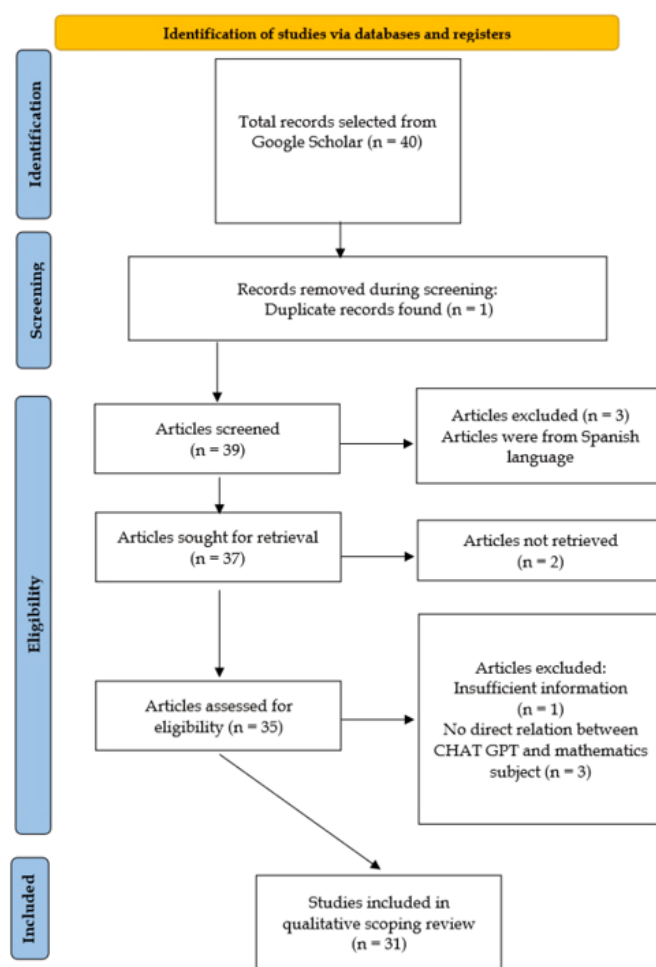

Figure 1. PRISMA framework (Page et al., 2021)

meta-analysis (PRISMA) framework has been selected (**Figure 1**).

Search Process

For the systematic review, a comprehensive search was conducted to identify relevant literature on the integration of ChatGPT in mathematics teaching and learning. Google Scholar was utilized as the primary database due to its extensive coverage of academic articles and journals in various disciplines.

Identification of Relevant Literature

The search strategy employed a combination of keywords related to 'ChatGPT,' 'mathematics education,' 'teaching,' and 'learning.' Boolean operators (AND, OR) were utilized to refine the search results. Moreover, citation chaining and reference list screening were employed to identify additional relevant studies.

PRISMA Framework

The PRISMA framework represents a comprehensive analysis of the inclusion and exclusion criteria.

Study Selection Criteria

The following selection criteria were defined while refining the PRISMA framework.

Inclusion criteria

1. Studies published in peer-reviewed journals or conference proceedings.
2. Studies focusing on integrating ChatGPT in mathematics teaching and learning.
3. Studies reporting outcomes related to student learning, engagement, or overall educational experiences.
4. Studies available in English.

Exclusion criteria

1. Studies not directly related to ChatGPT or mathematics education.
2. Studies lacking empirical data or evaluation of outcomes.
3. Non-English publications.
4. Duplicate publications or studies with insufficient information.

RESULTS

The thematic analysis in **Table 1** comprises of the 31 selected studies as a result of our PRISMA framework.

