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Mathematics Education in the AI Era: Preparing Teachers for Evolving Classroom Demands

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Abstract. With artificial intelligence (AI) redefining mathematics education, teachers must exhibit new competencies to be compliant with the evolving modern classroom requirements. This conceptual study investigated the transformation of mathematics education amid the rise of AI, centering on how to prepare teachers to meet new classroom demands. Guided by Activity Theory and AI Competency Frameworks for Teachers, the study synthesized current literature for strategic insights on teacher competencies, ethical practices, and inclusive, technology-based education principles. The research examined significant challenges and prospects associated with AI adoption, including the imperative for robust teacher preparation, the formulation of fair and transparent policies, and efforts to mitigate bias for all students. Through narrative literature review and thematic analysis, the study identified dominant themes and offered actionable recommendations for teacher education, institutional policy, and continuous professional development. By articulating the requisite skills and ethical imperatives for successful AI integration in mathematics education, this investigation informs adaptive teaching practices and establishes a trajectory for further scholarly inquiry in the field. The conclusion underscores the necessity of equipping teachers to responsibly maximize AI's potential while promoting ethical and equitable mathematics classrooms.

Keywords: Artificial intelligence; Mathematics education; Teacher preparation; Ethics; Inclusion and equity

1. Introduction

Artificial intelligence (AI) is rapidly revolutionizing mathematics education, opening new possibilities for personalized learning, adaptive assessment, and data-informed instructional practices. AI-enabled resources—including intelligent tutoring programs, automated assessment systems, and generative content platforms—are being widely implemented in mathematics classrooms

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globally, allowing teachers to personalize instruction and accommodate varied learning needs (Gabriel et al., 2025). This technological transformation boosts student engagement and success while driving a re-evaluation of pedagogical approaches and teacher roles in the digital era (Engelbrecht & Borba, 2024). As AI permeates educational contexts, it is imperative to evaluate how it impacts mathematics instruction, particularly about teacher readiness, ethics, and equity.

Applying AI-powered resources in mathematics education holds considerable potential for tackling entrenched inequalities and promoting inclusive teaching. By deploying AI-facilitated analytics and adaptive learning technologies, teachers can detect and remedy disparities in student achievement, thereby advancing equity in education (Kohnke & Zaugg, 2025). Nevertheless, employing AI in education also introduces concerns like algorithmic bias, data privacy threats, and the possibility of deepening current systemic inequalities if appropriate regulations are lacking (Adams et al., 2023). These issues necessitate a critical and reflective stance towards AI adoption, ensuring that technological innovations uplift rather than marginalize students (Lata, 2024).

Teachers are central to this transformation, as they are expected to fulfil emerging professional standards requiring technical expertise, ethical judgement, and adaptability. The transition to AI-supported classrooms compels teachers to develop digital literacy, ethical awareness, and the ability to assess AI tools for inclusivity and fairness (Filo et al., 2024; Wang et al., 2023). Accordingly, teacher education and professional learning opportunities should be reformed so that teachers can acquire the appropriate knowledge, expertise, and dispositions for incorporating AI in mathematics instruction (Chiu et al., 2024; Cukurova & Miao, 2024). This restructure involves clearly understanding the capabilities and constraints of AI and implementing measures to counteract unintended consequences stemming from its use.

Ethical matters take priority in AI adoption in mathematics education, especially concerning student privacy, fairness, and the rights of teachers and students. The design and deployment of AI systems in schools should be anchored in clear ethical guidelines that prioritize transparency, accountability, and inclusivity (Nguyen et al., 2023). Without such measures, AI can unintentionally reinforce discrimination or undermine trust in educational institutions. Continued collaboration among teachers, policymakers, technologists, and the wider communities must be maintained so that AI is responsibly managed and remains aligned with educational values (Flores-Viva & García-Peñalvo, 2023).

