





## Challenges of secondary mathematics pre-service teachers in using ChatGPT in mathematics learning

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### ABSTRACT

ChatGPT is widely known for enhancing student learning. However, it still presents challenges for pre-service teachers that have yet to be fully explored. This study used a descriptive qualitative research design, utilizing semi-structured interviews with the 20 secondary mathematics pre-service teachers selected through purposive sampling. The participants are students from a higher education institution in the Philippines with prior experience using ChatGPT to learn mathematical concepts. The findings identified challenges, including limited input and interface design, as well as concerns about accuracy and reliability stemming from response errors. ChatGPT's methods often differed from textbook approaches. Students also encountered technical issues, such as limited internet connectivity and system errors. Investing in reliable internet connectivity, a premium subscription, and educator training is essential to address these challenges. ChatGPT should also be used as a supplementary tool, with students encouraged to cross-validate its output. Collaboration between artificial intelligence (AI) developers and educators is essential to promote the ethical use of AI in education. Future researchers may conduct further studies to assess the long-term impacts and emphasize the use of ChatGPT as a complementary tool alongside other learning resources.

**Keywords:** ChatGPT, mathematics learning, pre-service teachers, challenges, qualitative research design, AI in teaching and learning, technology in education

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### INTRODUCTION

Since its launch in November 2022, ChatGPT has shown significant promise in fostering interactive learning environments (Dempere et al., 2023; Goar et al., 2023; Haleem et al., 2022; Roumeliotis & Tselikas, 2023). ChatGPT's ability to learn from structured and unstructured data makes it a highly flexible and versatile conversational artificial intelligence (AI) tool (Wei et al., 2022). It has become the fastest-growing consumer application in history, amassing 100 million monthly active users within two months of its launch (Trust et al., 2023). It can produce coherent and contextually relevant outputs for quicker and easier academic writing (Roumeliotis & Tselikas, 2023), simulate human conversations through sophisticated algorithms that understand natural language inputs and generate appropriate responses (Salvagno et al., 2023), and automate routine tasks and foster critical thinking by providing content students can build upon (Klepec, 2023). With the growing integration of technology in education, ChatGPT enables teachers and mentors to enhance their teaching methodologies (Lo, 2023; Shamsudin & Aris, 2023).

Researches from Woodhouse and Charlesworth (2023) and Zafrullah et al. (2023) have identified ChatGPT as a motivational tool that amplifies students' interest in mathematics and gauges their engagement in the subject. For instance, it helps develop problem-solving skills by generating word problems that connect math topics and content (Moore, 2023). Additionally, it offers benefits for students struggling to grasp mathematical principles, providing humanized explanations and insights (Supriyadi & Kuncoro, 2023). On the other hand, significant risks exist. One concern is the accuracy and effectiveness of ChatGPT's solutions, which vary depending on factors such as equation complexity, input data, and the instructions provided (Wardat et al., 2023). Furthermore, the possibility that students may become excessively dependent on AI could undermine their analytical and critical thinking skills (Kasneji et al., 2023; Tili et al., 2023; Wardat et al., 2023). This dependency could lead to a decline in essential cognitive abilities, including creativity, analytical reasoning, and problem-solving skills (Farrokhnia et al., 2023).

ChatGPT utilizes natural language processing and machine learning technology to quickly answer students' questions and provide detailed steps and analysis in mathematics (Zhao et al., 2023), break down complex concepts into simpler components, speed up

computations (Wu et al., 2023), produce symbolic solutions (Poola & Božić, 2023), and identify patterns in mathematical objects (He, 2023). However, ChatGPT struggles to solve logic problems accurately, often providing incorrect answers to math or logic problems with definitive solutions rather than probabilistic ones (Zhou et al., 2023). This finding is consistent with concerns expressed in another study about ChatGPT's accuracy and reliability, as it may sometimes provide incorrect or incomplete solutions to mathematical problems (Wu & Yu, 2023).

In the Philippines, the use of AI tools in education is an emerging trend, with various stakeholders exploring their benefits. AI's role in enhancing personalized learning experiences and preparing students for the digital era has been recognized (Estrellado & Miranda, 2023). This personalized approach enables students to understand concepts better and sharpen their critical thinking and problem-solving skills (Alipio et al., 2023). However, while there is significant research on AI in education in the Philippines, most studies focus on the advantages and challenges students and teachers face when using ChatGPT, particularly in mathematics learning. The role of ChatGPT in mathematics learning, particularly for pre-service teachers, presents challenges that have not yet been thoroughly explored, especially from the perspective of future teachers interacting with this tool.

Moreover, peer-reviewed research on the challenges of using ChatGPT in mathematics teacher education programs is currently limited, revealing an explicit knowledge and population gap, which highlights the need to explore the perspectives of mathematics education students on using ChatGPT in mathematics learning, particularly within a localized context. Despite the growing body of research highlighting ChatGPT's potential benefits and risks in education (Adeshola & Adepoju, 2024), existing studies primarily focus on general student populations, writing-related tasks (Imran & Almusharraf, 2023), or broad perceptions of AI use (Shoufan, 2023), with limited attention to mathematics learning and even less to pre-service teachers. This gap is significant because pre-service mathematics teachers occupy a dual role as learners and future educators, and their experiences with AI may shape both their mathematical understanding and future instructional practices. Moreover, mathematics involves high cognitive demands (Yip et al., 2025) that can intensify issues related to accuracy, overreliance, and conceptual understanding; yet these concerns remain underexplored from the perspective of pre-service teachers. To address this gap, the present study examines the challenges pre-service teachers face in using ChatGPT for mathematics learning in a Philippine higher education context, providing empirical evidence to inform theory and practice in AI-integrated mathematics education. By addressing these challenges, this study aims to contribute to the development of strategies that facilitate the effective integration of AI tools into educational practice. To guide this investigation, the following research questions have been formulated:

1. What challenges do pre-service teachers encounter when using ChatGPT in their mathematics?
2. How do these challenges in using ChatGPT affect pre-service teachers' motivation and confidence in learning mathematics?
3. What strategies do pre-service teachers employ to improve the accuracy of their prompt formulations when using ChatGPT for mathematics?

## LITERATURE REVIEW

### Understanding Technology Adoption Challenges in Teacher Education

Understanding how students adopt and utilize new technologies is critical in an era of rapid technological advancement, particularly in teacher education, where future educators develop beliefs and practices that shape their professional careers. One foundational framework for explaining technology adoption is Rogers' (2003) diffusion of innovations theory, which explains how and why innovations spread through social systems over time (Al-Rahmi et al., 2019; Dwivedi et al., 2023). This theory categorizes adopters into five groups: innovators, early adopters, early majority, late majority, and laggards, based on their readiness to adopt new technologies and their perceptions of factors such as relative advantage, compatibility, complexity, trialability, and observability (Raman et al., 2023; Rogers, 2003). In teacher education, these factors are particularly relevant, as pre-service teachers' willingness to adopt tools like ChatGPT depends on how well such technologies align with pedagogical beliefs, curricular demands, and instructional norms.

Building on diffusion theory, the technology acceptance model (TAM) proposed by Davis et al. (1989) provides a widely used framework for understanding individual technology adoption, including in educational contexts (Granić & Marangunić, 2019; Yilmaz et al., 2023). TAM posits that technology acceptance is primarily influenced by perceived usefulness (PU), the degree to which individuals believe a technology is free of effort, and perceived ease of use, the belief that a technology enhances task performance (Yilmaz et al., 2023). For pre-service teachers, these perceptions are critical, as they influence not only their own learning but also their future willingness to integrate technologies like ChatGPT into classroom practice. High cognitive demands, perceived complexity, and uncertainty about instructional value may pose challenges to adoption within teacher education programs.

Complementing these adoption-focused models, connectivism learning theory offers insight into how digital technologies reshape learning processes in networked environments (Siemens, 2004, as cited by Vitoulis, 2017). Connectivism emphasizes learning through connections among information sources, technologies, and social networks (Alam, 2023). In teacher education, this perspective emphasizes how tools like ChatGPT serve as knowledge nodes, facilitating access to information, peer interaction, and content generation (ElSayary, 2024). However, effective learning depends on learners' ability to critically evaluate and meaningfully engage with these tools (Revere & Kovach, 2011), an area that presents challenges for pre-service teachers still developing pedagogical and subject-matter expertise (Bostock, 2019).

Additionally, the community of inquiry framework offers a framework for understanding learning in online and technology-mediated environments (Garrison, 2016). It identifies cognitive, social, and teaching presence as essential elements for meaningful learning. Cognitive presence, in particular, emphasizes learners' ability to construct knowledge through reflection and critical inquiry (Garrison & Arbaugh, 2006). Within teacher education, challenges arise when AI tools such as ChatGPT support surface-level task completion but potentially weaken deeper cognitive engagement and reflective practice.