Table 1. Summary of the studies

No	References	Aims and design	Major findings	Recommendations
1	Remoto (2023)	To assess the relief and limitations of AI chat models in mathematics learning among higher education students (exploratory study).	AI models may produce inaccurate outcomes or incorrect methods initially, yet they occasionally provide correct responses upon re-prompting.	Future research should explore the efficacy of AI models in detecting errors, their impact on student motivation, and the development of tailored AI solutions for mathematics education.
2	Van Doc et al. (2023)	To explore the integration of an AI Chatbot in high school mathematics education to enhance mathematical thinking skills (descriptive study).	The AI Chatbot integration fosters dynamic learning environments, promoting real-world application of mathematics and supporting students' mathematical thinking development.	Advocate for the incorporation of AI technology to cultivate problem-solving abilities and stimulate creativity in mathematics education.
3	Ellis and Slade (2023)	To examine the potential of ChatGPT as an educational tool for statistics and data science (exploratory study).	ChatGPT can aid in developing course materials and foster responsible student interaction in statistics and data science classrooms.	Educators should guide the use of ChatGPT to leverage its benefits effectively in statistics and data science education.
4	Pelton and Pelton (2023)	To explore the potential of ChatGPT for teacher education in mathematics(exploratory study).	ChatGPT can generate grammatically correct and somewhat relevant text, showing potential as a resource for mathematics teachers.	Further experimentation and exploration with ChatGPT to harness its potential benefits for mathematics education.
5	Soygazi and Oguz (2023)	To assess the effectiveness of LLMs like ChatGPT and LLMMathChain in solving mathematics word problems (prompt analysis).	ChatGPT showed greater success in answering mathematics word problems compared to LLMMathChain, but both models fell short of expectations.	Suggestions for improving the performance of LLMs in solving mathematics word problems.
6	Korkmaz Guler et al. (2024)	To evaluate the academic performance of ChatGPT versions 3.5 and 4 in a national mathematics exam (case study approach).	ChatGPT-4 exhibited greater academic success compared to ChatGPT-3.5, demonstrating better understanding of questions, instructions, and providing more detailed solutions, despite both versions making common and distinct mistakes.	Utilizing ChatGPT versions in mathematics education for obtaining basic information and supervised assistance, considering the variability in its performance.
7	Pech-Rodríguez et al. (2023)	Evaluate the effectiveness of ChatGPT for writing essays and solving mathematical and scientific problems in academic and scientific settings (systematic case study).	ChatGPT demonstrated the ability to quickly generate written essays but lacked critical writing in most cases, and it struggled to solve complex mathematical equations.	Highlight the need for significant improvements to enhance ChatGPT's performance in solving complex mathematical problems and generating high-quality written content.
8	Sánchez-Ruiz et al. (2023)	Investigate the impact of ChatGPT on b-learning methodologies in engineering education, particularly in mathematics (employed a survey of 110 students and interviews with 10 volunteers).	Students quickly adopted ChatGPT, exhibiting confidence in its usage, but concerns arose regarding its potential impact on developing essential skills for future engineers.	Adapt teaching strategies and methodologies in engineering education to ensure the development of critical skills alongside the integration of ChatGPT.