This study is crucial because the current teacher preparation programs frequently lack comprehensive frameworks addressing the distinct challenges introduced by AI integration in mathematics education. With AI technologies rapidly redefining classroom dynamics, it becomes imperative to formulate clear competencies and ethical standards that enable teachers to promote equitable and inclusive learning environments. Moreover, confronting systemic bias embedded in AI systems demands deliberate strategies rooted in educational equity and ethical responsibility. By concentrating on these critical aspects, this research fills

significant gaps in knowledge and practice, ultimately supporting teacher capacity building to responsibly engage with AI-driven educational changes.

1.1. Problem Statement

Even as AI becomes more embedded in mathematics instruction, uncertainty persists regarding effective strategies for equipping teachers to meet the multidimensional challenges of AI-supported classrooms. While AI technologies open pathways to personalize learning and promote equity, their integration is beset by issues like algorithmic bias, ethical dilemmas, and the danger of worsening existing inequalities (Adams et al., 2023; Lata, 2024). Many teachers lack the necessary competencies to critically assess and ethically incorporate AI tools, largely attributable to limited professional development and insufficient exposure to AI literacy frameworks (Filo et al., 2024).

Furthermore, the absence of explicit ethical protocols for AI deployment in education heightens worries concerning student privacy, fairness, and rights (Eden et al., 2024). This concern is further intensified by the swift pace of technological advancement and the diversity of mathematics education contexts (Engelbrecht & Borba, 2024; Mukhibin et al., 2023). Consequently, there is an urgent necessity for research that synthesizes theoretical perspectives and empirical evidence to inform the preparation of teachers for these emerging requirements (Cukurova & Miao, 2024; Mouta et al., 2025). The present study responds to these concerns by exploring effective strategies for integrating AI to advance equity, determining the core competencies teachers need for ethical AI application, and articulating ethical standards guiding the design and deployment of AI in mathematics education.

1.2. Research Questions

The questions below were formulated to guide this conceptual study:

1. How can AI integration in mathematics education promote equity and reduce systemic bias?
2. What specific competencies do teachers require for ethical AI use in inclusive mathematics instruction?
3. What guiding ethical principles should be adopted for the design and deployment of AI in mathematics classrooms to protect student privacy, promote fairness, and uphold teacher and student rights?

2. Theoretical Framework

This study has integrated Activity Theory with AI Competency Frameworks for Teachers to deliver a nuanced perspective on how to equip mathematics teachers for the shifting demands of AI-mediated classrooms. The description of the framework follows.

2.1. Overview of Activity Theory in Mathematics Education

Developed by Lev Vygotsky in the 1920s and subsequently expanded by Alexei Leontiev and Yrjö Engeström, Activity Theory offers a valuable analytical lens for interpreting the intricacies of human activity, particularly in education (Engeström, 1987; Sannino et al., 2009). Engeström's contribution in the late 1980s

recognized learning as a collective, culturally mediated process, rather than as an isolated, individual pursuit. The theory asserts that human actions are shaped by the dynamic interplay between the subject (e.g., teacher or students), mediating tools (including technology), the community, established rules, and division of labor, all directed toward definite objectives.

In mathematics education, Activity Theory has been instrumental in examining the role of digital and AI tools in facilitating instructional processes, exposing the tensions, contradictions, and possibilities arising in classroom practices (Abboud et al., 2018; Loc et al., 2022). This perspective highlights the significance of context, collaboration, and goal-oriented activity in determining educational experiences.

2.2. Rationale and Relevance of AI Competency Frameworks for Teachers

In response to the expanding use of AI in education, AI Competency Frameworks for Teachers have been developed to specify the essential knowledge, skills, and ethical dispositions teachers require to succeed in their redefined job scope (Cukurova & Miao, 2024). Since the late 2010s, global agencies such as UNESCO have introduced comprehensive frameworks to meet the urgent demand for teacher readiness amid rapid technological shifts (Mutawa & Sruthi, 2025).

