Teaching Future Mathematics Teachers in the Age of AI: A Systematic Review of Preservice Teacher Education Research

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Abstract

This systematic literature review examined how course instructors engage preservice mathematics teachers in using artificial intelligence (AI) within instructional activities. Analysis of 12 studies revealed themes including lesson planning, mathematical task design, reflective practice, problem solving, prompting skills, and AI literacy, highlighting the importance of critical evaluation in AI-supported teacher preparation.

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Artificial intelligence (AI) is rapidly transforming education by influencing how teachers design instruction, develop assessments, and support student learning (Celik et al., 2022; Trust et al., 2023). As AI technologies continue to evolve, educators and teacher preparation programs (TPPs) are being challenged to reconsider traditional instructional practices and prepare preservice teachers (PSTs) for AI-supported classrooms. These developments make it increasingly important for TPPs to consider not only whether PSTs engage with AI, but also how they are prepared to use these technologies within their future instructional practice.

The expanding capabilities of AI present opportunities for teacher preparation. AI has the potential to support instructional design, automate educational tasks, and enhance student learning through data-driven technologies (Chen et al., 2020). At the same time, tools such as ChatGPT require critical examination of how AI can support teaching and learning and how future teachers are prepared to evaluate its use (Trust et al., 2023). Accordingly, understanding how teacher educators are engaging PSTs with AI is important for informing how TPPs can respond to the increasing presence of AI in educational practice.

This need is particularly important within mathematics teacher education, where AI presents both instructional opportunities and discipline-specific challenges. AI can enhance mathematics instruction but must be integrated strategically given potential limitations, including inaccurate mathematical computations and limited problem-solving capabilities (Opesemowo & Ndlovu, 2024). Additionally, AI should be used in ways that enhance student learning opportunities without reducing productive struggle (AI for Education & Student Achievement Partners, 2025; National Council of Teachers of Mathematics, 2014). Guided by the PRISMA framework (Page et al., 2021), this systematic literature review examines how course instructors engage mathematics PSTs in using AI to support instructional activities, providing insight into how they are being prepared for AI-supported classrooms.

Background

Existing systematic and narrative reviews have largely focused on specific domains. Zawacki-Richter et al. (2019) conducted a systematic review of AI applications in higher education, identifying trends such as adaptive systems, assessment tools, and student support, but with limited attention to teacher preparation contexts. Similarly, Crompton and Burke's (2023) systematic review of AI use in K–12 settings highlighted applications in writing, feedback, and instructional support, though primarily from a student-use perspective. In contrast, Chassignol et al. (2018) and Chen et al. (2020) offered broader literature reviews of AI in education, with a strong emphasis on STEM and technical applications rather than pedagogical implementation. While these reviews demonstrate the growing interest in AI across educational settings, they remain largely generalized or discipline-focused, with limited attention to how AI is implemented within TPPs. Notably, there is a lack of focused synthesis examining AI use specifically within mathematics education, particularly in preservice teacher coursework.

Technological Pedagogical Content Knowledge (TPACK) provides a useful lens for considering the knowledge PSTs need when integrating AI into mathematics instruction (Celik, 2023). TPACK emphasizes that effective technology integration requires more than technological knowledge alone; teachers must consider the relationships among content knowledge, pedagogical knowledge, and technological knowledge, as well as the intersection of knowledge in instructional practice. Within mathematics teacher education, content knowledge includes the mathematical understanding needed to solve and evaluate problems, pedagogical knowledge includes knowledge of lesson planning and instructional decision-making, and technological knowledge includes understanding how to effectively interact with and use technology. Celik (2023) extended the framework through Intelligent-TPACK, emphasizing AI-specific technological and pedagogical knowledge as well as teachers' capacity to evaluate the ethical implications of AI-supported decisions. This perspective is particularly relevant to mathematics teacher preparation, where PSTs must not only learn how to interact with AI tools but also determine whether AI-generated mathematical content is accurate and whether its use supports appropriate instructional goals.