Table 1 (Continued). Summary of the studies

No	References	Aims and design	Major findings	Recommendations
9	Zhao et al. (2023)	This paper explores the impact of ChatGPT on the higher mathematics curriculum (reflective approach).	The influence of ChatGPT on the future of advanced mathematics education is multifaceted, presenting both opportunities and obstacles.	Educators must navigate ChatGPT transformation with caution, leveraging its benefits to enhance teaching quality while mitigating potential drawbacks. Additionally, educators must guide students to the proper use of ChatGPT to develop their independent thinking and problem-solving skills.
10	Govender (2023)	To investigate the transformative role of ChatGPT and similar AI platforms in mathematics education (mixed-method approach).	ChatGPT offers personalized feedback, immediate support, and inclusive learning experiences, yet concerns include potential over-reliance, limitations in emotional intelligence emulation, and data privacy issues.	Advocate for a balanced integration of AI tools like ChatGPT with traditional teaching methods, emphasizing continual refinement, data literacy, and computational thinking while addressing concerns regarding over-dependence and privacy safeguards.
11	Dasari et al. (2024)	To explore the role of ChatGPT in mathematics education and its integration within the didactical tetrahedron framework (quasi-experimental design).	The students who have started to depend on ChatGPT for learning showed lower performance compared to those with teacher instructions, highlighting ChatGPT's potential augmentation of learning but emphasizing the essential role of human instructors.	There should be a balance between adopting ChatGPT and teacher guidance.
12	Wardat et al. (2023)	Explore stakeholders' perspectives on ChatGPT's use in teaching mathematics (qualitative case study).	ChatGPT is recognized for improved math capabilities but lacks understanding of spatial geometry.	Further research should address ChatGPT's efficacy in resolving complex mathematical problems and ensure its secure integration into mathematics education.
13	An et al. (2023)	Investigate if ChatGPT understands place values in numbers and explore the impact of English expressions on solving math word problems (experimental design).	ChatGPT; accuracy increased with explicit place value information in English expressions compared to numerical expressions.	Future research should focus on training models to better understand the concept of place value in numbers to improve ChatGPT's performance in solving math word problems.
14	Zafrullah et al. (2023)	To explore mathematics students' learning interest using ChatGPT, employing a quantitative descriptive approach (quantitative descriptive study).	Students' learning interest in mathematics using ChatGPT is "Very Good," with overall average score of 80.33%, suggesting ChatGPT's potential as a motivating learning tool.	Emphasize collaborative efforts to mitigate over-reliance on technology while harnessing ChatGPT's benefits to enhance mathematics education.
15	Gattupalli et al. (2023)	Compare teacher-written and AI-generated hints and strategies for solving fourth-grade math word problems (comparative analysis).	Teacher-written hints offer more differentiated learning opportunities with child-accessible language, visual aids, animations, and growth mindset-building statements compared to ChatGPT-4's text-heavy, procedural strategies.	Encourage the integration of both teacher-written and AI-generated hints to provide a comprehensive and inclusive approach to elementary math education, leveraging each tool's strengths for optimal student engagement and learning outcomes.
16	Rane (2023)	Investigate the roles and challenges of integrating generative AI tools like ChatGPT to enhance mathematical proficiency in education (scholarly examination).	AI tools are able to generate customized learning experiences, provide immediate feedback and solve problems however challenges are evident in terms of accuracy, biases and ethics.	Further studies should be conducted on balanced approached devised between generative AI and human intelligence.