## The Rise of ChatGPT and Artificial Intelligence in Education

ChatGPT, an AI chatbot developed by OpenAI, is trained on massive text datasets, enabling it to generate human-like responses and answer user questions through prompts (Kooli, 2023). The evolution of AI, once a science fiction seen in books and movies, has progressed from artificial narrow intelligence to artificial super intelligence, where systems can perform human-like thinking and decision-making (Saghiri et al., 2022). In education, AI is regarded as transformative, enhancing learning experiences, personalizing instruction, and streamlining administrative tasks (Adıgüzel et al., 2023; Chen et al., 2022). ChatGPT, specifically, is increasingly utilized for intelligent tutoring, providing tailored educational support based on analysis of students' learning styles and performance (Baidoo-Anu & Owusu Ansah, 2023; Kasneci et al., 2023; Qadir, 2022; Zhai, 2022; Zhang, 2023). This approach improves engagement and learning outcomes by adapting to individual needs (Onesi-Ozigagun et al., 2024). Furthermore, AI systems can monitor real-time learning processes and emotional states, facilitating personalized adaptive learning (Peng et al., 2019). The capabilities of generative AI (GenAI), such as ChatGPT, enhance these educational environments, offering innovative and interactive learning experiences for both teachers and students (Rudolph et al., 2023).

## The Potential and the Challenges of ChatGPT in Education

Recent literature highlights both the transformative potential and the challenges of ChatGPT in education. While ChatGPT supports personalized learning, interactive engagement, and academic assistance (Ansari, 2024), concerns have emerged regarding over-reliance, plagiarism, reduced critical thinking, and academic integrity (Haleem et al., 2022; Kooli, 2023; Sullivan et al., 2023). These challenges are particularly salient in teacher education, where excessive dependence on AI may undermine the development of essential pedagogical and analytical skills. Also, ChatGPT's ability to generate content that bypasses plagiarism detection tools raise concerns about authenticity and assessment validity (Ibrar, 2025), while issues related to accuracy, bias, privacy, and data security further complicate adoption decisions (Chinonso et al., 2023; Hualpa et al., 2023; Imran & Lashari, 2023).

Scholars have emphasized the need for ethical guidelines, transparency, and policy development to address these challenges in educational contexts (Ahmed & Sharo, 2023; García-Peñalvo, 2023; Watrionthos et al., 2023). Ethical concerns related to bias, data misuse, and intellectual property require careful consideration (Farrokhnia et al., 2023; Fergus et al., 2023), particularly in preparing pre-service teachers to use AI responsibly. At the same time, studies suggest that students are motivated to use ChatGPT as a supplemental learning tool to clarify complex concepts, support assignments, and explore topics beyond formal curricula (Ahmad et al., 2023; Haleem et al., 2022; Wardat et al., 2023). These motivations reflect both the PU of the tool and the adoption challenges associated with regulating its use for learning rather than academic shortcutting.

Despite varied perspectives, a common conclusion across studies is that ChatGPT can enhance teaching and learning when its use is guided by appropriate policies, pedagogical frameworks, and ethical standards (De Silva et al., 2023). For teacher education, this shows the importance of examining not only the benefits of ChatGPT but also the challenges mathematics pre-service teachers face in adopting and integrating it effectively. Understanding pre-service teachers' perceptions, experiences, and concerns is therefore essential, as these factors influence both current learning and future classroom practices.

## The Potential and Challenges of ChatGPT in Mathematics Education

Advances in educational technology have improved mathematics teaching and learning (Das, 2019). Among recent developments, ChatGPT, a conversational AI model, has received considerable attention due to its rapid adoption and potential to disrupt educational practices (Wardat et al., 2023). Prior research suggests that ChatGPT can support learning by identifying gaps in students' understanding and facilitating interactive dialogue with learners (Chaudhry & Kazim, 2022; Peng et al., 2019; Zhai, 2022), particularly in more challenging subjects such as mathematics. Through this interaction, the system provides personalized explanations and learning activities tailored to individual needs (Zhai, 2022). Additionally, ChatGPT has been demonstrated to support instructional processes by generating assessment materials, rubrics, progress reports, and automated feedback, thereby enhancing instructional efficiency (Zhai, 2023). When used as a "teachable agent," it can also promote learning through explanation and reflection, thereby reinforcing conceptual understanding (Tate et al., 2023).

Despite these potential benefits, the use of ChatGPT in mathematics education presents challenges that are more pronounced than in many other disciplines (Hankeln, 2024). Mathematics requires formal reasoning, symbolic manipulation, and procedural accuracy, whereas GenAI may not yet be perfected (Yang et al., 2024). Research by Asare et al. (2023) suggests that students already encounter difficulties with abstract mathematical concepts, manipulating mathematical symbols and notation, and procedural challenges, such as basic operations. They also often experience fear, anxiety, and diminished confidence and motivation, leading to poor performance in the subject. Within this context, ChatGPT's tendency to produce fluent but occasionally inaccurate or misleading responses is problematic, as errors in mathematical reasoning may not be readily detected by learners with limited prior knowledge or conceptual understanding (Wardat et al., 2023).

Empirical evidence further highlights ChatGPT's discipline-specific limitations in mathematics. Studies by Pelton and Pelton (2023) and Shakarian et al. (2023) demonstrate that the model's accuracy is not perfect and that it relies on the task requirements, with occasional failures when step-by-step reasoning is not explicitly required. Additionally, increasing problem complexity, such as the presence of multiple variables or operations, negatively impacts performance. Frieder et al. (2023) reported that ChatGPT's mathematical reasoning abilities are below those of an average mathematics graduate student, indicating limitations in addressing advanced or non-routine tasks. Although the system frequently interprets mathematical prompts correctly, it may still generate incomplete or conceptually flawed solutions, a limitation further constrained by its training data, which extends only to 2021.

These challenges are particularly relevant in pre-service teacher education. Pre-service mathematics teachers are developing both subject-matter knowledge and pedagogical competence (White et al., 2026). Their uncritical reliance on AI-generated solutions may reinforce misconceptions rather than support conceptual development (Asare et al., 2023; Wardat et al., 2023). Given that future teachers are expected to model clear mathematical reasoning and justify solution processes (Yigit, 2014), inconsistencies in ChatGPT's explanations raise important pedagogical concerns (Pelton & Pelton, 2023; Shakarian et al., 2023). The limitations identified by Frieder et al. (2023) further suggest that ChatGPT should be used cautiously as a supplementary

resource rather than an authoritative source for mathematical reasoning.

The literature indicates that while ChatGPT has the potential to support mathematics learning, its practical use requires careful pedagogical integration. In contrast to other disciplines, where it may primarily function as a generative or writing aid, mathematics education demands accuracy, transparency of reasoning, and alignment with curricular goals. Understanding how pre-service teachers perceive and address these challenges is therefore essential, as their experiences with AI tools influence both their own learning and their future instructional practices (Lancaster, 2023). Further research is needed to inform how teacher education programs can support critical, reflective, and pedagogically sound use of ChatGPT in mathematics education.

### The Role of Learners

Learners are at the heart of the learning process, especially when incorporating technologies such as ChatGPT into academic learning (Sosas et al., 2026). Their ability to interact effectively with such AI tools shapes learning outcomes and determines how these tools fulfill their educational purpose (Chen et al., 2020). Active engagement is key, as learners utilize ChatGPT to access diverse information, independently solve problems, and contribute to interactive learning scenarios (Baskara, 2023). However, successfully using AI tools hinges on learners' capacity to incorporate these technologies into their everyday learning habits (Pedro et al., 2019). This involves understanding how to apply ChatGPT's functionalities to specific tasks, such as generating ideas, clarifying concepts, or analyzing data. Simultaneously, learners must navigate the limitations of these tools, including inaccuracies, biases, and the ethical implications of their use (Limna et al., 2023; Zhai, 2023). While the potential benefits of AI tools like ChatGPT are widely acknowledged, the hurdles learners face in using them effectively remain a crucial concern. Existing studies have identified issues such as over-reliance on AI-generated responses, difficulty in interpreting complex outputs, and gaps in understanding the tool's limitations (Limna et al., 2023). The role of learners extends beyond mere users of technology to active participants who shape the success of AI integration in education.