Existing work has not systematically examined how AI is being integrated into mathematics-related courses

or how PSTs are engaged in using these tools to support instructional activities. Although the studies were synthesized inductively based on patterns in instructional activities, TPACK provides a useful framework for interpreting how these activities engage technological, pedagogical, and mathematical content knowledge. We sought to answer the following research question: *In what ways have course instructors engaged preservice mathematics teachers in using AI to support instructional activities?*

Method

This systematic review utilized three databases commonly used in education research:

The Education Resources Information Center (ERIC), Gale OneFile: Educators Reference, and SAGE Journals. ERIC provides extensive coverage of education-focused, peer-reviewed research, while Gale OneFile and SAGE Journals offer broader interdisciplinary and teacher education literature. Together, these databases supported a comprehensive search of literature related to AI use in preservice teacher education within mathematics contexts.

The search strategy was intentionally broad while targeting studies relevant to the research focus. The same filters were applied across all databases. Only peer-reviewed, full-text, English-language articles published from 2011 to the present were considered. Different keyword combinations were used across databases to align with each platform's search functionality. In ERIC, the search included ("artificial intelligence" OR "ChatGPT") AND ("preservice teacher*" OR "teacher candidate*") AND (mathematics OR math) NOT perception*. In Gale OneFile: Educators Reference, the search combined ("artificial intelligence" OR "ChatGPT") with ("preservice teacher*" OR "teacher education") and terms related to instructional use, including assignment*, "course design," "course redesign," implementation, integration, "instructional strategy," and "learning activity." In SAGE Journals, the search included ("artificial intelligence" OR "ChatGPT" OR "generative AI") AND ("teacher education" OR "preservice teacher" OR "initial teacher education") AND ("mathematics" OR "math education") AND (pedagogy OR curriculum).

The review followed a structured screening process guided by the PRISMA framework

(Page et al., 2021). Initially, 122 records were identified across the three databases: ERIC (n = 19), Gale OneFile: Educators Reference (n = 22), and SAGE Journals (n = 81). After removing two duplicate records, 120 articles remained and were screened at the title level. Title and full-text screening were conducted independently by two reviewers, with discrepancies resolved through consensus. During title screening, 83 records were excluded for not focusing on AI, not involving PSTs, or not being situated within a mathematics context. This resulted in 37 articles being retrieved and assessed for eligibility. Following full-text review, 30 studies were excluded for reasons including not being mathematics-specific (n = 9), not focusing on AI (n = 5), involving in-service teachers rather than PSTs (n = 6), not being empirical studies (n = 4), or not examining AI use within preservice teacher course assignments (n = 6).

This resulted in seven studies from database searches being included in the review.

These 7 studies were then used for citation searching, where reference lists were examined to identify additional relevant literature. This process yielded 12 additional records, six of which were excluded during title screening. The remaining six studies were retrieved, assessed for eligibility, and included in the final sample. In total, 12 studies were included in the review