Table 1 (Continued). Summary of the studies

No	References	Aims and design	Major findings	Recommendations
17	Bhandari et al. (2023)	Test ChatGPT's ability to generate mathematics assessment questions based solely on textbook content summarization (psychometric measurement methodological approach).	ChatGPT-generated items perform comparably or better than textbook items, exhibiting improved discrimination within the moderate ability group and higher discriminating power.	It is recommended to conduct future studies on ChatGPT in generating assessments and answering questions as compared to conventional textbook.
18	Supriyadi and Kuncoro (2023)	Explore potential futures in mathematics teaching from the perspective of ChatGPT (interview analysis).	Chat transcripts edited with ChatGPT suggest a future with integrated technology and AI, emphasizing personalized learning, computational thinking, and equity.	Emphasize thoughtful implementation, ongoing professional development, and adaptation to evolving technological advancements for quality teaching in mathematics education.
19	Pavlova (2024)	Explore using ChatGPT to enhance dialogic teaching methods in mathematics and informatics education (case study).	Flipped dialog learning with AI promotes easy access to platforms, reduces stress, and stimulates students' research skills and problem-solving abilities.	Encourage the integration of flipped dialog learning with AI to foster student engagement, research skills, and problem-solving abilities in educational settings.
20	Poola and Božić (2023)	Explore how machine learning, particularly ChatGPT, can aid mathematicians in generating new conjectures and theorems (machine learning methods).	Machine learning, exemplified by ChatGPT, can assist in identifying novel theorems and hypotheses in mathematical research, particularly by recognizing patterns and connections.	Future studies should research on attribution approaches to identify different patterns that occur among mathematical objects and leveraging of ML in context of ChatGPT.
21	Karjanto (2023)	Investigate challenges in undergraduate linear algebra studies and assess the effectiveness of SageMath and dynamic ChatGPT as supportive tools (employ SageMath and ChatGPT).	ChatGPT facilitates problem-solving and improved critical thinking competencies.	Utilize SageMath for accurate computations and dynamic ChatGPT for problem-solving assistance to improve students' understanding of matrix factorization concepts in linear algebra.
22	Dao and Le (2023)	Assess ChatGPT's performance in answering multiple-choice questions for the Vietnamese national high school graduation examination across different subjects and difficulty levels (analysis of a dataset of 250 questions).	ChatGPT performed best on low-difficulty questions (Level K), with an 83% accuracy rate, but struggled with higher difficulty levels, scoring only 10%. It excelled in topics like exponential and logarithmic functions but faced challenges with derivatives, spatial geometry, and spatial calculus.	Enhance ChatGPT's ability to handle graphical data and address challenges in responding to increasingly difficult questions to maximize its effectiveness as a teaching tool for mathematics.
23	Matzakos et al. (2023)	Explore the role of LLMs like ChatGPT in higher education mathematics teaching and compare them to existing tools (comparative analysis).	LLMs offer innovative possibilities in teaching, influencing curriculum and assessment approaches.	Advocate for further research on LLMs in mathematics education to harness their potential benefits effectively.
24	Truong (2023)	Explore integrating ChatGPT into Vietnamese high school mathematics education to enhance learning experiences and outcomes (review of literature).	ChatGPT integration offers interactive, personalized, and adaptive learning environments, fostering deeper understanding and problem-solving skills.	Present a comprehensive framework for integrating ChatGPT into the Vietnamese mathematics education system to revolutionize teaching and learning.
25	Frieder et al. (2023)	Investigate the mathematical capabilities of ChatGPT iterations and GPT-4 on publicly available datasets (test ChatGPT and GPT-4 on newly released datasets GHOSTS and miniGHOSTS to assess their mathematical reasoning abilities).	ChatGPT excels as a mathematical assistant for querying facts and acting as a search engine but performs below graduate-level expectations overall.	Use ChatGPT for undergraduate-level mathematics tasks, but for graduate-level difficulties, seek alternative solutions as its performance may not meet expectations.

Table 1 (Continued). Summary of the studies

No	References	Aims and design	Major findings	Recommendations
26	Cao et al. (2023)	Explore the application of ChatGPT in teaching high school mathematics in Vietnam (reflective approach).	ChatGPT exhibits potential but has limitations in teaching and learning high school mathematics.	Despite limitations, explore ChatGPT's potential as a supplementary tool for high school mathematics education, alongside traditional methods.
27	Getenet (2024)	Compare problem-solving abilities of pre-service teachers (PSTs) and ChatGPT in solving a mathematical word problem (prompt analysis).	PSTs employed diverse strategies with accurate solutions but not always relevant to children's understanding; ChatGPT used similar strategies but mostly produced incorrect solutions.	Consider integrating ChatGPT into teacher education programs for teaching problem-solving strategies, contextualizing its use in primary school mathematics education.
28	Patero (2023)	Explore the integration of ChatGPT in math education to enhance personalized learning, interactive problem-solving, and student success (mixed-methods approach).	Simulated results show positive shifts in student attitudes, improved self-efficacy, and enhanced learning outcomes, supported by qualitative insights on collaborative learning.	Pioneer a new era of math instruction by harnessing ChatGPT's capabilities, addressing ethical concerns, and reshaping math education for adaptable learners.
29	Li et al. (2023)	Investigate ChatGPT's impact on middle school students' math learning and self-regulation in flipped classrooms (prompt analysis).	ChatGPT demonstrated high accuracy rates (90% overall) in answering exam questions, exceeding 80% accuracy in each major area of math education, suggesting its potential as a valuable learning tool in middle school math education.	Utilize ChatGPT in flipped math classrooms to enhance personalized learning, address self-regulation issues, and improve students' math learning outcomes.
30	Poola (2023)	Investigate weaknesses in LLMs, particularly hallucinations, and compare the effectiveness of process-supervised reward models (PRMs) versus outcome-supervised reward models (ORMs) in controlling LLM training (comparative analysis).	PRMs offer more accurate feedback by identifying faults in the reasoning chain, providing benefits for AI alignment and human comprehension compared to ORMs, which may produce false positive solutions.	Prioritize PRMs for controlling LLM training to improve accuracy and mitigate hallucinations, particularly in contexts where human understanding and alignment are crucial.
31	Javaid et al. (2023)	Discuss the potential applications of ChatGPT in education, focusing on personalized learning, language instruction, and automating classroom tasks (theoretical analysis).	ChatGPT enables personalized learning, language instruction, and task automation, enhancing teaching and learning experiences.	Utilize ChatGPT to design personalized lessons, provide instant feedback, and automate tasks for optimized education processes.

