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How Utilizing Generative AI When Addressing Pedagogical and Mathematical Events Contributes to Mathematics Teacher Educators' TPACK (Technological Pedagogical Content Knowledge)

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Abstract

This study examines the contribution that generative AI (ChatGPT) can make to the TPACK (Technological Pedagogical Content Knowledge) of mathematics teacher educators (MTEs) when addressing pedagogical and mathematical events. The study involved 15 experienced MTEs who were tasked with planning training sessions for elementary school teachers. The MTEs were asked to formulate pedagogical and mathematical issues they wished to address using ChatGPT. The process was documented and analyzed to identify key themes in the MTEs' prompts and the responses received from ChatGPT. The findings reveal the challenges MTEs face with respect to pedagogical issues (adapting new teaching methods, managing classroom/session time, motivating veteran teachers to engage with new teaching approaches, etc.) and with respect to issues regarding mathematics instruction (teaching abstract topics, operations on the number line, dividing fractions, etc.). The results showed that ChatGPT provided creative solutions and diverse strategies to overcome such challenges, thus highlighting the value of integrating AI into teaching practices as a tool to enhance the quality of teacher training.

Introduction

In today's fast-paced environment, mathematics teachers' body of knowledge changes and develops according to their academic education, their participation (as in-service teachers) in formal and informal professional development settings, and as a result of actual teaching. The knowledge mathematics teachers require for teaching serves as the basis for the knowledge mathematics teacher educators (MTEs) require (Chapman, 2021; Chick & Beswick, 2018), meaning that the knowledge mathematics teachers develop during their reflective processes for mathematical and pedagogical tasks serves as an essential basis for MTEs when constructing and integrating tasks related and connected to classroom pedagogical and mathematical events (Da Ponte & Chapman, 2006).

Constructing tasks for mathematics teachers is a challenging process. While teachers have many resources that can assist in their teaching (books, teacher guides, websites, digital environments with teaching and learning

resources, and so forth), the means available to MTEs (professional journals, books by researchers that include personal experiences, and the like) are limited (Jahangiri et al. 2021; Segal et al., 2018, 2021). This poses a challenge for MTEs when preparing suitable materials and appropriate tasks for teachers (Peled & HersHKovitz, 2004; Zaslavsky, 2008), suggesting that scaffolding that can offer new perspectives and suggest mathematical and pedagogical events for teachers would be highly advantageous.

The recent emergence and accessibility of artificial intelligence (AI) technology are yielding fresh opportunities for education systems, teacher educators, and teachers (Baidoo-Anu & Ansah, 2023). Although the integration of AI into the education system is still in its infancy, teacher educators and teachers are seeking appropriate paths. The ever-developing AI algorithms can now serve to assist where pre- and in-service teachers have difficulty, such as with posing problems.

This point is addressed in this current study, where MTEs explored the processes of addressing different pedagogical approaches for teaching and learning mathematics, integrating various technologies, and developing various perspectives for solving problems in mathematics. Since this group of MTEs had not yet utilized AI, we had them address pedagogical and mathematical tasks for teachers while working with an AI “assistant” (in this case, ChatGPT) and then explored the contribution that AI made to the MTEs’ technological, pedagogical, and mathematical content knowledge (TPACK).

We chose ChatGPT since, based on our experience as instructors, we were aware that it is a familiar and accessible tool for users. The choice was also driven by its many advantages, including its user-friendly interface and ease of use. Additionally, ChatGPT is built on advanced natural language processing models that have demonstrated accurate understanding of user intentions and the ability to generate highly complex content. Nevertheless, it is important to note that the development of AI-based technological environments is rapid and dynamic, so it is possible that in the future – even in the very near future – another environment may prove more optimal.

Literature Review

MTEs’ Knowledge, Practice, and Challenges

The knowledge and skills that MTEs require are inseparable from and interdependent with the changing contextual realities and the emerging needs of pre- and in-service mathematics teachers (Chick & Beswick, 2018). MTEs need to be aware of the knowledge and skills teachers require, and this awareness serves as a crucial basis for their work to promote teachers’ professional development (Chapman, 2021). The literature presents various models for characterizing the knowledge and skills mathematics teachers require that can serve as a foundation for what MTEs present. For example, Zaslavsky and Leikin (2004) borrowed ideas from Jaworski’s (1992, 1994) teaching triad and Steinbring’s (1999) teaching and learning models and suggested that MTEs need to be aware of mathematical knowledge for teaching. This includes pedagogical content knowledge and subject matter knowledge as described by Ball et al. (2008). Mishra and Koehler (2006) and Koehler et al. (2013) added the technology component to this model, terming this inclusive model as “technological pedagogical and content knowledge” (TPACK).