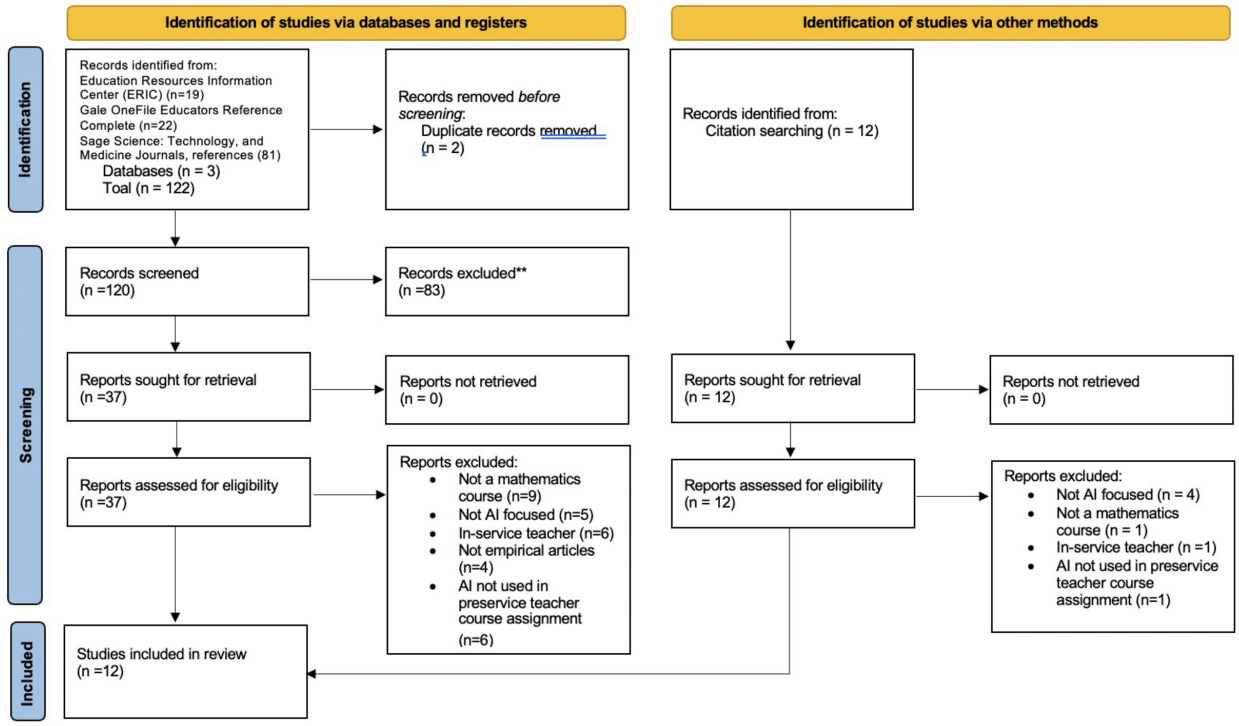
Descriptive information from each study was organized using a structured Excel spreadsheet that included categories such as research questions, study design, participant characteristics, course context, AI use within the course, and overall themes. Following screening, each article was reviewed by two of the three authors to support multiple perspectives during analysis. After data extraction, the reviewers met to identify common patterns across studies. An inductive thematic analysis approach was used to group recurring ideas into broader themes describing how AI was integrated into instructional activities within preservice teacher education (Saldaña, 2021).

Results

This systematic literature review examined the question: I*n what ways have course instructors engaged preservice mathematics teachers in using AI to support*

Figure 1

PRISMA Flow Diagram of Study Selection for AI Use in Preservice Mathematics Teacher Education



Note. Adapted from the PRISMA framework (Page et al., 2021).

instructional activities? A total of 12 studies met the inclusion criteria. The studies represented a range of methodological approaches, including six qualitative studies, two quantitative studies, three mixed-methods studies, and one quasi-experimental study.

Across the studies, course contexts varied. Four studies were situated in mathematics methods-related coursework, where PSTs engaged in designing instruction (Gurl et al., 2025; Pişkin Tunç, 2024; Tapan Broutın, 2023; Yanar & Ergene, 2025). Three studies were conducted in mathematics content-focused contexts, including geometry and advanced mathematics courses (Biton & Segal, 2025; Dilling & Herrmann, 2024; Segal & Biton, 2024). The remaining five studies were situated in broader teacher education or general mathematics education contexts without a clearly defined course structure (Asare & Boateng, 2025; Dinçer, 2026; Filiz & Gür, 2025; Getenet, 2024; Pavlova, 2024).

The grade levels represented across the studies also varied. Two studies focused on elementary or primary mathematics contexts (Filiz & Gür, 2025; Getenet, 2024), two studies focused on middle school mathematics (Pişkin Tunç, 2024; Yanar & Ergene, 2025), and two studies focused on high school or advanced high school mathematics (Biton & Segal, 2025;

Segal & Biton, 2024). One study was situated in a general secondary mathematics context (Gurl et al., 2025), while the remaining studies did not specify a particular grade level and instead focused on general mathematics or teacher education contexts (Asare & Boateng, 2025; Dilling & Herrmann, 2024; Dinçer, 2026; Pavlova, 2024; Tapan Broutın, 2023). Analysis of the included studies resulted in six themes describing how PSTs engaged with AI in instructional activities. Although these themes emerged inductively, they also reflect different dimensions of the knowledge represented within TPACK, including pedagogical, content, and technological knowledge, and the intersections among them.