## METHODOLOGY

### Research Design

The study used a descriptive qualitative research design, employing qualitative data to examine the challenges pre-service teachers face when using ChatGPT in mathematics learning (Adel et al., 2024). It carefully describes and interprets a phenomenon without manipulating variables or testing hypotheses. This design facilitates an in-depth exploration of participants' unique perspectives (Lim, 2024). The choice of this design lies in its ability to provide rich, detailed data that can inform development of targeted strategies and interventions to enhance support for pre-service teachers in similar educational contexts.

The researchers are mathematics educators and pre-service teachers with an interest in educational technology, which may have influenced the study's design and interpretation. Their experience with AI tools shaped the study's focus and demanded careful reflection on the potential for bias in their evaluation. To address this, the researchers employed a comprehensive thematic analysis to center participants' voices. Throughout the study, they reflected on how their backgrounds might influence their interpretations and on distinguishing their own

perspectives from those of the participants. This approach aimed at improving transparency and trustworthiness in the analysis.

### Sample and Data Collection

Participants for this study were selected through purposive sampling, focusing on secondary mathematics pre-service teachers from a top-performing higher education institution in Cebu, Philippines. This sampling method was employed to ensure the inclusion of participants with prior experience using ChatGPT in mathematics and who had encountered challenges in its application. The 20 participants were selected after data saturation, enabling the comprehensive exploration of recurring themes and insights. A semi-structured interview format was employed, allowing for in-depth, one-on-one discussions. This allowed participants to express their thoughts and experiences freely, addressing the study's objectives. (Limna et al., 2023).

Data collection was conducted in accordance with ethical standards, including obtaining informed consent from all participants, particularly when audio recordings were used. Interviews were scheduled at mutually convenient times and conducted in private, quiet environments to uphold confidentiality and minimize potential disruptions. Each interview was digitally recorded to ensure accurate transcription and facilitate reliable analysis. All data were treated confidentially. Participants' identities were protected through anonymization, and any identifying information will be removed from transcripts and reports.

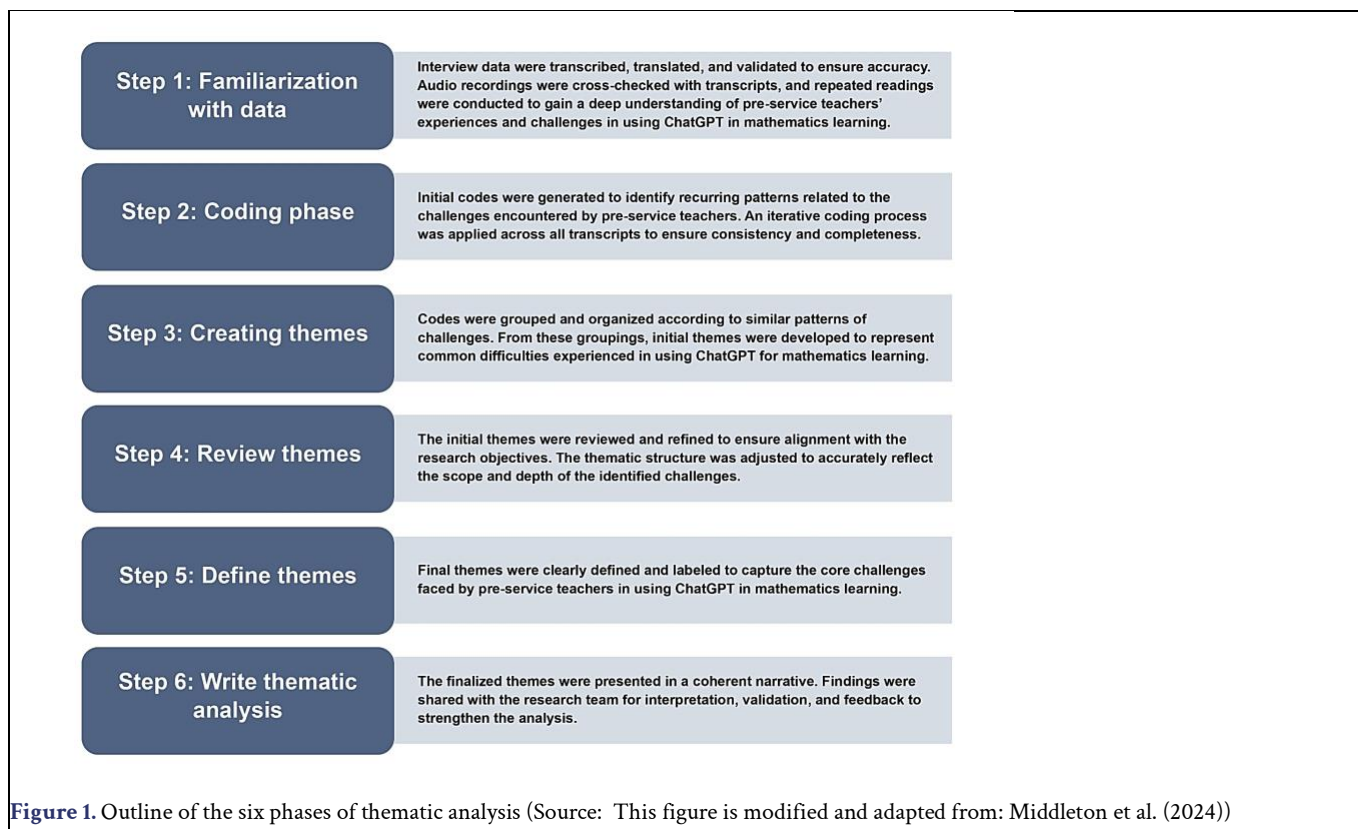
### Analysis of Data

Following the guidelines established by Braun and Clarke (2006), the interview transcripts were analyzed using a thematic analysis approach. This qualitative approach enables the systematic identification, analysis, and organization of themes within the data to discover the patterns that inform classifications and interpretations (Alhojailan, 2012). By employing this method, the study adhered to a structured framework that enhances the accuracy and depth of research interpretation, thereby supporting a comprehensive understanding of complex and diverse subjects, specifically the challenges associated with using ChatGPT in mathematics (Perera, 2023).

To ensure the consistency and reliability of the findings, the data were carefully analyzed, cross-checked, and triangulated (Schlunegger et al., 2024). To strengthen inter-coder reliability, multiple researchers independently coded a subset of the data and then compared and discussed their coding. Discrepancies were resolved through collaborative discussion until consensus was reached, and the agreed-upon coding framework was subsequently applied to the full dataset. **Figure 1** is a detailed outline of the six phases of thematic analysis as implemented in this study.

## FINDINGS/RESULTS

After analyzing the interviews, the following challenges were identified as experienced by the pre-service teachers when using ChatGPT in mathematics:



### Input and Interface Challenges

There are various input and interface issues related to difficulties users experience when entering data and receiving output from a system. Four participants noted the lack of visual representations, emphasizing that ChatGPT's text-only format limits its ability to convey complex mathematical concepts effectively. Some participants also experienced difficulty in accurately typing mathematical expressions, particularly on mobile devices. Additionally, eight participants found the complex terminology in ChatGPT responses confusing. Furthermore, 12 participants struggled to formulate prompts accurately, leading to inaccurate responses from ChatGPT.

P1: "ChatGPT cannot generate or present pictures such as examples [to illustrate trigonometric problems] as this only provides merely textual responses. With this, you could not understand, as you will only see texts without visual representations."

P2: "Maybe I am not aware that what I have written had some mistakes, making ChatGPT provide no answer to my queries."

P3: "Sometimes, it is difficult to type mathematical expressions. If you are using a cellphone, it's challenging to input expressions such as exponents or whatever else that may cause ChatGPT to misunderstand my questions, leading to incorrect answers or ChatGPT saying, "I don't know the answer."

P5: "Sometimes it's confusing because the words used are profound. So, I think the challenge lies in the difficult words provided or complex definitions ..."

### Dependency and Reliance on ChatGPT

This theme encompasses both users' tendency to rely on ChatGPT and the potential for overreliance on it. Based on the findings, one

participant admitted to cheating with the help of ChatGPT. Some participants also reported losing attention during the instructors' lectures, noting that they could better understand the topics with ChatGPT. While some participants viewed ChatGPT as a useful supplemental tool, 10 students preferred human interaction and guidance, expressing concerns about the accuracy of ChatGPT's responses. Additionally, sixteen participants emphasized the importance of not relying solely on ChatGPT for numerical solutions, recognizing its limitations and the potential for generating misleading information.

P18: "Sometimes, there is an overreliance on ChatGPT for all my answers and actions, leading to dependency solely on its capabilities, not mine. This reliance can prevent me from relying on my skills, as ChatGPT becomes the primary source for everything."