These frameworks typically address technical expertise with AI, an understanding of AI's educational potential, data literacy, critical evaluation of AI for bias and inclusivity, and adherence to its ethical principles (Chiu et al., 2024). The intent is to prepare teachers capable of implementing AI effectively to support equity, protect student rights, and foster inclusive learning environments (Filo et al., 2024). Thus, these competency frameworks are increasingly regarded as fundamental to teacher education and professional growth in the digital age.

2.3. Synergizing Both Theoretical Frameworks

Integrating Activity Theory and AI Competency Frameworks for Teachers yields a holistic approach for preparing mathematics teachers for AI-rich classrooms. Activity Theory situates teacher practice within the broader sociocultural system highlighting how AI technologies mediate relationships among subjects, community, and learning goals (Abboud et al., 2018). Overlaying AI competency frameworks enables the analysis of how teachers' technical, pedagogical, and ethical skills interact with the activity system, especially as AI reshapes classroom dynamics (Engelbrecht & Borba, 2024).

This synergy facilitates an in-depth exploration of teacher readiness and agency, shaped by both individual and systemic factors. This is crucial for a thorough investigation of equity, vital teacher skills, and guiding ethical principles for AI in mathematics education (Cukurova & Miao, 2024; Filo et al., 2024). This integrated approach underpins the development of evidence-based strategies for teacher preparation for AI-enhanced mathematics classrooms.

3. Conceptual Framework

3.1. Definition of Key Concepts

The following definitions are provided to establish a shared understanding of key terms used in this study as they specifically relate to the integration of AI in mathematics classrooms.

3.1.1 Equity

Means fair access, participation, and outcomes in mathematics education for all students, irrespective of ability or background, for AI tools to assist in bridging existing disparities rather than widen them (Kohnke & Zaugg, 2025; Sato et al., 2024).

3.1.2 Bias

Arises when algorithms or data unfairly disadvantage certain groups, often exacerbating societal prejudices. Addressing this is critical to guard against further exclusion of marginalized students (Lin et al., 2021; Roshanaei, 2024).

3.1.3 Competency

Encompasses the knowledge, skills, and dispositions teachers must demonstrate for effective and ethical AI integration, including technical proficiency, data literacy, and adaptable pedagogy (Chiu et al., 2024; Cukurova & Miao, 2024).

3.1.4 Ethics

Refers to the principles governing responsible AI use—like transparency, privacy, accountability, and the protection of student and teacher rights—which are fundamental to promoting inclusive and just mathematics education (Adams et al., 2023; Nguyen et al., 2023).

3.2. Conceptual Model Illustrating Preparation of Mathematics Teachers for AI-Integrated Education

This study's conceptual model has drawn on the integration of Activity Theory and the AI Competency Framework for Teachers to understand the complex dynamics of AI adoption in mathematics education. Activity Theory conceptualizes AI integration as a mediated activity system involving teachers (subjects), AI tools (artifacts) and a community structured by rules and division of labor to achieve equitable, ethical learning outcomes (Abboud et al., 2018).

The AI Competency Frameworks for Teachers, in turn, specifies the essential technical, pedagogical, and ethical skills teachers need to function effectively in this system (Cukurova & Miao, 2024; Filo et al., 2024). This model recognizes the interplay between teacher agency and systemic influences, illustrating how teacher competencies and ethical considerations shape AI's role in promoting equity and reducing bias in mathematics classrooms. It also underlines continuous professional development and reflective practice as key mechanisms for sustainable AI integration (Engelbrecht & Borba, 2024; Wang et al., 2023). Figure 1 visually represents the conceptual model.