Since then, the TPACK framework has served as a comprehensive analysis of teachers' knowledge, allows researchers and teacher educators to focus on how to successfully incorporate technology into educational practices, serves as a basis for characterizing MTEs' TPACK, and allows identifying objectives for implementing digital tools into mathematics education in its different forms and combinations (Drijvers & Sinclair, 2024; Biton & Segal, 2025; Fellus & Segal, 2024; Segal & Biton, 2024). For example, the pedagogical content knowledge (PCK) of MTEs has been explored by Appova and Taylor (2019) regarding how teachers' classroom practices and instructional goals can be shaped by contextual elements, including curriculum (i.e., pedagogical) requirements. Milner-Bolotin (2018) examined how integrating technology into mathematics-teacher preparation programs can foster essential 21st-century competencies including the ability to handle uncertain information, interpret complex data sets, convey technical concepts effectively, and establish meaningful connections between mathematics, science, and real-world applications (technological content knowledge, TCK).

One of the challenges MTEs face and that is reflected in the above-mentioned studies is the process of planning and implementing learning tasks for teachers, a complex process that requires continuous cycles of task adaptation and refinement. It requires understanding both the students' classroom learning processes and the teachers' learning and teaching processes, meaning that the MTEs themselves must have solid mathematical knowledge in solving tasks and be able to present examples that encourage mathematical connectivity and will ultimately be relevant to the students. Then, they must be able to present the tasks to the teachers in a way that allows the teachers to reflect on their work and their interaction with those tasks (Segal & Fellus, 2024; Zaslavsky, 2007).

Introducing Technology into Professional Development

One way to mitigate the above-mentioned absence of reliable resources for MTEs in their quest to prepare appropriate activities for teachers is to give them the opportunity to utilize AI-based environments that can served as a "partner." Over the past few years, teachers and teacher educators have been continuously confronted with the accelerated development of technology and the teaching and learning opportunities it offers. This was especially apparent during the COVID-19 pandemic, when teachers and teacher educators had to suddenly face integrating technology for remote teaching and learning (Klemer et al., 2023; Ng et al., 2023; Rave et al., 2025; Turnbull et al., 2021), which continued after the pandemic itself. More importantly, the emergence and accessibility of Generative AI (GenAI) technology in recent years has produced a new reality (Baidoo-Anu & Ansah, 2023) that brings new educational challenges.

GenAI refers to a group of machine learning algorithms designed to allow users to create new content by asking questions (providing prompts). By imitating human communication, GenAI environments can provide factual information, answer questions, edit existing texts, or produce new texts and images (Baidoo-Anu & Ansah, 2023; Chan & Hu, 2023; Marienko et al., 2020). ChatGPT is one form of GenAI and has the potential to promote personalized and interactive learning. In the context of education, ChatGPT can serve as an "assistant" or "partner" that can provide suggestions and prompts for teachers and instructors who must prepare courses and design teaching/learning resources and materials.

The use of GenAI in education systems is still not widespread. A study by Chan (2023) indicated that both teachers and students in various higher institutions of learning in Hong Kong reported relatively low experience with AI, suggesting that there is significant room for growth for its integration into future teaching and learning practices as teachers begin to recognize the potential benefits of AI technologies. A subsequent study (Chan & Hu, 2023) with 399 undergraduate and postgraduate students from various disciplines and an exploratory study by Baidoo-Anu and Ansah (2023) that reviewed recent extant literature on the subject explored the various advantages and disadvantages of working with GenAI. Its benefits include personalized coaching, immediate learning support and feedback, writing and brainstorming assistance, and interactive and adaptive learning. However, its downside includes lack of human interaction, GenAI's limited mathematical understanding, a lack of creativity, and a high dependence on data. Further are concerns about accuracy, privacy, ethical issues, and the impact on personal development, career prospects, and societal values. However, by understanding teachers' perceptions and addressing their concerns, teacher educators can establish strategies to effectively implement GenAI, ultimately enhancing teaching and learning experiences (Chan & Hu, 2023).