P19: "Another is that because of ChatGPT, I am not attentive in listening to my instructor because I can understand more in ChatGPT than some of those instructors... Sometimes our instructor provides equations and answers, but when it comes to ChatGPT, the answers are inaccurate or not the same."

P20: "This reliance on ChatGPT has hindered my ability to verify answers and critically evaluate my solutions independently."

### Reliability and Accuracy Concerns

Reliability and accuracy concerns refer to the extent to which a system consistently provides incorrect information. The findings reveal that ChatGPT's reliability is a significant concern for users, with 16 participants encountering incomplete or incorrect solutions. Some participants also explicitly expressed hesitation in using ChatGPT due to perceived inconsistencies and unreliability in its responses. This

**Table 1.** Summary of identified challenges

Theme	Description
Input and interface challenges	Difficulty with text-only explanations, typing mathematical expressions, complex terminology, & prompt formulation
Dependency and reliance on ChatGPT	Overreliance, reduced attention in class, cheating, and a preference for human guidance
Reliability and accuracy concerns	Incorrect, incomplete, or inconsistent mathematical solutions
Misalignment with classroom instruction	Differences between ChatGPT's methods and teachers' or textbooks' approaches
Technical and connectivity issues	Slow performance, unstable internet access, system errors, and crashes

issue was especially pronounced in mathematical contexts, where discrepancies between ChatGPT's answers and participants' expectations led to confusion and frustration. Additionally, eight participants expressed disappointment and a loss of confidence upon discovering errors in ChatGPT's responses.

P1: "I don't usually use ChatGPT because of its inconsistent (unreliable) responses, making it inaccurate for me."

P4: "There are instances where the solutions or step-by-step processes generated by ChatGPT are incomplete or presented in a shortcut manner. Consequently, I sometimes doubt the accuracy or certainty of the answers provided."

P12: "...but when it comes to more complex concepts, especially the problems in higher math, it wasn't very reliable."

P14: "I find it very amusing because, for example... when I have an answer, and I want to check to ChatGPT if my answer is correct, then, if I prove that the answer that ChatGPT provided is a mistake and then I can confirm that my answer is indeed correct. I will ask the ChatGPT, "How about this answer, then I'm amused by its reply like "Yes, yes, you got it right, I'm sorry, I... I made some mistake." By that experience, I conclude ... ChatGPT is not reliable in solving or in answering in mathematics concepts."

### Misalignment with Classroom Instruction

Misalignment between classroom instruction and methods and solutions provided by external tools, such as ChatGPT, occurs when the latter differ from those taught in the classroom. Eight participants expressed a misalignment between the methods and answers provided by their teachers and those offered by ChatGPT. Eight participants specifically mentioned that ChatGPT's process for answering questions and the solutions it offered did not align with the approaches presented by their teachers or found in textbooks. Additionally, two participants shared that while they found ChatGPT helpful, they still relied more on their instructors and classmates for a clearer understanding.

P10: "Also, my teachers' methods differ from ChatGPT because ChatGPT simplifies my questions. It's not the same as what the teacher teaches. Sometimes, it will generate correct answers, but the process is different."

P14: "Perhaps the process and the answers provided by ChatGPT are different, and the solutions that it will present are different compared to the teachers and the books."

### Technical and Connectivity Issues

Technical and connectivity issues involve challenges related to internet access and system reliability that disrupt the use of a tool or service. The findings reveal technical and connectivity issues, with 8 participants reporting slow internet and instability. Specifically, eight participants reported that ChatGPT was slow or unavailable due to

unstable network conditions, particularly in schools in provinces with unreliable internet connections. Additionally, three participants encountered technical issues, including bugs, system errors, and website crashes. Of these, three participants also specifically reported instances in which ChatGPT became unresponsive or crashed.

P2: "ChatGPT runs slowly because of an intermittent internet connection. There were also times when system errors occurred."

P18: "Sometimes, ChatGPT may not be immediately available when you have unstable internet connectivity, especially in environments like our school, where internet stability is an issue."

### Summary

**Table 1** summarizes the identified challenge themes and their key characteristics.

## DISCUSSION

Although ChatGPT has been widely promoted as a supportive tool for learning in mathematics (Wardat et al., 2023), this study's findings suggest that its use in mathematics education introduces significant pedagogical tensions rather than delivering unqualified benefits. Consistent with prior research (Azaria et al., 2024; Kasneci et al., 2023; Zhang, 2023), participants' experiences indicate that interface constraints, overdependency (Ebhomien & Omokhomion, 2025), and reliability concerns (Wardat et al., 2023) collectively undermine ChatGPT's effectiveness as a mathematics learning tool. While some of these challenges are intensified by local contextual conditions, the convergence of these findings with international studies suggests that many of the identified tensions are not unique to this setting.

A central issue identified in this study concerns input and interface limitations, which fundamentally shape how mathematical knowledge is represented and understood. ChatGPT's reliance on text-based interaction limits its ability to convey the symbolic, spatial, and visual aspects of mathematics—elements central to mathematical reasoning (Haleem et al., 2022; Kalla & Kuraku, 2023). For learners who depend on diagrams, graphs, or step-by-step visual representations, this limitation is not merely technical but pedagogically consequential (Nguyen & Sirichokcharoenkun, 2023). Difficulties in typing mathematical expressions, particularly on mobile devices commonly used in the Philippine context, further introduce cognitive and mechanical burdens that may distort learners' questions and lead to misleading outputs (Rane, 2023; Shoaib et al., 2023). While these issues may be intensified in contexts where mobile-first access and limited digital infrastructure are prevalent, similar interface-related challenges have been documented in studies from other educational systems, suggesting a broader structural limitation of current chatbot designs (Amin, 2023; Slavych et al., 2024).

While proponents argue that improved prompt engineering can mitigate these issues, this study complicates that assumption. Although one participant noted that refining prompt formulation enhanced response quality, this places the burden of effective interaction on the learner rather than the tool itself. This raises critical questions about equity, as students with stronger language skills or prior AI experience are more likely to benefit, while others remain disadvantaged (Farr, 2024; Maitland et al., 2024). Although disparities in language and digital skills may be more pronounced in certain institutional or national contexts, the underlying issue, unequal distribution of the skills required to use AI effectively, suggests that ChatGPT may inadvertently privilege specific learners, contradicting claims of its democratizing potential in education.

Equally concerning is the issue of dependency and overreliance. The admission of cheating by one participant highlights ethical risks associated with unregulated AI use, reinforcing concerns that ChatGPT can undermine academic integrity (Rane et al., 2023). Beyond this isolated case, participants' reports of reduced attention during classroom instruction suggest a shift from active engagement toward passive reliance on AI-generated explanations. While ChatGPT may serve as a supplementary resource (Mohebi, 2024), excessive reliance risks weakening students' autonomy in problem-solving, analytical reasoning, and metacognitive development (Chukwuere, 2024). Although institutional policies, assessment practices, and classroom norms may shape the extent of this dependency, similar concerns have been raised internationally, suggesting that the risk of cognitive offloading is not confined to a single educational context. This tension underscores a critical contradiction: while ChatGPT may enhance short-term understanding, it may simultaneously erode long-term mathematical thinking skills if used uncritically.

Participants' preference for human interaction further reinforces these concerns. Despite ChatGPT's convenience, students expressed greater trust in instructors and peers, particularly when accuracy and conceptual clarity were essential. This finding aligns with growing evidence that AI-generated responses require ongoing verification due to their susceptibility to errors and hallucinations (Amaro et al., 2023; Shen et al., 2023). Rather than functioning as an authoritative tutor, ChatGPT operates as an unstable knowledge intermediary—one that demands users possess sufficient expertise to identify its mistakes. This paradox is especially problematic in mathematics education, where novice learners may lack the expertise needed to detect flawed reasoning. While trust in human instruction may be culturally reinforced in some contexts, the instability of large language models represents a more universal limitation.

Reliability and accuracy concerns emerged as one of the most critical challenges, directly undermining ChatGPT's educational credibility. Participants encountered incomplete or incorrect solutions, and confidence in the tool diminished further when errors were acknowledged only after being challenged. Such behavior raises serious concerns, as it obscures the distinction between validated mathematical knowledge and probabilistic text generation (Wu & Yu, 2023). These findings echo broader critiques that large language models prioritize linguistic plausibility over formal mathematical correctness (Dwivedi et al., 2023; Wagner & Ertl, 2023). While students with strong mathematical foundations may be able to use ChatGPT critically, its reliability remains particularly problematic for novice learners across contexts, limiting its suitability as a primary instructional resource.

