Pre-Service Teachers' Perceptions of Adopting Generative AI Tools in Teaching Mathematics: Insights from a TPACK-based Workshop

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Abstract: This study explores perceptions of pre-service teachers (PSTs) toward integrating Generative AI (GenAI) in mathematics instruction through a TPACK-based professional development (PD) workshop. Findings reveal that while PSTs recognize GenAI's potential for lesson planning, differentiated instruction, and improving efficiency, concerns persist regarding accuracy, student overreliance, and ethical risks. The workshop fostered critical reflections on GenAI's pedagogical applications, but PSTs highlighted the need for structured training and institutional guidance. These insights underscore the importance of comprehensive AI literacy and TPACK-driven PD programs to equip future educators with the skills to critically and effectively integrate GenAI in mathematics classrooms.

Keywords: Generative AI, TPACK, Professional Development, Mathematics Education, Pre-service Teachers

Introduction

Integrating Generative AI (GenAI) in mathematics education presents new opportunities to enhance teaching and learning. Research underscores GenAI's capacity to generate instructional materials (Ellis & Slade, 2023; Guler et al., 2024), tailor math tasks for different math and language proficiency levels (Getenet, 2024), and deliver personalized support (Li et al., 2023). Despite these promising applications, several challenges hinder the effective use of GenAI tools in mathematics education. Scholars have voiced concerns about the accuracy of GenAI-generated math content (Matzakos et al., 2023) and potential student overreliance on these tools (Sánchez-Ruiz et al., 2023). Therefore, we posit that GenAI should be used as a supplementary resource that enhances teaching practices rather than replacing traditional instructional methods.

Without proper guidance, pre-service teachers (PSTs) may struggle to determine how to incorporate GenAI technology into their lessons (Dasari et al., 2024). Thus, teacher education programs must equip PSTs with the knowledge and skills to integrate GenAI into their pedagogical practices (Getenet, 2024). However, limited research explores how PSTs perceive and engage with AI tools in educational contexts. While prior studies emphasize the importance of Professional Development (PD) programs for fostering PSTs' technology adoption (Daher et al., 2021), few structured PD models have been developed to train PSTs in GenAI-enhanced mathematics instruction.

This study addresses this gap by adopting the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006), which informs a holistic approach to integrating technology in teaching. Despite the increasing interest in applying TPACK to AI-based instruction (Mishra et al., 2023), research exploring how TPACK can support GenAI adoption among PSTs for teaching mathematics remains sparse. The study builds on TPACK by introducing a structured professional development workshop based on the TPACK-based Professional Learning Design Model (TPLDM; Figg & Jaipal-Jamani, 2013). The workshop is designed to provide PSTs with hands-on experience with GenAI tools and facilitate pedagogical discussions on GenAI's effective use. This research explores how PSTs perceive and engage with GenAI tools within a structured TPACK-based workshop setting. The central research question for this study is: How do PSTs participating in a TPACK-based workshop designed to develop their GenAI skills for mathematics instruction perceive and utilize GenAI tools in educational settings? By addressing this research question, the study provides empirical insights into effective strategies for preparing PSTs to integrate AI tools into mathematics instruction.

Literature Review

With GenAI-powered tools becoming more prevalent in instructional settings, it is crucial to equip PSTs with the necessary competencies to integrate these technologies into their teaching practices. However, research suggests that many PSTs lack sufficient training and hands-on experience with GenAI tools (Yang & Appleget, 2024). While PSTs recognize the pedagogical value of GenAI, they may struggle to incorporate these tools meaningfully into their teaching practices. The need for effective PD has been widely emphasized in technology adoption among teachers (Daher et al., 2021). Access to technical support and hands-on learning opportunities influence PSTs' willingness to adopt new technologies (Gurer, 2021). Özbek et al. (2023) found that even passive exposure to digital tools, such as reading about their applications, can improve PST's perceptions of adopting a new technology. However, structured learning experiences that provide opportunities for experimentation and reflection are more effective in fostering technology adoption. For instance, Daher et al. (2021) found that a structured PD program incorporating TPACK-based discussions and collaborative digital content creation improved PSTs' self-efficacy and intention to integrate digital tools into instruction. Yang and Appleget (2024) demonstrated that when PSTs engaged with GenAI tools through structured activities, most PSTs recognized the value of GenAI tools in instructional support. However, they also raised concerns about teacher agency, technology reliability, and AI's ethical implications. These findings underscore the importance of PD programs that not only introduce GenAI tools among PSTs but also encourage critical evaluation of the affordances and limitations of the technology.