Another aspect to consider is that, to use GenAI, teachers and teacher educators must have AI literacy, that is, skills to evaluate, communicate, and use AI effectively based on a basic understanding of its essence, the ability to interact with the various tools, and the ability to exercise critical thinking about the process and the product obtained as a result of that interaction (Druga et al., 2019). There is a correlation between AI literacy and frequency of use (Chan & Hu, 2023), and effective implementation requires gathering experience. The critical role of experience while utilizing AI was emphasized by Kim (2024), who described three phases of teacher-AI collaboration evolution: teachers as passive AI recipients, teachers as active AI users, and teachers and AI as constructive partners.

The study of Segal & Biton(2024), and Biton & Segal (2025), presents complementary findings on using ChatGPT for mathematical problems posing among pre-service teachers. Both studies examined how 15 pre-service mathematics teachers utilized ChatGPT to enhance their problem-posing skills and TPACK (Technological, Pedagogical, and Content Knowledge). Key findings indicate that ChatGPT significantly improved the quality of mathematical problems in several dimensions: enhancing clarity through better structure and formulation; increasing problem difficulty with appropriate challenges; improving mathematical precision; adding real-world applications to make problems more relevant; incorporating visual aids and diagrams; encouraging inquiry-based thinking; and providing guidance for struggling students. The teachers reported that ChatGPT served as an effective "partner" that offered personalized, non-judgmental feedback, which allowed them to customize problems according to specific educational needs while developing critical thinking skills to evaluate AI suggestions. This process enhanced their technological knowledge through prompt refinement, pedagogical knowledge by tailoring problems to student needs, and content knowledge by exposing them to varied mathematical representations and real-world applications.

Based on a study conducted by the Chartered Institute for IT (BCS, 2024) with 1,000 principals and teachers in multiple schools, it seems that the lack of time to learn about AI-based tools and the lack of technological confidence may constitute the main barriers to its use. However, another hindrance may be that MTEs lack

appropriate training to impart the informed use of these advanced tools. Hence, both teachers and MTEs need opportunities to effectively gain experience on how to integrate GenAI technologies into the various pedagogical dimensions (assessment, developing teacher and student competencies, etc.), meaning that MTEs must encourage a balanced approach to adopting AI in the various disciplines of education.

TPACK: A Framework for MTE's Technological Pedagogical and Content Knowledge

In this study, we use the TPACK model to describe the knowledge that the participant MTEs acquired as a result of utilizing ChatGPT for planning mathematical and pedagogical events for teachers. As mentioned above, TPACK, an amalgamation of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), is an important model for describing the sum total of teachers' knowledge (Koehler & Mishra, 2009; Koehler et al. 2013; Schmidt et al., 2009, based on Shulman, 1986). This model also implies that all three "major" bodies of knowledge intersect at various levels of complexity (Jahangiri et al. 2021, Segal et al.2021), thus forming technological pedagogical knowledge (TPK) and technological content knowledge (TCK). Because it defines the various combinations of knowledge teachers require to effectively integrate technology into their teaching, this model has become a useful framework for understanding the goals involved in integrating technology into teacher education as well as a way to map teacher knowledge and developing research tools, (Caniglia & Meadows, 2018; Nantschev et al., 2020; Polly & Orrill, 2012). The model's complexity is reflected in the components and combinations of basic knowledge. For example, TK is knowledge about the various technologies available for planning and teaching in the classroom and online environments (Tondeur et al., 2020). However, TCK is knowledge about how technology can create different representations for a specific concept (which demands that teachers be aware how using specific technologies can affect learners' skills and understand the relevant concepts and content), and TPK implies familiarity with the range of technologies that can be integrated into teaching and understanding how they can affect teaching methods and promote teachers' educational needs. Teachers who have deep, expansive TPK can use technologies to expose their students to a variety of physical and virtual means of thought, thereby improving their students' thinking and understanding skills (Özerem, 2012; Stoilescu, 2015). Teachers can also use technology for student assessment in a variety of ways: self-evaluation, peer evaluation, and more (Torres-Madroño et al., 2020). The technology also enables the promotion of students' inquiry skills and active learning (Klemer & Rapoport, 2020; Segal et al., 2018).