DISCUSSION

ChatGPT can provide diverse responses in teaching mathematics, utilizing patterns learned during training rather than performing deterministic calculations like a calculator (Soygazi, & Oguz, 2023). Moreover, ChatGPT assists teachers by offering learning opportunities in various subjects, aiding in lesson planning, student support, question answering, assessment, writing, supervision, and facilitating programming learning (Guler et al., 2024). ChatGPT aids teachers and students by providing clear explanations and recognizing the logical complexity of paradoxes, enhancing understanding (An et al., 2023).

The findings of Zafrullah et al. (2023) concluded that student's learning interest and motivation in mathematics increased by 80.33% indicating ChatGPT being a critical learning tool. Dao and Le (2023) found ChatGPT demonstrating strong performance on level K questions, achieving an 83% accuracy rate. However, its accuracy significantly dropped to 10% on higher difficulty levels. While excelling in topics such as exponential and logarithmic functions, it encountered difficulties with derivatives, spatial geometry, and spatial calculus. Numerous research findings demonstrate that there are both opportunities and obstacles associated with integrating ChatGPT into mathematics education (Remoto, 2023). According to preliminary exploratory research, AI chat models have the potential for iterative learning because, while first producing faulty results or incorrect techniques, they can generate right responses when prompted again, actually, it depends on the continuous collaboration between the students and ChatGPT (Remoto, 2023). This highlights the necessity of conducting additional research to investigate the effectiveness of AI models in identifying errors and their influence on student motivation considering whether there is a limit for that collaboration before students getting demotivated due to unsatisfactory answers, in addition to creating customized AI solutions for mathematics instruction.

Moreover, descriptive research has demonstrated that incorporating AI chatbots into mathematics instruction in high school creates dynamic learning