Research has demonstrated that developing TPACK competencies enhances PSTs' ability to evaluate and use digital tools effectively (Kiyici & Övez, 2021). Higher TPACK proficiency has been associated with increased confidence in technology integration, as seen in studies on AI-powered tools for education (Wang et al., 2024). While TPACK provides a strong conceptual foundation for technology integration, it does not specify how PD programs should be structured to develop these competencies. To operationalize TPACK in teacher training, Figg and Jaipal-Jamani (2013) introduced the TPACK-based Professional Learning Design Model (TPLDM). The TPLDM provides a structured approach to PD by guiding educators through four key stages: (1) modeling a technology-enhanced learning activity, (2) integrating pedagogical dialogue to reflect on the activity, (3) developing technical skills through short tool demonstrations, and (4) applying TPACK to design their own lesson plans. This model has shown effectiveness in enhancing the competence and confidence of university and K-12 educators in integrating technology into teaching (Jaipal-Jamani et al., 2018; Tai, 2015). While existing research highlights the importance of PD in fostering PSTs' technology adoption, few have examined how PSTs can be trained to integrate GenAI into instructional practices. The TPACK framework provides a strong foundation for technology-enhanced instruction, but there are no empirical studies yet that have implemented PD programs based on TPACK to help PSTs incorporate GenAI tools into mathematics instruction. This study seeks to address these gaps by implementing a TPLDM-based workshop designed to support PSTs in developing competencies for leveraging GenAI to teach mathematics. By analyzing PSTs' perceptions, engagement, and reflections during and after the workshop, this research aims to provide insights into how structured PD can enhance GenAI adoption in mathematics education.

Theoretical Framework

The Technological Pedagogical Content Knowledge (TPACK) framework, conceptualized by Mishra and Koehler (2006), provides a comprehensive lens for examining and enhancing technology integration into teaching. TPACK emphasizes the interplay between three core knowledge domains: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). The effectiveness of technology-enhanced teaching depends not only on proficiency in these areas individually but also on their interconnected application in instructional design and delivery. As a widely recognized model, TPACK has been extensively utilized in teacher education to evaluate and support pre-service and in-service teachers in developing competencies for integrating digital tools into their pedagogical practices (Mayer & Girwidz, 2019). Mishra et al. (2023) redefined the TPACK framework in light of GenAI's capabilities, highlighting that the generative and interactive features of GenAI necessitate a critical reevaluation of traditional pedagogical approaches, assessment strategies, and disciplinary knowledge among educators. Thus, by situating this study within the TPACK framework, we examine how PSTs navigate the intersections of content, pedagogy, and emerging GenAI technologies.

Methods

The TPLDM-based workshop was conducted with PSTs enrolled in two courses of a 4-year teacher preparation program at a large public university in the Midwest United States. One was a K-12 mathematics methods course, while the other was a learning technologies course, emphasizing technology integration in STEM education. Three 90-minute workshops were held: one for the mathematics methods course, attended by 12 PSTs, and two for the learning technologies course, attended by 29 PSTs across two sections. 41 PSTs attended the workshops, and 28 participants voluntarily participated in the study. The sample included eight male and 20 female PSTs. Participants represented different academic levels: six sophomores, 12 juniors, eight seniors, and two master's students.

The workshop was designed to enhance PSTs' competencies in integrating GenAI tools with their pedagogical and content knowledge through structured activities aligned with the TPLDM. It began with a simulation of a student's interaction with Khanmigo, a GenAI-powered tutoring tool in Khan Academy, allowing PSTs to critically examine its affordances and limitations in supporting problem-solving in mathematics. This was followed by structured pedagogical discussions, where PSTs reflected individually and in groups on how GenAI tutors can facilitate differentiation in mixed-ability classrooms and their potential drawbacks. After the discussion, PSTs responded to a prompt about how teachers use GenAI tools for mathematics instruction. Next, PSTs were shown live demonstrations of ChatGPT, Microsoft Copilot, Google Gemini, and Anthropic Claude Sonnet for supporting instruction, such as generating interactive math problems, modifying problems for scaffolding, creating visual aids, and designing hints for problem-solving. Finally, PSTs participated in a hands-on design task, using a GenAI tool of their choice to create instructional materials aligned with specific learning objectives.