As noted by Welder et al. (2022), the TPACK framework remains underutilized in research focused on MTEs' professional work. Our study, nevertheless, uses this model to assess how GenAI can address pedagogical and mathematical challenges and contribute to MTEs' TPACK. This is done by exploring how the MTEs' TPACK develops through an iterative process of events to prepare teachers for using dynamic educational environments and that includes planning learning tasks and then refining and adapting them (Segal & Fellus, 2024).

Utilizing GenAI effectively to support mathematics teachers' learning is a meaningful challenge for MTEs. GenAI can provide personalized feedback and specific support to teachers during the process of learning mathematical subjects, understanding complex content (Jia, 2015), and increasing proficiency (Rane, 2023; Wardat et al., 2023). Although there are few reports on teachers who have been exposed to working with AI-based environments (Egara

& Mosimege, 2024), a qualitative study conducted by Wardat et al. (2023) that focused on educational professionals regarding the use of ChatGPT in mathematical instruction found that most of the participants who experienced it believed that, given its ability to engage in intelligent conversation, ChatGPT could facilitate solving various mathematical problems and provide instructional support. In fact, utilizing GenAI for solving mathematical problems in various mathematical subjects can assist learning processes by explaining and visualizing mathematical concepts and theorems or presenting the properties of geometrical shapes. GenAI facilitates personalized and adaptive learning experiences and enables teachers to receive immediate feedback, participate in interactive problem-solving dialogues, and access step-by-step solutions that align with their requirements. So, teachers can strengthen and expand their understanding of mathematical concepts and improve their learning experience and mathematical competencies (Kasneci et al., 2023; Rane, 2023; Wardat et al., 2023). GenAI can be implemented as a lever for promoting collaborative learning discussions with peers (Rane, 2023).

However, as noted above, GenAI is not without its challenges. ChatGPT does not have a deep understanding of some mathematical topics (e.g., geometry) and may provide incorrect or incomplete solutions to mathematical problems thereby not allowing effective handling of misconceptions (Rane, 2023; Wardat et al., 2023). For example, Wardat et al. (2023) observed that ChatGPT generalized the Pythagorean theorem to encompass all triangles (not only right triangles)—a potential distortion of a mathematical concept—and also created “mysterious” arithmetic errors that a simple calculator would not have (when using the definition of the derivative of a given function, $f(x)$, it provided an incorrect answer when substituting $x = -1$ into $f'(x)$). Such examples show the ChatGPT’s lack of deep mathematical understanding can preclude providing effective feedback and can generate misconceptions if the users are not familiar enough with the topic and able to critically evaluate every suggestion received.

To strengthen ChatGPT’s accuracy and reliability, it is essential to consider the specific context and field of knowledge, give it precise, well-defined input, and cross-reference the information provided with other sources (Wardat et al., 2023). Users also need to be aware of ethical concerns, such as data privacy, intellectual property, liability issues, and the ethical implications of AI-driven decision-making processes (Rane, 2023; Wardat et al., 2023). Baidoo-Anu and Ansah (2023) called for further studies to explore how to integrate GenAI tools into teacher-education programs to prepare in- and pre-service mathematics teachers to use AI tools safely and constructively and to support student learning and teachers’ TPACK.

Method

Research Question

How does ChatGPT, when used to address pedagogical and mathematical content-related issues arising in teacher training sessions, enhance the MTEs’ TPACK?

Research Population

This study focused on 15 MTEs who had extensive experience in training elementary school mathematics teachers

(grades 1–6). Their current assignment was to train mathematics teachers in a novel learning method (entitled “Shvilim”) developed by a content company, and that included both printed and digital material. These MTEs conducted face-to-face training sessions in over 400 schools across the country, meeting with entire teaching teams by grade level. The training included explaining the rationale behind the “Shvilim” method, demonstrating its application using digital platforms, and addressing practical questions related to its implementation. The teachers with whom the MTEs were working had diverse backgrounds in terms of teaching experience and mathematical knowledge, requiring the MTEs to tailor their training accordingly.