settings and aids in the development of students' mathematical thinking (Van Doc et al., 2023). The usefulness of integrating AI technology in mathematics education is suggested by the way that this integration reinforces higher order thinking skills such as problem-solving and encourages the application of mathematics in real-world settings. Furthermore, ChatGPT has been investigated as a data science and statistics teaching tool–given that some of the mathematics strands include or depend on mathematics–demonstrating promise in creating course materials and encouraging responsible student involvement (Ellis & Slade, 2023). Nonetheless, uncertainties persist concerning its capacity to resolve intricate mathematical problems and produce quality written material, underscoring the want for noteworthy enhancements (Pech-Rodríguez et al., 2023). According to preliminary research, ChatGPT can produce grammatically accurate and relatively relevant content in the context of mathematics teacher education, suggesting its potential use for math teachers (Pelton & Pelton, 2023). To fully realize its advantages for teacher professional development, more research is necessary. Notwithstanding these encouraging results, ChatGPT optimization for mathematics teaching still faces obstacles. Compared to previous models, it has demonstrated success in solving word problems in mathematics; nonetheless, its performance is not up to par (Soygazi & Oguz, 2023; Remoto, 2023). Additionally, a qualitative case study investigating stakeholders' opinions regarding ChatGPT's application in mathematics education was carried out by Wardat et al. (2023). While ChatGPT's potential to enhance math skills was acknowledged, its shortcomings in comprehending spatial geometry indicated the need for additional study, in line with Pelton and Pelton's (2023) recommendations to investigate and enhance ChatGPT's math education potential and also aligned with Getenet (2024) who examined how well pre-service teachers (PSTs) and ChatGPT solved a mathematical word problem. PSTs used various tactics, but ChatGPT's answers were typically erroneous. PSTs show lack of the competence needed in science, technology, engineering, and mathematics (Almarashdi et al., 2022). Therefore, ChatGPT is seen as a tool that can help PSTs to improve their skills. However, a balanced integration approach is required because of concerns regarding its possible effects on the development of critical skills and over-reliance in engineering education (Sánchez-Ruiz et al., 2023). In response to Soygazi and Oguz's (2023) worries over ChatGPT's ability to solve complex mathematical issues, An et al. (2023) looked into the program's comprehension of place values in numbers and how it affected the solution of math word problems. An et al.'s recommendations for future research directions are in line with those of Remoto (2023) and Govender (2023), who both want to investigate ChatGPT's effectiveness in mistake detection and make sure that a balanced

integration is made that maximizes its advantages while minimizing any potential disadvantages.

Furthermore, Gattupalli et al. (2023) emphasized the significance of combining teacher assistance with AI technology in mathematics education by comparing instructor-written and AI-generated tips and techniques for answering fourth-grade math word problems. This is in line with Govender's (2023) balanced integration strategy and emphasizes the necessity of teamwork to use ChatGPT's advantages while resolving its drawbacks. Rane (2023) examined the functions and difficulties of incorporating generative AI tools, such as ChatGPT, to improve mathematical competency in the classroom. This research echoes worries expressed by Sánchez-Ruiz et al. (2023) over ChatGPT's possible influence on the development of critical abilities. These results highlight the need for continued investigation and careful application in order to navigate ChatGPT integration successfully in mathematics teaching. However, and from a different perspective that discusses these obstacles and challenges related to use of AI ChatGPT, it is worth emphasizing that the importance of human-AI interaction and collaboration to get the most accurate and satisfactory answers for all educators and students (Khurma et al., 2023, 2024). However, as highlighted in both research of Khurma et al. (2023, 2024), this interaction allows those users to keep sharpening their prompts until they get the most effective response, which indirectly builds their ability to evaluate the efficiency of the prompts and judge their potential for beneficial use, which is a higher order thinking skill according to Bloom's taxonomy. Teachers need to be cautious and proactive while integrating ChatGPT into mathematics instruction. Although it provides tailored feedback, prompt assistance, and inclusive learning opportunities, challenges like data privacy and emotional intelligence emulation limits must be solved (Govender, 2023). Teachers should support a well-balanced integration of AI tools, such as ChatGPT, with conventional teaching techniques, focusing on data literacy, computational thinking, and ongoing improvement. To promote autonomous thought and problem-solving abilities in their students, teachers must also help them use ChatGPT appropriately. This will ensure that integrating ChatGPT into the classroom improves instruction while minimizing potential negative effects. On another side, Dasari et al. (2024) found that students who heavily relied on ChatGPT for learning exhibited lower performance compared to those who received instructions from human teachers, echoing concerns about over-reliance on technology highlighted in previous studies. This underscores the importance of creating a balance between adopting ChatGPT and providing teacher guidance, consistent with the emphasis on balanced integration advocated by Govender (2023).