AI as a Tool for Lesson Planning and Instructional Design

Across multiple studies, AI was used to support lesson planning and instructional design, reflecting pedagogical knowledge integrated with technological

knowledge. PSTs used ChatGPT to generate lesson activities, explanations, assessments, and lesson objectives. Yanar and Ergene (2025) reported that PSTs used ChatGPT across all phases of the 5E instructional model to develop lessons, while Pişkin Tunç (2024) found that AI was used to create instructional content, examples, and assessments. Gurl et al. (2025) reported that PSTs generated lesson objectives using ChatGPT and revised them to align with instructional goals. Similarly, Tapan Broutın (2023) found that PSTs used AI to organize lesson components and improve instructional flow over time. PSTs used AI to make decisions about lesson structure, instructional goals, assessment, and learning activities. AI also supported revision and refinement during lesson planning. Gurl et al. (2025) and Yanar and Ergene (2025) found that PSTs compared their lesson plans with AI-generated outputs and revised their work accordingly. Pişkin Tunç (2024) and Tapan Broutın (2023) similarly highlighted how AI supported refinement of lesson structure and organization. PSTs were expected to determine how AI-generated ideas could be adapted to support instructional purposes rather than simply use the technology to produce content.

AI for Designing Mathematical Tasks and Instructional Content

Several studies demonstrated that AI was used to design mathematical tasks and instructional materials, requiring PSTs to integrate pedagogical, content, and technological knowledge. PSTs used ChatGPT to generate mathematical problems, examples, and explanations for classroom use. Biton and Segal (2025) found that PSTs generated and refined mathematical problems using AI to improve clarity, challenge level, and alignment with learning goals. Similarly, Segal and Biton (2024) reported that AI was used to adapt and extend mathematical tasks to support instructional objectives. Pişkin Tunç (2024) also found that PSTs used AI to create mathematical problems and explain concepts while developing lesson materials. PSTs evaluated both the mathematical quality of AI-generated tasks and their usefulness.

AI was additionally used to evaluate and revise mathematical tasks. Biton and Segal (2025) and Segal and Biton (2024) described how PSTs modified AI-generated problems to improve instructional usefulness. Dinçer (2026) found that AI-supported work demonstrated higher levels of accuracy, but lower levels of originality compared to non-AI-supported work.

AI for Comparison, Revision, and Reflective Practice

AI was frequently used as a tool for comparison, revision, and reflection, demonstrating the importance of drawing on content and pedagogical knowledge to make informed judgments about technologically generated content. PSTs compared their own work with AI-generated outputs and evaluated differences in accuracy, quality, and instructional usefulness. Gurl et al. (2025) found that PSTs compared lesson objectives with ChatGPT-generated objectives and reflected their usefulness. Similarly, Getenet (2024) reported that PSTs compared their own problem-solving strategies with AI-generated solutions.

Evaluation of AI-generated responses was a consistent pattern across studies. Getenet (2024) and Yanar and Ergene (2025) found that PSTs assessed the correctness and usefulness of AI-generated outputs, often identifying responses that were too general or incomplete. Based on these evaluations, PSTs revised lesson plans and instructional materials. Asare and Boateng (2025) also found that ChatGPT supported self-reflection and self-regulated learning.

AI for Mathematical Reasoning and Problem-Solving Engagement

Several studies highlighted AI use in mathematical reasoning and problem-solving, foregrounding the need for strong mathematical content knowledge to evaluate and reason with AI-generated solutions. PSTs used ChatGPT to solve problems, verify solutions, explore alternative strategies, and analyze mathematical reasoning. Pavlova (2024) described how PSTs engaged in dialogue-based interactions with AI to work through mathematical problems and refine reasoning. Similarly, Filiz and Gür (2025) found that PSTs used AI to verify solutions and explore alternative strategies through step-by-step reasoning.