PSTs' individual reflections on discussion prompts and hands-on activities during the workshop were collected from 24 participating PSTs. Additionally, five PSTs participated in follow-up semi-structured interviews, lasting 40 to 60 minutes, exploring their perceptions of integrating GenAI in educational contexts. Thematic analysis (Braun & Clarke, 2006) was conducted on workshop responses and interview transcripts, using the TPACK framework as a guiding lens. After initial open coding, codes demonstrating similar patterns were grouped, and overarching themes were identified, to capture how PSTs perceive, engage with, and adapt GenAI tools in mathematics education. Participant names were replaced with pseudonyms to ensure confidentiality.

Findings

The findings reveal a dual sentiment of enthusiasm and skepticism among PSTs toward GenAI as a pedagogical tool. The workshop experience enhanced their understanding, exposing new instructional possibilities and gaps in their preparedness. The four major themes below illustrate their evolving perspectives, self-confidence in AI integration, and the need for structured guidance in teacher education programs.

AI as a Teaching Assistant: Perceived Benefits and Affordances of GenAI

PSTs recognized GenAI as a time-saving tool for lesson planning, differentiation, and generating engaging instructional materials. Figure 1 shows the analysis of 35 responses about how teachers use GenAI tools for mathematics instruction collected from participating PSTs during the workshop, visualized as a word cloud to highlight PSTs' most commonly perceived use cases of GenAI in math instruction. Many PSTs viewed GenAI as an *"efficiency booster"* that enables them to focus on student engagement rather than repetitive administrative tasks.

> *"I've noticed ChatGPT allows me to make lesson plans a lot faster. And so thinking into the future, when I have to create a lesson plan every day, it can be helpful in that aspect."* - Jade Pryce, Interview

> *"It (Khanmigo) can provide suggestions for teachers to provide scaffolding and challenges for students who need differentiation."* - Avery Nale, Workshop

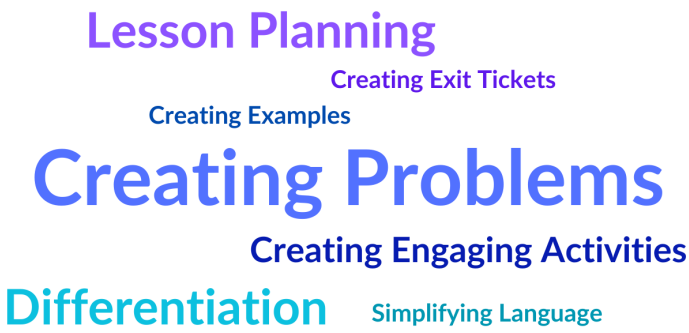

Figure 1. Word Cloud Representing PST' Perceived Uses of GenAI for Math Instruction

While most PSTs previously only focused on the capabilities of GenAI to accelerate instructional design, the workshop introduced the potential of GenAI as an intelligent tutor that *"can provide scaffolding for students to solve problems and help students persevere."* Many PSTs highlighted the potential of GenAI technology for offering personalized learning to students during the workshop discussions.

Trust but Verify: Pedagogical and Ethical Concerns about GenAI in Education

Despite acknowledging GenAI's potential instructional benefits, PSTs raised critical concerns about its pedagogical effectiveness and ethical implications. Many PSTs questioned GenAI technology's accuracy, noting that GenAI-generated math content sometimes contained logical errors, requiring human oversight. Ethical concerns, such as data privacy, misinformation, and academic dishonesty, were frequently discussed. A GenAI-enhanced learning activity was modeled during the workshop using Khanmigo, as illustrated in Figure 2. In this activity, the GenAI tutor directly provided the answer rather than facilitating the learning process through guiding questions. Many PSTs showed concerns about this flawed tendency of the GenAI-powered tutor, saying, *"Students would trick it (Khanmigo) into just giving them the answer as we saw."* The PSTs worried that *"students might resort to immediately using the tool instead of attempting the problems on their own,"* leading to overreliance, reduced student agency, and diminished critical thinking skills.