As evidenced by a number of research findings, the use of ChatGPT in teaching mathematics represents a paradigm shift in educational practices that has both potential and obstacles. These results highlight the possible advantages of using ChatGPT while also illuminating its drawbacks and offering insightful information on how it affects student learning, engagement, and overall educational experiences. For example, a comparative investigation investigating the function of large language models (LLMs) such as ChatGPT in teaching mathematics in higher education was carried out by Matzakos et al. (2023). They discovered that LLMs provide creative teaching opportunities that impact curriculum and evaluation strategies. This emphasizes the need for more research in order to fully utilize the potential advantages of LLMs in mathematics education, supporting a thorough analysis of their incorporation into teaching methods and integrating it into the learning environment, as emphasized by Truong (2023).

However, regarding adult learning through the use of ChatGPT, Frieder et al. (2023) found limitations in ChatGPT's performance, especially at the graduate level, after studying the mathematical skills of GPT-4 and ChatGPT iterations on publicly accessible datasets. While it can serve as a useful mathematical helper for activities at the undergraduate level, it might not be sufficient to solve graduate-level problems. This result emphasizes how crucial it is to consider ChatGPT's limits and investigate substitute strategies when dealing with more difficult mathematical problems. This is aligned with Cao et al. (2023), who investigated ChatGPT's use in Vietnamese high school mathematics instruction, recognizing both the technology's advantages and disadvantages and recommending checking alternative tools or strategies when dealing with higher levels of difficulties in mathematical problems. Unlike the use of ChatGPT by middle schools' students, it was found that ChatGPT had a high accuracy rate while answering exam questions and might be a useful teaching tool for middle school arithmetic (Li et al., 2023). A final finding out of these 31 studies that provide a precise potential benefit, is Patero's (2023) study, who investigated how ChatGPT might be incorporated into math instruction to improve student achievement, interactive problem-solving, and individualized learning. It showed improvements in learning outcomes, increased self-efficacy, and positive changes in student attitudes, suggesting the advent of a new age in math instruction by utilizing ChatGPT's capabilities.

To sum up, the integration of ChatGPT into mathematics education offers creative ways to personalize learning and increase student engagement. For more difficult mathematical issues, it is necessary to consider its limitations and look into alternative approaches. By adopting a balanced approach to integration and appropriately using ChatGPT's features, educators may optimize mathematics teaching and learning experiences. These research findings highlight the need for a well-rounded approach that recognizes and balances ChatGPT's benefits and limitations, contributing to a more nuanced understanding of technology's incorporation in mathematics education. These results provide educators and researchers with valuable information about how to use ChatGPT in mathematics instruction. They build upon earlier studies' findings and recommendations.

Limitations and Implications

According to Ellis and Slade (2023), the education community's initial reaction towards ChatGPT has been concerned primarily with educationists and educational institutions adopting measures to limit its utilization within academic environments. One of the critical implications is the issue of students potentially using ChatGPT for developing content that lacks originality, raising issues for academic integrity and plagiarism. As per analysis of Pech-Rodríguez et al. (2023), it is critical for educating the professors/teachers and students regarding ethics and plagiarism regarding AI usage. The development of strict measures is important for preventing the misuse of ChatGPT (cheating). However, overall ChatGPT has been proven to be beneficial for teachers and students both in generating answers and solving mathematical problems.

CONCLUSIONS

In conclusion, the incorporation of ChatGPT into mathematics education signifies a noteworthy progression in teaching methodologies, providing a range of responses and augmenting multiple facets of instruction and learning. Research by Dao and Le (2023) and Zafrullah et al. (2023) has shown significant gains in students' learning motivations, with 80.33% increases in motivation noted. Studies such as those conducted by Guler et al. (2024) have shown that ChatGPT is useful for helping with lesson planning, offering student support, and responding to inquiries. Nevertheless, despite these advantages, there have been reported limits in ChatGPT's capacity to solve challenging or sophisticated mathematical problems, especially in domains like spatial geometry and derivatives. This emphasizes the importance of acknowledging ChatGPT's advantages and disadvantages and implementing a thoughtful strategy for integrating it into math teaching. Teachers may maximize ChatGPT's potential to improve student learning outcomes in mathematics education and increase teaching effectiveness by utilizing its strengths and resolving its limitations.

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