The misalignment between ChatGPT's solution strategies and classroom instruction further complicates its pedagogical value. Mathematics education often emphasizes specific procedures, representations, and justifications aligned with curricular standards

and assessment expectations (Aydın-Güç & Daltaban, 2021). When ChatGPT generates alternative methods—even if mathematically valid—it may confuse learners or conflict with instructional goals (Aithal & Aithal, 2023). While curricular rigidity varies across educational systems, this lack of contextual sensitivity highlights a broader limitation of AI tutors: their inability to adapt meaningfully to local instructional norms without explicit guidance. Consequently, ChatGPT appears more appropriate as a supplementary aid rather than a replacement for structured instruction and teacher mediation (Aktay et al., 2023).

Finally, technical and connectivity issues expose structural constraints that shape students' access to AI tools. In educational settings with unstable internet infrastructure, such as many institutions in the Philippines, ChatGPT's effectiveness is significantly compromised (Ratnam et al., 2023). Frequent disruptions, slow response times, and system errors not only frustrate learners but also interrupt cognitive engagement and learning continuity. Although these challenges are more acute in resource-constrained contexts, they underscore a broader point: the successful integration of AI tools depends not only on pedagogical design but also on institutional capacity and technological infrastructure (Božić & Poola, 2023).

Taken together, these findings suggest that while ChatGPT holds potential as a supplementary learning tool, its uncritical adoption in mathematics education risks undermining pedagogical coherence, equity, and learning quality. Although the Philippine context may intensify specific challenges—particularly those related to infrastructure and access—issues of reliability, dependency, and instructional misalignment resonate strongly with international research, supporting the broader transferability of these findings. Future research should therefore move beyond asking whether ChatGPT “works” and instead examine how, when, and under what pedagogical, institutional, and contextual conditions its use can be educationally justified.

## CONCLUSION

There are several challenges associated with using ChatGPT in mathematics learning. These include difficulties in processing complex mathematical expressions and the absence of visual representations, which limit its ability to convey core mathematical concepts effectively. Interactions are further complicated by the need for precise, sophisticated prompts, which reduces accessibility for learners with varying levels of mathematical and technological proficiency. Participants also reported risks of overreliance, raising concerns about diminished analytical skill development and academic integrity. Additionally, inaccuracies, incomplete responses, and misalignment with conventional classroom instruction undermine students' trust and create confusion, while technical and connectivity issues, particularly in contexts with unstable internet access, further disrupt learning.

Beyond documenting these challenges, this study makes several important contributions to the existing literature on AI in mathematics education. First, it provides grounded evidence of how students actually experience and negotiate the use of ChatGPT in mathematics learning, moving beyond speculative or tool-centered evaluations to foreground learner perspectives. Second, the study extends prior research by showing that challenges such as reliability, overdependence, and instructional misalignment are not isolated technical flaws but interconnected pedagogical tensions that shape learning quality, equity, and engagement. Third, by situating these findings within a resource-constrained context, this study highlights how infrastructural and

institutional conditions mediate the effectiveness of AI tools, thereby strengthening the transferability and contextual sensitivity of AI-in-education research.

## RECOMMENDATIONS

Researchers recommend enhancing ChatGPT's integration into mathematics learning by addressing several key areas. Educational institutions should invest in reliable internet connectivity and updated hardware to facilitate their practical use. Educators would benefit from training sessions and workshops that enable them to integrate ChatGPT into their teaching practices. For students, ChatGPT should be used as a supplementary resource, with an emphasis on cross-validating its responses and consulting other sources, especially for complex problems. Collaboration between AI developers and educators is essential to ensure ChatGPT's features align with pedagogical practices and curriculum standards.

At the same time, policymakers should advocate for AI tools as complementary resources rather than replacements for traditional methods. Communities can also support technological literacy by promoting programs that provide resources and training on AI tools like ChatGPT, involving local organizations and educational institutions. Emphasizing ChatGPT as a complementary tool within a broader educational framework is important, and further research should assess its long-term impact on students' mathematical skills, using a mixed-method approach to explore its potential, challenges, and benefits.

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## REFERENCES

- Adel, A., Ahsan, A., & Davison, C. (2024). ChatGPT promises and challenges in education: Computational and ethical perspectives. *Education Sciences*, 14(8), Article 814. <https://doi.org/10.3390/educsci14080814>
- Adeshola, I., & Adepoju, A. P. (2024). The opportunities and challenges of ChatGPT in education. *Interactive Learning Environments*, 32(10), 6159-6172. <https://doi.org/10.1080/10494820.2023.2253858>
- Adigüzel, T., Kaya, M. H., & Cansu, F. K. (2023). Revolutionizing education with AI: Exploring the transformative potential of ChatGPT. *Contemporary Educational Technology*, 15(3), Article ep429. <https://doi.org/10.30935/cedtech/13152>
- Ahmad, A., Waseem, M., Liang, P., Fahmideh, M., Aktar, M. S., & Mikkonen, T. (2023). Towards human bot collaborative software architecting with ChatGPT. In *Proceedings of the 27<sup>th</sup> International Conference on Evaluation and Assessment in Software Engineering* (pp. 279-285). ACM. <https://doi.org/10.1145/3593434.3593468>
- Ahmed, Y. A., & Sharo, A. A. (2023). On the education effect of ChatGPT: Is AI ChatGPT to dominate the education career profession? In *Proceedings of the 2023 International Conference on Intelligent Computing, Communication, Networking and Services* (pp. 79-87). IEEE. <https://doi.org/10.1109/iccns58795.2023.10192993>
- Aithal, S., & Aithal, P. S. (2023). Effects of AI-based ChatGPT on higher education libraries. *International Journal of Management, Technology, and Social Sciences*, 8(2), 95-108. <https://doi.org/10.47992/ijmts.2581.6012.0272>
- Aktay, S., Gök, S., & Uzunoğlu, D. (2023). ChatGPT in education. *TAY Journal*, 7(2), 378-406. <https://doi.org/10.29329/tayjournal.2023.543.03>
- Alam, A. (2023). Connectivism learning theory and connectivist approach in teaching and learning: A review of literature. *Bhartiyam International Journal of Education & Research*, 12(2), 1-15. <https://tinyurl.com/bddtzu6h>
- Alhojailan, M. I. (2012). Thematic analysis: A critical review of its process and evaluation. *West East Journal of Social Sciences*, 1, 39-47. Please add this URL: [https://faculty.ksu.edu.sa/sites/default/files/ta\\_thematic\\_analysis\\_dr\\_mohammed\\_alhojailan.pdf](https://faculty.ksu.edu.sa/sites/default/files/ta_thematic_analysis_dr_mohammed_alhojailan.pdf)
- Alipio, M., Lantajo, G. M., & Pregoner, J. D. (2023). On the use of ChatGPT in health science education: Opportunities and obstacles. *IMCC Journal of Science*, 3(2), 1-7. <https://doi.org/10.65931/p7c2q8m5>
- Al-Rahmi, W. M., Yahaya, N., Aldraiweesh, A. A., Alamri, M. M., Aljarboa, N. A., & Alturki, U. (2019). Integrating technology acceptance model with innovation diffusion theory: An empirical investigation on students' intention to use e-learning systems. *IEEE Access*, 7, 26797-26809. <https://doi.org/10.1109/ACCESS.2019.2899368>
- Amaro, I., Della Greca, A., Francese, R., Tortora, G., & Tucci, C. (2023). AI unreliable answers: A case study on ChatGPT. In H. Degen, & S. Ntoa (Eds.), *Artificial intelligence in HCI. HCII 2023. Lecture notes in computer science* (pp. 23-40). Springer. [https://doi.org/10.1007/978-3-031-35894-4\\_2](https://doi.org/10.1007/978-3-031-35894-4_2)
- Amin, M. Y. M. (2023). AI and ChatGPT in language teaching: Enhancing EFL classroom support and transforming assessment techniques. *International Journal of Higher Education Pedagogies*, 4(4), 1-15. <https://doi.org/10.33422/ijhep.v4i4.554>
- Ansari, A. N., Ahmad, S., & Bhutta, S. M. (2024). Mapping the global evidence around the use of ChatGPT in higher education: A systematic scoping review. *Education and Information Technologies*, 29(9), 11281-11321. <https://doi.org/10.1007/s10639-023-12223-4>