Research Process

As part of the professional development of the community of MTEs, the authors of this paper were tasked with developing programs to instruct the MTEs prior to their meeting the teachers. To this end, the authors conducted learning sessions—some face-to-face and some online. Two of these meetings focused on the integration of AI into instructional practices. In them, the MTEs were asked to present instructional issues for which they wished to consult AI. First, they were asked to define a general pedagogical issue (not necessarily directly related to mathematics instruction), specify what they wished to inquire about, formulate a prompt (an example was provided), document the chatbot’s response, and reflect on what they learned from the response. A similar process was then carried out for mathematics-content instruction issues for which the MTEs sought deeper insight. A dedicated environment was provided to the MTEs to document the entire process. We conducted content analysis of the issues the MTEs had suggested, identifying themes that emerged in the written prompts and analyzing the themes that emerged from the feedback they received from AI.

Results

Before analyzing the findings, we present two example dialogues between an MTE (Vicky) and ChatGPT – the first a pedagogical issue and the second mathematical – to help the reader better understand the process by which ChatGPT was integrated into the current research.

Example A: Pedagogical issue

Stage 1: Posing the pedagogical issue and formulating prompts to stimulate suggestions from ChatGPT

Vicky wrote:

Here are two issues that concern me in the training:

1. How can we engage a teacher with a new, imposed teaching method when she is deeply connected to the old, successful method?
2. How can we engage a teacher with a new textbook when they are aware that it lacks pedagogical strengths compared to competing textbooks ?

I would appreciate it if you could provide me with three recommendations on how to address each of these issues. Additionally, please include a hypothetical script with a teacher who is concerned about one of these issues and suggest how I should respond. Please also provide a table with

suggestions for improving the training based on the script.

Stage 2: ChatGPT responded with the following suggestions:

1. How to engage a teacher with a new teaching method when they are attached to the old method:
 - a. Listen to the teacher's concerns and understand the successes they have achieved with the old method. Show respect for their experience and accomplishments.
 - b. Highlight the pedagogical advantages of the new method and its potential to enhance the students' learning process.
 - c. Suggest a gradual transition period, where the teacher can combine both the new and old methods until they feel comfortable with the change.
2. How to engage a teacher with a new textbook when they compare it to competing textbooks:
 - a. Comparing with other books is an opportunity to emphasize the unique advantages of the new textbook.
 - b. Acknowledge the strengths of the competing books but highlight the innovations and new approaches presented in the new textbook.
 - c. Point out that comparing it to other textbooks is a positive step as it shows the teacher is critically evaluating the material.

ChatGPT then offered the following sample dialogue:

Teacher: "I see that this new textbook offers an innovative approach, but it lacks some important points that I find in competing books."

MTE's response: "You're right. Every textbook has its strengths and weaknesses. This new one is indeed different in its approach, but it's based on the latest research in learning. I'd love to hear which specific points you think are missing, and maybe we can find ways to incorporate them."

ChatGPT provided the following table with suggestions for improving the pedagogical issues

Topic	Suggestion
Personal connection	One-on-one meetings with teachers to understand their background and experience
Flexibility and listening	Willingness to adapt the new method to the teachers' needs
Focused training	Workshops and training sessions that focus on the specific challenges teachers raise
Collaborative learning	Learning groups where teachers can share experiences, successes, and challenges
Evaluation and improvement	Continuous feedback and opportunities to improve and adapt the program

Stage 3: Vicky considered the dialogue with ChatGPT and decided which suggestions to accept.

I accepted almost everything except the suggestion to change the content in the development itself. The needs can be communicated to the development team, but I am not in a position of development and cannot change the method or the book.

Example B: Mathematical issue

Stage 1: Posing the mathematical issue and formulating prompts to stimulate suggestions from ChatGPT

Vicky wrote:

The mathematical topics that present challenges for me in teacher training are:

1. Teachers find it difficult to teach students operations on the number line; it is a very theoretical subject.
2. Teachers struggle with teaching word problems in mathematics that require deep understanding of the text.

I would appreciate it if you could provide me with three recommendations on how to address each of these issues. Additionally, please include an example script with a teacher who is concerned about one of these issues and suggest how I can respond, as well as a table with suggestions for improving the training based on the script.

Stage 2: ChatGPT responded with the following suggestions:

For teaching operations on the number line (a theoretical topic):

- a. Use visual and concrete examples, such as a ruler or number line to illustrate the concept.
- b. Connect the topic to real-life situations where a number line is used, such as temperatures or debts and credits.
- c. Allow students to discover the rules and relationships themselves through inquiry-based activities and games.