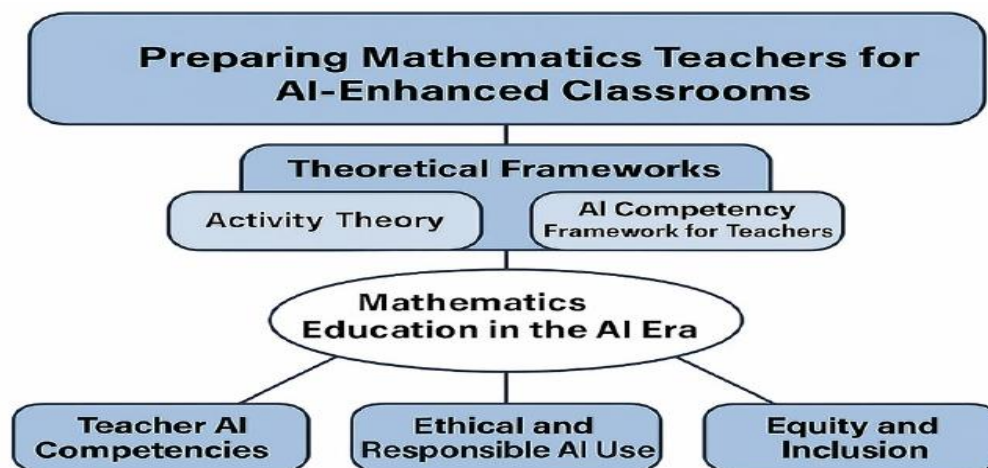


Figure 1: The Conceptual framework for preparing mathematics teachers for AI-integrated, equitable, and ethical classrooms – developed by the researchers through Literature synthesis

3.3. Mapping the Conceptual Framework to Research Questions

This integrated framework systematically aligns each research question with core constructs – equity, bias, competency, and ethics. Table 1 presents the mapping process and highlights relevant literature, clarifying the analytical approach and demonstrating the framework’s relevance to the research purpose.

Table 1: Mapping research questions to relevant conceptual framework components

Research Questions	Key Conceptual Elements	Framework Component(s)	Major Supporting References
RQ-1: How can AI integration in mathematics education foster equity and reduce systemic bias?	AI as a mediating tool for personalized, equitable learning; addressing algorithmic bias; teacher agency in promoting fairness	Activity Theory AI Competency Frameworks (equity, bias)	Kohnke & Zaugg, 2025; Lin et al., 2021 Abboud et al., 2018
RQ-2: What competencies do teachers need for ethical AI use in inclusive mathematics instruction?	Technical, pedagogical, and ethical competencies; critical data literacy; reflective, adaptive practice	AI Competency Framework (Competency)	Cukurova & Miao, 2024; Chiu et al., 2024 Filo et al., 2024
RQ-3: What ethical principles should be adopted for AI design and deployment in math class to protect student privacy, promote fairness, and uphold teacher and student rights?	Transparency, privacy, accountability; protection of rights; ethical standards for AI in education	AI Competency Framework (Ethics) Activity Theory (Rules, Community)	Adams et al., 2023 Nguyen et al., 2023 Sannino et al., 2009

4. Methodology

4.1. Data Collection Approach

This study adopted a narrative literature review approach to synthesize and critically interpret existing literature, thereby deepening understanding of how AI-supported mathematics education can prepare teachers for evolving classroom demands (Chiu et al., 2024; Cukurova & Miao, 2024; Pautasso, 2019). In contrast to systematic reviews, narrative literature approaches allow for greater flexibility in selecting and integrating studies, making them particularly suitable for exploring complex or rapidly evolving fields (Basheer, 2022).

This method prioritizes meaningful interpretation and thematic connections rather than mere aggregation of data. It enables researchers to craft a coherent account of the state of the discipline, highlight knowledge gaps, and suggest future research directions. Narrative reviews are particularly valuable when the goal is to develop a conceptual framework or situate a study within a broader context (Josselson & Hammack, 2021). Accordingly, employing a narrative review approach strengthened the methodological foundation of this research by ensuring a nuanced, critically informed background.