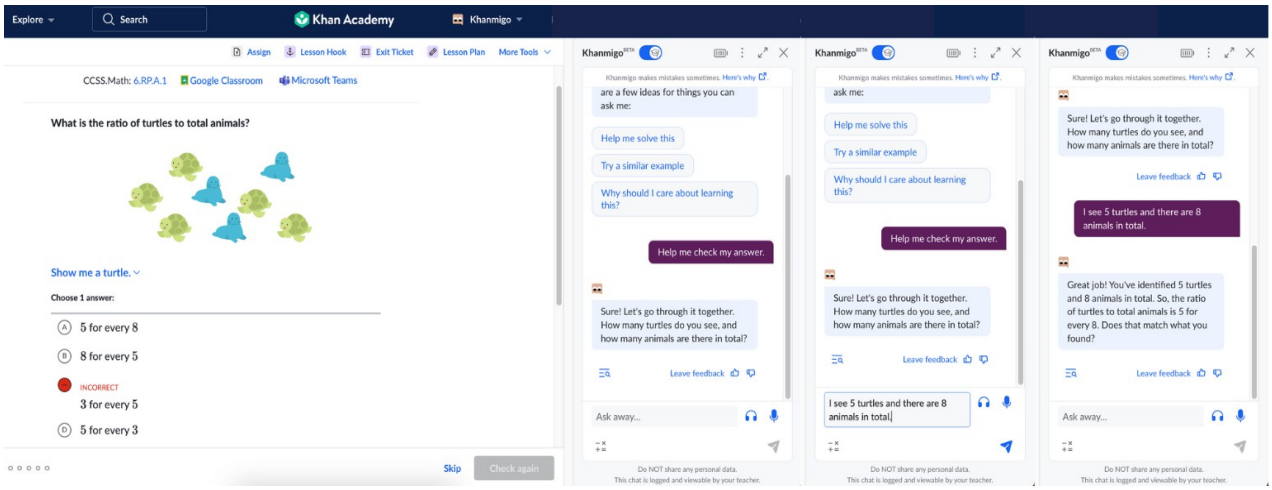

Figure 2. Modeled activity on Khan Academy simulating Khanmigo's personalized help for ratio questions

From Hesitation to AI-enhanced Teaching: TPACK for Integrating GenAI in Mathematics Classrooms

The PSTs exhibited varying levels of self-confidence and preparedness to integrate GenAI into teaching. Some PSTs highlighted their ability to critically evaluate and refine GenAI outputs, while others remained hesitant about their abilities. Nonetheless, all PSTs reflected thoughtfully on the potential impacts of GenAI-supported teaching on student learning outcomes. Despite their varying levels of expertise and confidence, all PSTs believed that, with practical classroom experience, they could successfully integrate GenAI into mathematics instruction.

> "If I'm asking to do a math task, I approach it significantly differently than asking you to do an English task, right? If I'm approaching a programming task, I ask to do something significantly different than

> writing or a math task, you know. If you can teach the approach of prompt crafting depending on what they want. I think that's important." - *Caleb Masters, Interview*

Lost in AI Maze: Navigating Uncertainty and Seeking Guidance in Teacher Preparation

While the PSTs had been introduced to GenAI tools in their teacher education programs, all interviewed PSTs felt that formal training on GenAI integration was insufficient and lacked practical guidance. The workshop was the first opportunity for some to engage in hands-on tasks with GenAI tools and application areas that elicited deeper pedagogical discussions. The PSTs desired more structured training on effectively integrating GenAI into curriculum-aligned lesson planning and classroom activities. Another major concern was institutional uncertainty, as many PSTs were unsure whether their future schools or districts would support GenAI use.

> "I liked the activity with Khanmigo, feeding it, pretending to be a middle schooler because I was like, all right, what does it do when there's a typical middle schooler response?" - *Amanda Weiss, Interview*

> "I feel like just using it creatively would have been a nice touch to give us. Obviously, they told us about it. They told us that it exists, but they should have been teaching us how to use it to get more creative lesson plans or maybe have it even do the work for us." - *Logan Everett, Interview*

Discussion and Implications

Consistent with previous research (Ellis & Slade, 2023; Guler et al., 2024), PSTs in this study acknowledged the benefits of GenAI for lesson planning, differentiation, and instructional material generation. However, despite recognizing these affordances, PSTs expressed apprehensions about GenAI's appropriateness for student learning (Matzakos et al., 2023). This emphasizes the importance of equipping educators with strategic evaluation skills to ensure GenAI-assisted instruction is pedagogically sound (Sánchez-Ruiz et al., 2023). The TPACK-based workshop provided a structured environment where PSTs actively experimented with GenAI's various instructional applications and critically reflected on its strengths and limitations. The workshop also prompted PSTs to critically evaluate their AI collaboration capabilities to moderate the AI-generated content and their pedagogical decisions. This aligns with Mishra et al.'s (2023) argument that GenAI should be viewed as a collaborative agent rather than a simple technological tool. While the study offered valuable insights, a single workshop is insufficient to develop deep and sustained competence among the PSTs. Longitudinal studies and long-term PD are essential for effectively embedding GenAI into pedagogical practice. Future studies should study how PSTs' attitudes, confidence, and competencies in using GenAI evolve over an extended period of time.

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