For teaching word problems that require deep understanding:

- a. Teach strategies for critically reading the problem and separating important information from irrelevant details.
- b. Use examples, demonstrations, and illustrations of similar problems to develop understanding.
- c. Engage students in analyzing the problems and jointly building the appropriate mathematical models.

ChatGPT then offered the following sample dialogue:

Teacher: “My students really struggle with word problems. They just can’t seem to understand the data and what is required of them.”

MTE’s response: “I understand the difficulty. Word problems often require a high level of comprehension. But there are a few strategies that can help. First, it’s important to teach students to read carefully and identify key information. Then, we can present examples and analyze them together to show how to reach the solution. Marking and highlighting key terms in the problem can also be very helpful.”

ChatGPT provided the following table with suggestions for improving the mathematical issues

Topic	Suggestion
Examples and practice	Prepare a bank of diverse examples for different types of problems

Collaboration	Teacher workgroups to develop effective teaching strategies
Experiential learning	Use games, simulations, and illustrative videos
Technological toolkit	Apps, software, and digital tools for practice and visualization. Focusing on various methods of illustrating theoretical topics and word problems, along with the use of technology and peer learning, can greatly assist both teachers and students.
Formative assessment	Regular tests, observations, and feedback to identify challenges and improve investing in the development of high-quality learning materials.

Stage 3: Vicky considered the dialogue with ChatGPT and wrote:

I will adopt the ideas presented by the chat by introducing them to a teacher workgroup and decide which are effective.

Qualitative Analyses of Findings

The examples shown illustrate examples of pedagogical and mathematical challenges identified by MTEs along with ChatGPT's responses. The tables below present the key pedagogical (Table 1) and mathematical (Table 2) issues identified by analyzing the teachers' prompts and the corresponding responses provided by ChatGPT.

Table 1. Pedagogical Issues Raised by MTEs and Corresponding Suggestions from ChatGPT

Issue	MTEs' Questions	Chat GPT's Suggestions
Teachers who resist new teaching methods or material	"How can we engage a teacher with a new teaching method when it has been imposed on them, especially when they are deeply attached to methods with which they have proven success?" "Teachers who have taught with other textbooks for many years find it difficult to change. How can I ease this?"	"Listen to the teacher's concerns and acknowledge their successes with the old method." "Highlight the pedagogical strengths of the new method and its potential to enhance student learning." "Help the teacher understand how to combine the old textbooks with the new materials. Show appreciation for the teacher's perspective on the textbooks they prefer."
Time management: teachers have difficulty planning lessons and covering all the required content to meet targets and deadlines in a limited time	"How can I help teachers manage their time? Between planning and, designing worksheets, they find it challenging to cover everything in the curriculum." "How can I advise teachers on how to manage to teach all the material?" "How can we handle the large amount of content that MTEs need to	"MTEs and teachers should plan lessons weeks or even months in advance to ensure enough time is allocated to each topic." "Advise teachers to include breaks between lessons to prepare for the next topic and reset their focus." "Advise teachers to use digital tools to help track the lessons and students'

Issue	MTEs' Questions	Chat GPT's Suggestions
	introduce to the teachers throughout the year?"	progress."
Dealing with veteran teachers who "know everything"	"How do you handle veteran teachers who feel they know everything and have seen it all?" "What can I say to a teacher who believes she knows all the materials and does not want to receive training?"	"Use the teachers' experience to adapt and implement new changes, such as integrating technology or new pedagogical approaches." "Give the teachers the feeling that they are collaborating with you on finding new solutions."
Resistance to the use of digital tools	"How do I handle teachers who avoid using digital tools for ideological reasons?"	"Here's a script to discuss ethical and ideological concerns in using technology with a teacher."
The need for creativity and diverse teaching methods to accommodate the needs of younger students or those struggling with traditional learning approaches	"Can you give me some suggestions for special teaching methods for first graders (creative ways to present different topics) that I can pass on to teachers?"	"Creative methods for teaching first graders in mathematics include role-playing and games to help students engage with complex topics in a fun way." "Try using mathematical role-play activities like 'Math Store'." "Digital tools can enhance student engagement and comprehension in subjects like mathematics."