PSTs also analyzed AI-generated mathematical solutions. Getenet (2024) and Dilling and Herrmann (2024) reported that students examined AI-generated responses to better understand mathematical processes. Dilling and Herrmann (2024) specifically found that

PSTs used ChatGPT to generate and analyze mathematical proofs, although many relied on simple prompts requesting direct answers.

Development of Prompting and AI Interaction Skills

Several studies demonstrated that PSTs developed skills related to prompting and AI interaction, an emerging form of technological knowledge needed to effectively use AI. Biton and Segal (2025) and Segal and Biton (2024) found that PSTs practiced writing and refining prompts to improve AI-generated outputs, demonstrating that prompt quality influenced response usefulness and accuracy. PSTs also engaged in iterative dialogue with AI systems. Pavlova (2024) found that students refined questioning strategies over time through repeated interaction with ChatGPT. However, Dilling and Herrmann (2024) observed that many PSTs relied on simple one-step prompts with limited follow-up interaction, demonstrating variability in prompting skills. Therefore, the usefulness of this technological knowledge depends on PSTs' ability to connect their interactions with AI to mathematical and pedagogical knowledge.

Critical Evaluation and AI Literacy

Across studies, PSTs were consistently required to critically evaluate AI-generated content for accuracy, instructional usefulness, and mathematical quality, requiring them to combine their pedagogical, mathematical content, and technological knowledge. Gurl et al. (2025), Getenet (2024), and Yanar and Ergene (2025) found that PSTs evaluated AI-generated lesson materials and mathematical responses, often identifying outputs that were overly general, incomplete, or incorrect. Similarly, Biton and Segal (2025), Segal and Biton (2024), Pişkin Tunç (2024), and Tapan Broutın (2023) demonstrated that AI-generated instructional materials and mathematical tasks required revision and refinement to align with instructional goals.

Several studies also emphasized the role of metacognition, reflection, and intentional engagement when interacting with AI. Filiz and Gür (2025) found that PSTs with higher levels of metacognitive awareness were better able to critically assess AI-generated responses, while Asare and Boateng (2025) reported that AI-supported activities promoted self-regulated learning and reflection. Pavlova (2024) similarly highlighted the importance of identifying and correcting errors through dialogue-based interaction with AI.

Challenges related to overreliance on AI were also identified. Dinçer (2026) found that AI-supported work demonstrated lower levels of originality, while Dilling and Herrmann (2024) observed that many PSTs relied on simple prompts requesting direct answers rather than critically engaging with AI-generated content. Across lesson planning, mathematical task design, and problem-solving activities, studies consistently demonstrated that effective AI use depended on PSTs' ability to critically evaluate, adapt, and refine AI-generated outputs (Biton & Segal, 2025; Filiz & Gür, 2025; Getenet, 2024; Gurl et al., 2025; Pavlova, 2024; Pişkin Tunç, 2024; Segal & Biton, 2024; Tapan Broutın, 2023; Yanar & Ergene, 2025).

Discussion

This systematic review examined how course instructors engaged preservice mathematics teachers in using AI to support instructional activities. Consistent with previous reviews (e.g., Celik et al., 2022; Trust et al., 2023), the reviewed studies indicate that AI is becoming an increasingly important component of mathematics teacher preparation. Collectively, these findings suggest that mathematics teacher educators are moving beyond introducing AI as a standalone technological tool and are instead embedding it within authentic teaching practices. This shift may better prepare PSTs to make informed instructional decisions in classrooms where AI is becoming increasingly common.

Course instructors integrated AI into lesson planning and instructional design activities, including generating lesson ideas (Yanar & Ergene, 2025), planning instructional flow (Tapan Broutın, 2023), and exploring different ways to solve mathematical problems (Pişkin Tunç, 2024). Across these learning activities, PSTs were consistently required to reflect upon, revise, and adapt AI-generated content before submitting their final assignments. Rather than emphasizing AI as a tool for producing lesson materials, these instructional activities positioned AI as a thought partner that supported PSTs' thinking throughout the lesson planning process. Mathematics teacher educators are intentionally designing learning experiences that reinforce teachers' pedagogical and technological knowledge by requiring

PSTs to critically evaluate and refine AI-generated ideas before incorporating them into instructional decisions.