- Asare, B., Arthur, Y. D., & Boateng, F. O. (2023). Exploring the impact of ChatGPT on mathematics performance: The influential role of student interest. *Education Science and Management*, 1(3), 158-168. <https://doi.org/10.56578/esm010304>
- Aydın-Güç, F., & Daltaban, D. (2021). An investigation of the use of specific problem-solving strategies by mathematics teachers in lessons. *Journal of Pedagogical Research*, 5(1), 126-140. <http://doi.org/10.33902/JPR.2021067307>
- Azaria, A., Azoulay, R., & Reches, S. (2024). ChatGPT is a remarkable tool—For experts. *Data Intelligence*, 6(1), 240-296. [https://doi.org/10.1162/dint\\_a\\_00235](https://doi.org/10.1162/dint_a_00235)
- Baidoo-Anu, D., & Owusu Ansah, L. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *Journal of AI*, 7(1), 52-62. <https://doi.org/10.61969/jai.1337500>
- Baskara, F. R. (2023). AI-driven dynamics: ChatGPT transforming ELT teacher-student interactions. *Lensa: Kajian Kebahasaan, Kesusastraan, dan Budaya*, 13(2), 261-275. <https://doi.org/10.26714/lensa.13.2.2023.261-275>
- Bostock, J. (2019). Exploring in-service trainee teacher expertise and practice: Developing pedagogical content knowledge. *Innovations in Education and Teaching International*, 56(5), 605-616. <https://doi.org/10.1080/14703297.2018.1562358>
- Božić, V., & Poola, I. (2023). Chat GPT and education. *Scribd*. <https://www.scribd.com/document/715782599/CPT>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Chaudhry, M. A., & Kazim, E. (2022). Artificial intelligence in education (AIEd): A high-level academic and industry note 2021. *AI and Ethics*, 2(1), 157-165. <https://doi.org/10.1007/s43681-021-00074-z>
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, 8, 75264-75278. <https://doi.org/10.1109/ACCESS.2020.2988510>
- Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education: Contributors, collaborations, research topics, challenges, and future directions. *Educational Technology & Society*, 25(1), 28-47. <https://psycnet.apa.org/record/2022-66872-003>
- Chinonso, O. E., Theresa, A. M., & Aduke, T. C. (2023). ChatGPT for teaching, learning, and research: Prospects and challenges. *Global Academic Journal of Humanities and Social Sciences*, 5(2), 33-40. <https://doi.org/10.36348/gajhss.2023.v05i02.001>
- Chukwuere, J. E. (2024). The use of ChatGPT in higher education: The advantages and disadvantages. *The Indonesian Journal of Computer Science*, 14(5), 8355-8365. <https://doi.org/10.33022/ijcs.v14i5.5009>
- Das, K. (2019). The role of ICT in better mathematics teaching. *Shanlax International Journal of Education*, 7(4), 19-28. <https://doi.org/10.34293/education.v7i4.641>
- Davis, F. D. (1989). Technology acceptance model: TAM. *Al-Suqri, MN, Al-Aufi, AS: Information Seeking Behavior and Technology Adoption*, 205(219), Article 5.
- De Silva, D., Mills, N., El-Ayoubi, M., Manic, M., & Alahakoon, D. (2023). ChatGPT and generative AI guidelines for addressing academic integrity and augmenting pre-existing chatbots. In *Proceedings of the 2023 IEEE International Conference on Industrial Technology* (pp. 1-6). IEEE. <https://doi.org/10.1109/ICIT58465.2023.10143123>
- Dempere, J., Modugu, K., Allam, H., & Ramasamy, L. (2023). The impact of ChatGPT on higher education. *Frontiers in Education*, 8, Article 1206936. <https://doi.org/10.3389/feduc.2023.1206936>
- Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kar, A. K., Baabdullah, A. M., Koochang, A., Raghavan, V., Ahuja, M., Albanna, H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., . . . Wright, R. (2023). Opinion paper: "So what if ChatGPT wrote it?" Multidisciplinary perspectives on opportunities, challenges, and implications of generative conversational AI for research, practice, and policy. *International Journal of Information Management*, 71, Article 102642. <https://doi.org/10.1016/j.ijinfomgt.2023.102642>
- Ebhomien, P. A., & Omokhomion, V. O. (2025). The transformative role of ChatGPT in the teaching and learning of mathematics in the Nigerian education system. *AAU Journal of Business Educators*, 5(1), 252-257. <https://www.aaujbe.com.ng/index/index.php/aaujbe/article/view/171>
- ElSary, A. (2024). Enhancing education in the digital era: Leveraging ChatGPT for transformative learning. In A. Olowoselu, & A. ElSary (Eds.), *International perspectives on educational administration using educational inquiry* (pp. 32-40). Routledge. <https://doi.org/10.4324/9781032621296-5>
- Estrellado, C. J. P., & Miranda, J. P. (2023). Artificial intelligence in the Philippine educational context: Circumspection and future inquiries. *International Journal of Scientific and Research Publications*, 13(5), 16-22. <https://doi.org/10.29322/ijsrp.13.05.2023.p13704>
- Farr, C. (2024). *Unmasking ChatGPT: The challenges of using Artificial Intelligence for learning vocabulary in English as an additional language* [Master's thesis, University of Victoria]. <http://hdl.handle.net/1828/15835>
- Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2023). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, 61(3), 460-474. <https://doi.org/10.1080/14703297.2023.2195846>
- Fergus, S., Botha, M., & Ostovar, M. (2023). Evaluating academic answers generated using ChatGPT. *Journal of Chemical Education*, 100(4), 1672-1675. <https://doi.org/10.1021/acs.jchemed.3c00087>
- Frieder, S., Pinchetti, L., Griffiths, R., Salvatori, T., Lukasiewicz, T., Petersen, P., Chevalier, A., & Berner, J. (2023). *Mathematical capabilities of ChatGPT*. arXiv. <https://doi.org/10.48550/arxiv.2301.13867>
- García-Peñalvo, F. J. (2023). The perception of Artificial Intelligence in educational contexts after the launch of ChatGPT: Disruption or panic. *Education in the Knowledge Society*, 24, Article e31279. <https://doi.org/10.14201/eks.31279>
- Garrison, D. R. (2016). *E-learning in the 21st century: A community of inquiry framework for research and practice*. Routledge.
- Garrison, D. R., & Arbaugh, J. (2006). Researching the community of inquiry framework: Review, issues, and future directions. *The Internet and Higher Education*, 10(3), 157-172. <https://doi.org/10.1016/j.iheduc.2007.04.001>