Table 2. Mathematical Issues Raised by MTEs and Corresponding Suggestions from ChatGPT

Issue	MTEs' Questions	Chat GPT's Suggestions
Operations on the number line	"Teachers find it difficult to teach students operations on the number line; it is a very theoretical subject."	"Use visual and concrete examples to illustrate the concept." "Use real life scenarios relevant to the student, such as measuring a long jump." "Relate the topic to real-life situations such as temperatures or debts and credits."
Teaching mathematical word problems	"What suggestions can I give to teachers struggling with teaching word problems in mathematics that require a deep understanding of the text." "Word problems require advanced analytical skills. How can these be encouraged?"	"Teach strategies for critically reading the problem and separating important information from unnecessary details." "Use examples, demonstrations, and visual aids to help develop understanding."

Issue	MTEs' Questions	Chat GPT's Suggestions
Teaching fraction division as recommended by the "Shvilim" method	"How do you convince teachers to teach fraction division as recommended in the new textbook instead of starting with the easier technique?" "How can I encourage teachers to instill deep understanding about fraction division?"	"Emphasize the importance of teaching fraction division through deep understanding rather than just mechanical techniques." "Remind teachers that the approach focuses on developing mathematical thinking and solving complex problems in the future." "It's important to teach fraction division so that there is deep understanding, not just the mechanical technique."
Teaching addition and subtraction in tens in first grade using the "Shvilim" disc method	"How would you suggest teaching addition and subtraction of two-digit numbers in first grade using the 'Shvilim' disc card?"	"Point out to the teachers that the 'Shvilim' disc method is a unique and engaging approach for teaching addition in tens."
Teaching multiplication and division	"Can you give me some creative ideas for games and activities that will help students memorize multiplication and division?"	"Memory games involving multiplication and division are good choices." "Using digital media to illustrate multiplication and division in an engaging way can help."
Teaching long division	"How can I deal with the difficulty teachers have in helping their students solve long division problems?" "How can teachers make the idea of long division more accessible?"	"Students who understand basic concepts develop stronger and deeper mathematical thinking."
Calculating percentages and real-life applications	"What real-life examples can I suggest to teachers for teaching percentage calculations?"	"Use practical models of percentage like calculating discounts in shopping, compound interest, or quantitative growth." "Suggest activities that focus on practical and interactive models for understanding this topic."

The results point to some of the pedagogical challenges that MTEs encounter when introducing new ideas to teachers. They reflect the complexity of modern teaching environments, and the various factors MTEs must navigate when guiding teachers to incorporate new methods and materials. Their ChatGPT "assistant" provided some practical, helpful, structured strategies and suggestions that they may not have thought about on their own. These included issues of time management, easing teachers into using new methods while respecting their knowledge and experience, and inviting them to collaborate to develop methods to incorporate and balance deep-

rooted, familiar, trustworthy material into the new curriculum elements and methods. Another issue mentioned by the MTEs was teachers' tendency to bypass complex methods in favor of simpler techniques, indicating a need for guidance and precision in their teaching approach.

With respect to mathematical issues, MTEs encounter a wide range of challenges that mathematics teachers face in the classroom, particularly when teaching abstract topics, fraction division, complex word problems, and misconceptions regarding the addition of fractions. Thus, MTEs are constantly seeking tangible and creative tools and methods to show teachers how to better present such mathematical content. To this end, ChatGPT suggested a number of interesting, creative, and novel practices and activities to make complex mathematical ideas accessible to students by using concrete tools and real-world examples to turn theoretical concepts into tangible ideas and foster deep mathematical thinking. It also suggested some dialogue that could help the MTEs better "convince" their teachers to be more amenable to trying new methods.

Discussion and Conclusion

The integration of ChatGPT as a non-judgmental "partner" that can foster personalized and interactive learning (Baidoo-Anu & Ansah, 2023; Lo, 2023) offered MTEs a safe environment, eased the challenge, and provided them the experience of success, which can strengthen their confidence.

GenAI as a Lever for MTEs to Address Pedagogical Challenges

The results indicate how integrating GenAI, specifically ChatGPT, in MTE training supports them in navigating the pedagogical challenges they may encounter. Consistent with Chick & Beswick (2018), in this study, the MTEs met difficulties when guiding teachers through transitions to new methodologies and ChatGPT provided strategies that support gradual transitions while respecting teachers' existing expertise and fostering collaborative learning environments. These strategies emphasized the iterative adaptation in teacher training as recommended by Zaslavsky (2007). ChatGPT also provided other solutions, such as providing ideas for addressing teachers' resistance to technology by tailoring personalized and immediate support; helping MTEs become content creators by crafting scripts and introducing arguments to resolve pedagogical challenges (similar to the findings of Chan and Hu, 2023); and offering tailored solutions for time management, a challenge consistently noted in the literature (Appova & Taylor, 2019).