Additionally, course instructors leveraged AI to support mathematical reasoning and problem-solving by engaging PSTs in generating problems, verifying solutions, evaluating proofs, and exploring alternative solution pathways (Dilling & Herrmann, 2024; Filiz & Gür, 2025; Pavlova, 2024; Getenet, 2024; Gurl et al., 2025; Yanar & Ergene, 2025). However, across these studies, PSTs did not consistently identify incorrect AI-generated responses and sometimes accepted initial outputs without sufficient evaluation. Collectively, these findings indicate that AI does not reduce the need for mathematical content knowledge; rather, it may increase its importance. As AI becomes more integrated into mathematics instruction, PSTs must possess sufficient content knowledge to evaluate AI-generated responses, recognize inaccuracies, and determine whether AI-generated content is instructionally appropriate before using it in classroom practice.

Finally, the findings argue for building strong technological knowledge, so PSTs can effectively interact with generative AI tools. Across most studies, it was evident that successful use of AI relied on PSTs' ability to critically evaluate AI-generated output for accuracy and pedagogical strengths and weaknesses (e.g., Getenet, 2024; Gurl et al., 2025; Yanar & Ergene, 2025). Given the range of interactions and prompting strategies, AI literacy is an important competency that PSTs need to develop alongside their content and pedagogical knowledge.

Effective AI integration requires PSTs to understand how, when, and why to use AI to support mathematical learning goals, using their pedagogical, content, and technological knowledge to evaluate the accuracy, instructional value, and ethical implications of AI-generated content (Celik, 2023). Collectively, PSTs should be equipped with content knowledge to determine whether AI-generated solutions and tasks are accurate, pedagogical knowledge to decide whether those outputs support student learning, and technological knowledge to use and refine AI-generated responses. AI integration should be part of a teacher's professional knowledge rather than treated as a separate technology skill.

The value of AI in preservice mathematics teacher education lies not in the technology itself, but in how teacher educators intentionally design learning experiences that promote critical reflection, mathematical reasoning, and professional judgment.

Action Steps for Teacher Educators

- Design AI assignments that require critical evaluation and revision of AI-generated content.
- Embed AI within teaching activities to provide application opportunities for development of integrated technological, pedagogical, and mathematical content knowledge.
- Build AI literacy through explicit opportunities to practice prompting, content evaluation, and instructional decision-making

Limitations of the Review

This systematic literature review has several limitations. Although a structured and systematic search process was employed, it is unlikely that all relevant studies were captured, as the use of specific databases, search terms, filters, and inclusion criteria may have excluded relevant research. Additionally, this review intentionally focused only on mathematics-related preservice teacher education contexts in which AI was used within instructional or course-based activities, excluding studies from other subject areas as well as studies centered solely on perceptions or general AI use outside structured coursework. The small sample size (n = 12), along with the varied course contexts and educational levels represented, allowed us to identify broad patterns of AI integration but did not support context-specific conclusions or broad generalizations across teacher education programs. More large-scale and longitudinal research is needed. Finally, this review focused on identifying patterns in how AI was integrated into instructional activities, not evaluating the effectiveness of these practices. We do not provide evidence regarding impacts on learning outcomes, instructional quality, or long-term preservice teacher development.

Conclusion

Course instructors are integrating AI into preservice mathematics teacher coursework in a variety of ways,

including lesson planning, instructional design, mathematical task development, reflective practice, and support for mathematical reasoning and problem solving. Preparing preservice mathematics teachers for AI-supported classrooms requires integrated development of technological, pedagogical, and content knowledge rather than technological skills alone. As AI continues to evolve, further research is needed to examine the effectiveness of AI use and its influence on PSTs' mathematical knowledge, instructional decision-making, critical use and evaluation of AI-generated content.

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