- Goar, V., Yadav, N. S., & Singh Yadav, P. (2023). Conversational AI for natural language processing: A review of ChatGPT. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(3S), 109-117. <https://doi.org/10.17762/ijritcc.v11i3s.6161>
- Granić, A., & Marangunić, N. (2019). Technology acceptance model in educational context: A systematic literature review. *British Journal of Educational Technology*, 50(5), 2572-2593. <https://doi.org/10.1111/bjet.12864>
- Haleem, A., Javaid, M., & Singh, R. (2022). An era of ChatGPT as a significant futuristic support tool: A study on features, abilities, and challenges. *BenchCouncil Transactions on Benchmarks, Standards and Evaluations*, 2, Article 100089. <https://doi.org/10.1016/j.tbench.2023.100089>
- Hankeln, C. (2024). Challenges in using ChatGPT for assessing conceptual understanding in mathematics education. *Journal of Mathematics Education*, 17(1), 1-15. <https://journalofmathed.scholasticahq.com/article/125448-challenges-in-using-chatgpt-for-assessing-conceptual-understanding-in-mathematics-education/attachment/260591.pdf>
- He, Y. H. (2023). Machine-learning mathematical structures. *International Journal of Data Science in the Mathematical Sciences*, 1(1), 23-47. <https://doi.org/10.1142/S2810939222500010>
- Huallpa, J. J., Arocutipá, J.P.F., Panduro, W.D., Huete, L.C., Limo, F.A.F., Herrera, E.E., Callacna, R.A.A., Flores, V.A.A., Romero, M.A.M., Quispe, I.M., Hernandez, F.A.H., (2023). Exploring the ethical considerations of using Chat GPT in university education. *Periodicals of Engineering and Natural Sciences*, 11(4), 105-115. <https://doi.org/10.21533/pen.v11.i4.200>
- Ibrar, W., Mahmood, D., Al-Shamayleh, A. S., Ahmed, G., Alharthi, S. Z., & Akhunzada, A. (2025). Generative AI: A double-edged sword in the cyber threat landscape. *Artificial Intelligence Review*, 58(9), Article 285. <https://doi.org/10.1007/s10462-025-11285-9>
- Imran, M., & Almusharraf, N. (2023). Analyzing the role of ChatGPT as a writing assistant at higher education level: A systematic review of the literature. *Contemporary Educational Technology*, 15(4), Article ep464. <https://doi.org/10.30935/cedtech/13605>
- Imran, A. A., & Lashari, A. A. (2023). Exploring the world of artificial intelligence: The perception of the university students about ChatGPT for academic purpose. *Global Social Sciences Review*, VIII(1), 375-384. [https://doi.org/10.31703/gssr.2023\(viii-i\).34](https://doi.org/10.31703/gssr.2023(viii-i).34)
- Kalla, D., & Kuraku, S. (2023). Advantages, disadvantages and risks associated with ChatGPT and AI on cybersecurity. *Journal of Emerging Technologies and Innovative Research*, 10(10), 84-94. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=4619204](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4619204)
- Kasneji, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidal, T., ... Kasneji, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, Article 102274. <https://doi.org/10.1016/j.lindif.2023.102274>
- Klepce, K. (2023). ChatGPT, a blessing or a curse? *DU Clarion*. <https://duclarion.com/2023/01/chatgpt-a-blessing-or-a-curse/>
- Kooli, C. (2023). Chatbots in education and research: A critical examination of ethical implications and solutions. *Sustainability*, 15(7), Article 5614. <https://doi.org/10.3390/su15075614>
- Lancaster, T. (2023). Artificial intelligence, text generation tools and ChatGPT—Does digital watermarking offer a solution? *International Journal for Educational Integrity*, 19(1), Article 10. <https://doi.org/10.1007/s40979-023-00131-6>
- Lim, W. M. (2024). What is qualitative research? An overview and guidelines. *Australasian Marketing Journal*, 33(2), 199-229. <https://doi.org/10.1177/14413582241264619>
- Limna, P., Kraiwani, T., Jangjarat, K., Klayklung, P., & Chocksathaporn, P. (2023). The use of ChatGPT in the digital era: Perspectives on chatbot implementation. *Journal of Advanced Learning Technology*, 6(1), Article 32. <https://doi.org/10.37074/jalt.2023.6.1.32>
- Lo, C. K. (2023). What is the impact of ChatGPT on education? A rapid review of the literature. *Education Sciences*, 13(4), Article 410. <https://doi.org/10.3390/educsci13040410>
- Maitland, A., Fowkes, R., & Maitland, S. (2024). Can ChatGPT pass the MRCP (UK) written examinations? Analysis of performance and errors using a clinical decision-reasoning framework. *BMJ Open*, 14(3), Article e080558. <https://doi.org/10.1136/bmjopen-2023-080558>
- Middleton, G., Johnson, B. J., Dutch, D., Trost, S. G., Bryne, R., Christian, H.E., Henry, A., Terranova, C. O., Williams, K.E., Chai, L.K., Brooke, D.S.K., Simon, K., Golley, R. K. (2024). A great way to bring up health behaviour topics at playground: a qualitative evaluation of the Healthy Conversations @ Playgroup program. *BMC Public Health*, 24, Article 890. <https://doi.org/10.1186/s12889-024-17703-x>
- Mohebi, L. (2024). Empowering learners with ChatGPT: Insights from a systematic literature exploration. *Discover Education*, 3, Article 36. <https://doi.org/10.1007/s44217-024-00120-y>
- Moore, K. (2023). Using ChatGPT in math lesson planning. *EduTopia*. <https://www.edutopia.org/article/usingchatgpt-plan-high-school-math-lessons/>
- Nguyen, T., & Sirichokcharoenkun, Y. (2023). The limitations and potential of ChatGPT in chemistry education. *ResearchGate*. [https://www.researchgate.net/publication/374087925\\_The\\_Limitations\\_and\\_Potential\\_of\\_ChatGPT\\_in\\_Chemistry\\_Education](https://www.researchgate.net/publication/374087925_The_Limitations_and_Potential_of_ChatGPT_in_Chemistry_Education)
- Onesi-Ozigagun, O., Ololade, Y. J., Eyo-Udo, N. L., & Ogundipe, D. O. (2024). Revolutionizing education through AI: A comprehensive review of enhancing learning experiences. *International Journal of Advanced Research in Social Sciences*, 6(4), 589-607. <https://doi.org/10.51594/ijarss.v6i4.1011>
- Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development. *UNESCO*. <https://unesdoc.unesco.org/ark:/48223/pf0000366994>
- Pelton, T. & Francis Pelton, L. (2024). Using generative AI in mathematics education: Critical discussions and practical strategies for preservice teachers, teachers, and teacher educators. In J. Cohen & G. Solano (Eds.), *Proceedings of society for information technology & teacher education international conference* (pp. 1800-1805). Association for the Advancement of Computing in Education (AACE). <https://www.learnedtechlib.org/primary/p/224212/>
- Peng, H., Ma, S., & Spector, J. M. (2019). Personalized adaptive learning: An emerging pedagogical approach enabled by a smart learning environment. *Smart Learning Environments*, 6, Article 9. <https://doi.org/10.1186/s40561-019-0089-y>

- Perera, K. D. R. L. J. (2023). Applying thematic analysis to analyse qualitative data: A researcher's experience. *International Journal of Research and Innovation in Social Science*, 7, 1334-1340. <https://rsisinternational.org/journals/ijriss/articles/applying-thematic-analysis-to-analyse-qualitative-data-a-researchers-experience/>
- Poola, I., & Božić, V. (2023). Guiding AI with human intuition for solving mathematical problems in ChatGPT. *ResearchGate*. <https://www.researchgate.net/publication/373447147>
- Qadir, J. (2022). *Engineering education in the era of ChatGPT: Promise and pitfalls of generative AI for education*. TechRxiv. <https://doi.org/10.36227/techrxiv.21789434.v1>
- Raman, R., Mandal, S., Das, P., Kaur, T., Sanjanasri, J. P., & Nedungadi, P. (2023). University students as early adopters of ChatGPT: Innovation diffusion study. *Research Square*. <https://doi.org/10.21203/rs.3.rs-2734142/v1>
- Rane, N. (2023). *Enhancing mathematical capabilities through ChatGPT and similar generative artificial intelligence: Roles and challenges in solving mathematical problems*. SSRN. <https://doi.org/10.2139/ssrn.4603237>
- Rane, N. L., Choudhary, S. P., Tawde, A., & Rane, J. (2023). ChatGPT is not capable of serving as an author: Ethical concerns and challenges of large language models in education. *International Research Journal of Modernization in Engineering Technology and Science*, 5(10), 851-874. <https://doi.org/10.56726/irjmet545212>
- Ratnam, M., Sharma, B., & Tomer, A. (2023). ChatGPT: Educational artificial intelligence. *International Journal of Advanced Trends in Computer Science and Engineering*, 12(2), 91-222. <https://doi.org/10.30534/ijatcse/2023/091222023>
- Revere, L., & Kovach, J. V. (2011). Online technologies for engaged learning: A meaningful synthesis for educators. *Quarterly Review of Distance Education*, 12(2), 113-124. <https://doi.org/10.1108/QRDE-06-2011-0004>
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- Roumeliotis, K. I., & Tselikas, N. D. (2023). ChatGPT and Open-AI models: A preliminary review. *Future Internet*, 15(6), Article 192. <https://doi.org/10.3390/fi15060192>
- Rudolph, J., Tan, S., & Tan, S. (2023). ChatGPT: Bullshit spewer or the end of traditional assessments in higher education? *Journal of Applied Learning & Teaching*, 6(1), 342-363. <https://doi.org/10.37074/jalt.2023.6.1.9>
- Saghiri, A. M., Vahidipour, S. M., Jabbarpour, M. R., Sookhak, M., & Forestiero, A. (2022). A survey of artificial intelligence challenges: Analyzing the definitions, relationships, and evolutions. *Applied Sciences*, 12(8), Article 4054. <https://doi.org/10.3390/app12084054>
- Salvagno, M., ChatGPT, Taccone, F., & Gerli, A. G. (2023). Can artificial intelligence help for scientific writing? *Critical Care*, 27, Article 75. <https://doi.org/10.1186/s13054-023-04380-2>
- Schlunegger, M. C., Zumstein-Shaha, M., & Palm, R. (2024). Methodologic and data-analysis triangulation in case studies: A scoping review. *Western Journal of Nursing Research*, 46(8), 611-622. <https://doi.org/10.1177/01939459241263011>
- Shakarian, P., Koyyalamudi, A., Ngu, N., & Mareedu, L. (2023). *An independent evaluation of ChatGPT on mathematical word problems (MWP)*. arXiv. <https://doi.org/10.48550/arXiv.2302.13814>
- Shamsudin, N. M., & Aris, S. R. S. (2023). Perspectives of ChatGPT for teachers trainee programs in designing STEM lessons. *International Journal of Academic Research in Progressive Education and Development*, 12(3), 1684-1689. <https://doi.org/10.6007/IJARPED/v12-i3/19219>
- Shen, Y., Heacock, L., Elias, J., Hentel, K. D., Reig, B., Shih, G., & Moy, L. (2023). ChatGPT and other large language models are double-edged swords. *Radiology*, 307(2), 1-4. <https://doi.org/10.1148/radiol.230163>
- Shoib, M., Khan, S., Fitzpatrick, D., & Pitt, I. (2023). A mobile e-learning application for enhancement of basic mathematical skills in visually impaired children. *Universal Access in the Information Society*, 23, 1091-1101. <https://doi.org/10.1007/s10209-023-00990-3>
- Shoufan, A. (2023). Exploring students' perceptions of ChatGPT: Thematic analysis and follow-up survey. *IEEE Access*, 11, 38805-38818. <https://doi.org/10.1109/ACCESS.2023.3268224>
- Siemens, G. (2004). Connectivism: A learning theory for the digital age. *Elearnspace*. [https://eclass.uoa.gr/modules/document/file.php/PPP130/DIME/NTE09/elearnspace.%20Connectivism\\_%20...pdf](https://eclass.uoa.gr/modules/document/file.php/PPP130/DIME/NTE09/elearnspace.%20Connectivism_%20...pdf)
- Slavych, B. K., Atcherson, S. R., & Zraick, R. (2024). Using ChatGPT to improve health communication and plain language writing for students in communication sciences and disorders. *Perspectives of the ASHA Special Interest Groups*, 9(3), 599-612. [https://doi.org/10.1044/2024\\_PERSP-23-00167](https://doi.org/10.1044/2024_PERSP-23-00167)
- Sosas, M. R. D., Fat, A. F. G., Dangculos, J. M. M., Anoba, H. R. P., Remiscal, C. G., & Aleguen, J. M. (2026). Use of ChatGPT as a supplemental learning tool in mathematics. *Contemporary Mathematics and Science Education*, 7(1), Article ep26004. <https://doi.org/10.30935/conmaths/17989>
- Sullivan, M., Kelly, A., & McLaughlan, P. (2023). ChatGPT in higher education: Considerations for academic integrity and student learning. *Journal of Applied Learning & Teaching*, 6(1), 31-40. <https://doi.org/10.37074/jalt.2023.6.1.17>
- Supriyadi, E., & Kuncoro, K. S. (2023). Exploring the future of mathematics teaching: Insight with ChatGPT. *Union: Jurnal Ilmiah Pendidikan Matematika*, 11(2), 305-316. <https://doi.org/10.30738/union.v11i2.14898>
- Tate, T. P., Doroudi, S., Ritchie, D., Xu, Y., & Uci, M. (2023). *Educational research and AI-generated writing: Confronting the coming tsunami*. EdArXiv. <https://doi.org/10.35542/osf.io/4mec3>
- Tlili, A., Shehata, B., Adarkwah, M. A., et al. (2023). What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education. *Smart Learning Environments*, 10, Article 15. <https://doi.org/10.1186/s40561-023-00237-x>
- Trust, T., Whalen, J., & Mouza, C. (2023). Editorial: ChatGPT: Challenges, opportunities, and implications for teacher education. *Contemporary Issues in Technology and Teacher Education*, 23(1), 1-23. <https://citejournal.org/volume-23/issue-1-23/editorial/editorial-chatgpt-challenges-opportunities-and-implications-for-teacher-education/>
- Vitoullis, M. (2017). Prospects of connectivism in lifelong professional training of early childhood educator in the framework of digital pedagogy-perceptions, attitudes and intentions. *European Journal of Social Sciences Studies*, 2(7), 1-21. <https://oapub.org/soc/index.php/EJSSS/article/view/156/457>