These practical applications highlight the contribution of ChatGPT as a tool for enhancing MTEs technological and pedagogical content knowledge, resulting in increased training effectiveness. Working with ChatGPT helped advance MTEs personalized instruction methods to address teachers' pedagogical and mathematical needs without any limitations on time, how much instruction they might require, and the accuracy of the prompts they fed ChatGPT. It also allowed the MTEs to refine their prompts to meet the unique needs of the teachers. The findings of the current study, like those of Wardat et al. (2023) and Rane (2023), suggest that the personalized feedback that participants receive from GenAI promote their proficiency and capabilities in planning mathematical and pedagogical events.

GenAI as a Lever for MTEs to Address Mathematical Challenges

The findings of this study also point out the contribution of ChatGPT to MTEs capacity to address abstract and challenging mathematics concepts when planning mathematics teachers' instruction. For example, operations on the number line and fraction division, frequently cited in the literature as difficult to teach (Cai & Rott, 2024), can be more accessible by adopting ChatGPT's suggestions of using visual aids and real-life analogies. These suggestions are aligned with Mishra and Koehler's (2006) TPACK framework, which emphasize the importance of technological tools in concretizing abstract concepts, and with Chapman (2021) and Segal & Fellus (2024), who emphasized the critical role that strong TPACK has in allowing MTEs to instruct teachers on how to teach mathematics, especially utilizing digital environments. Additionally, the current study underscored the use of ChatGPT to scaffold how MTEs can address the mathematical challenges of teaching word problems. By advising teachers to demonstrate to their students how to critically read and break down complex problems into manageable steps, ChatGPT supported MTEs in designing instructional resources that address deep comprehension needs.

The overarching theme that emerges is the need for MTEs to use creative, adaptable approaches that foster deep mathematical understanding while respecting teachers' existing expertise. ChatGPT's responses support these efforts by providing practical, tailored suggestions that align with MTEs instructional needs and pedagogical goals. Ultimately, the findings underscore the value of integrating AI as a supportive tool in both pedagogical and mathematical contexts, enriching teacher guidance and facilitating more effective instructional strategies.

Contribution to MTEs' TPACK Development

The secondary focus of this study was to explore the connection between the challenges MTEs face (as underscored by Chick & Beswick, 2018), their ability to address teachers' pedagogical and mathematical challenges, and their TPACK (Chapman, 2021), specifically how working with ChatGPT improves the latter. This study highlights the potential of ChatGPT to enhance MTEs' TPACK.

Contribution to TK

Through the iterative engagement with GenAI, MTEs refined and expanded their TK by exploring this innovative tool and its capabilities and limitations. For example, while the MTEs recognized ChatGPT ability to generate content, they also realized they had to implement critical thinking to evaluate its accuracy, similar to the findings of Badioo-Anu and Ansah (2023), Rane (2023), and Wardat et al. (2023).

Contribution to TPK, TCK, and PCK

The MTEs enhanced their TPK via ChatGPT's suggestions to use innovative technology environments to address teachers' pedagogical challenges, such as when engaging teachers with new teaching method, or a new textbook. ChatGPT's suggestions also led the MTEs to develop their TCK such as using technological solutions for teaching theoretical mathematical subjects. The MTEs' PCK development was reflected during refinement of instruction resources for teaching teachers. The iterative interactions between the MTEs and ChatGPT (demonstrated in the

examples) served as a catalyst for deepening and developing understanding of how this technology can intersect with pedagogical and mathematical issues when addressing specific events for teaching mathematics teachers.

Study Limitations and Suggestions for Future Research

The current study was conducted with a group of 15 MTEs enrolled in a unique program for training primary school mathematics teachers to use a new study program. The small sample set means the findings cannot be generalized; a similar study with a larger group of MTEs would allow better generalization and more accurate findings. Future research might also explore the long-term impact of GenAI on MTEs TPACK development, and its broader implications for providing resources and instructional design for MTEs.

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