- Wagner, M., & Ertl-Wagner, B. (2023). Accuracy of information and references using ChatGPT-3 for retrieval of clinical radiological information. *Canadian Association of Radiologists Journal*, 75(1), 69-73. <https://doi.org/10.1177/08465371231171125>
- Wardat, Y., Tashtoush, M. A., AlAli, R., & Jarrah, A. M. (2023). ChatGPT: A revolutionary tool for teaching and learning mathematics. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(7), Article em2286. <https://doi.org/10.29333/ejmste/13272>
- Watrianthos, R., Ahmad, S. T., & Muskhir, M. (2023). Charting the growth and structure of early ChatGPT-education research: A bibliometric study. *Journal of Information Technology Education: Innovations in Practice*, 22, 235-253. <https://doi.org/10.28945/5221>
- Wei, J., Bosma, M., Zhao, V. Y., Guu, K., Yu, A. W., Lester, B., Du, N., Dai, A. M., & Le, Q. V. (2022). *Finetuned language models are zero-shot learners*. arXiv. <https://arxiv.org/abs/2109.01652>
- White, A., Way, J., Perry, B., & Southwell, B. (2006). Mathematical attitudes, beliefs, and achievement in pre-service mathematics teacher education. *Mathematics Teacher Education and Development*, 7(2006), 33-52. <https://researchers.westernsydney.edu.au/en/publications/mathematical-attitudes-beliefs-and-achievement-in-pre-service-mat/>
- Woodhouse, D., & Charlesworth, A. (2023). Can CHATGPT predict future interest rate decisions?. *SSRN Electronic Journal [Preprint]*. <http://doi.org/10.2139/ssrn.4572831>
- Wu, R., & Yu, Z. (2023). Do AI chatbots improve students' learning outcomes? Evidence from a meta-analysis. *British Journal of Educational Technology*, 55(1), 10-33. <https://doi.org/10.1111/bjet.13334>
- Wu, X., et al. (2023). A brief overview of ChatGPT: The history, status quo, and potential future development. *IEEE/CAA Journal of Automatica Sinica*, 10(5), 1122-1136. <https://doi.org/10.1109/JAS.2023.123618>
- Yang, K., Poesia, G., He, J., Li, W., Lauter, K., Chaudhuri, S., & Song, D. (2024). *Formal mathematical reasoning: A new frontier in AI*. arXiv. <https://arxiv.org/abs/2412.16075>
- Yigit, M. (2014). A review of the literature: How pre-service mathematics teachers develop their technological, pedagogical, and content knowledge. *International Journal of Education in Mathematics, Science and Technology*, 2(1), 26-35. <https://files.eric.ed.gov/fulltext/EJ1066346.pdf>
- Yilmaz, H., Maxutov, S., Baitekoy, A., & Balta, N. (2023). Student attitudes towards Chat GPT: A technology acceptance model survey. *International Educational Review*, 1(1), 57-83. <https://doi.org/10.58693/ier.114>
- Yip, S. Y. (2025). Transition into teaching: Examining the pedagogical content knowledge (PCK) development of pre-service STEM career-change teachers. *Journal of Education for Teaching*, 51(3), 525-540. <https://doi.org/10.1080/02607476.2025.2471901>
- Young, J. C., & Shishido, M. (2023). Investigating OpenAI's ChatGPT potentials in generating chatbot's dialogue for English as a foreign language learning. *International Journal of Advanced Computer Science and Applications*, 14(6), 65-72. <https://doi.org/10.14569/IJACSA.2023.0140607>
- Zafrullah, Z., Hakim, M. L., & Angga, M. (2023). ChatGPT OpenAI: Analysis of mathematics education students' learning interest. *Journal of Technology Global*, 1(1), 1-10. [https://www.researchgate.net/publication/397482323\\_ChatGPT\\_Open\\_AI\\_Analysis\\_of\\_Mathematics\\_Education\\_Students\\_Learning\\_Interest](https://www.researchgate.net/publication/397482323_ChatGPT_Open_AI_Analysis_of_Mathematics_Education_Students_Learning_Interest)
- Zhai, X. (2022). *ChatGPT user experience: Implications for education*. SSRN. <https://doi.org/10.2139/ssrn.4312418>
- Zhai, X. (2023). *ChatGPT for next-generation science learning*. SSRN. <https://doi.org/10.2139/ssrn.4331313>
- Zhang, B. (2023). Preparing educators and students for ChatGPT and AI technology in higher education. *Comparative & International Education Series*. <https://doi.org/10.13140/RG.2.2.32105.98404>
- Zhao, S., Shen, Y., & Qi, Z. (2023). Research on ChatGPT-driven advanced mathematics course. *Academic Journal of Mathematical Sciences*, 4(5), 42-47. <https://doi.org/10.25236/AJMS.2023.040506>
- Zhou, J., Ke, P., Qiu, X., Huang, M., & Zhang, J. (2023). ChatGPT: Potential, prospects, and limitations. *Frontiers of Information Technology & Electronic Engineering*, 25, 6-11. <https://doi.org/10.1631/FITEE.2300089>