4.2. Literature Search and Selection Criteria

Literature search process involved three leading academic databases—Scopus, Eric, and Web of Science—to identify relevant peer-reviewed journal articles, book chapters, and policy papers. The search strategy incorporated keywords, that were specifically relevant to this study, like “artificial intelligence,” “mathematics education,” “teacher competency,” “ethics,” and “equity,” with the Boolean operators (“and”, “or”) applied to combine search terms and refine results effectively.

This enabled precise targeting of the publications focusing on studies that examined AI integration specifically within mathematics education or teacher preparation for AI. Additional relevant sources were discovered through reference chaining and expert consultation, in consistency with established practices that emphasize the methodological rigor of this technique in uncovering seminal and less accessible studies, as well as tracing the developmental trajectory of ideas in the field.

To maintain the focus and quality of the review, inclusion parameters required publications to be peer-reviewed, written in English, and published from 2019 to 2025. Eligible studies must address AI’s role in mathematics education or teacher preparation, including empirical, theoretical, or conceptual work centered on teacher competencies, ethical considerations, or educational equity in AI contexts. Conversely, exclusion criteria filtered out studies published before 2019, non-peer-reviewed materials such as opinion pieces or informal reports, and research outside the mathematics education domain—such as AI applications in other STEM subjects without explicit relevance to mathematics instruction or teacher preparation.

Additionally, works solely focused on student technology use without discussing teacher roles or ethical implications were excluded. This deliberate delineation of criteria ensured that the selected literature provided a comprehensive, relevant, and rigorous foundation for analyzing AI's evolving impact on mathematics education and teacher development. Although a total of 148 publications were identified in the initial search, only 34 of them met the criteria for review.

4.3. Thematic Analysis Procedures

The thematic analysis of the selected literature was undertaken following established protocols for coding, categorizing, and synthesizing qualitative data suggested by Braun and Clarke (2006). The initial step involved data familiarization through repeated, focused readings of the collected literature. This enabled the identification of recurrent themes related to teacher readiness, competency frameworks, equity, ethics, and institutional support. Subsequently, methodical coding was applied whereby textual segments pertinent to these topics were assigned descriptive labels. These initial codes were then organized and collated into broader conceptual clusters based on emerging patterns and relationships across the datasets.

The identified clusters were reviewed and refined through an iterative process to guarantee coherence and relevance to the research questions. Themes were then articulated and named to accurately reflect their core meanings and the nuanced interrelationship of the data. The process culminated in seven inter-related themes: AI competency frameworks and teacher roles; equity, access and inclusion; ethics and challenges in AI implementation; mitigating bias and promoting fairness; institutional and policy support; and impact on pedagogy and assessment. This methodical and reflective approach offered a comprehensive, meaningful thematic structure that directly addressed the focus of the study. Table 2 outlines the study's thematic coding approach.

Table 2: Summary of thematic coding approach followed in the study

Theme	Code(s)	Description	Sample References
Teacher readiness and professional development	TR, PD	Teachers' preparedness, willingness, and need for ongoing, context-sensitive training for AI	Ayanwale et al., 2022 Wang et al., 2023 Mouta et al., 2025
AI competency frameworks and teacher roles	CF, ER	Frameworks outlining AI-related knowledge/skills and the evolving roles of teachers	Cukurova & Miao, 2024 Chiu et al., 2024 Shen & Su, 2020
Equity, access and inclusion	EQ, IN	AI's potential and risks for bridging or widening educational gaps; inclusive practices	Kohnke & Zaugg, 2025 Pagliara et al., 2024 Sato et al., 2024
Ethics and challenges in AI implementation	ET, CH	Core ethical concerns (privacy, transparency, accountability) and implementation challenges	Adams et al., 2023 Nguyen et al., 2023 Peterson, 2024

Mitigating bias and promoting fairness	MB, FR	Strategies for identifying and reducing algorithmic/systemic bias, ensuring fairness	Lin et al., 2021 Roshanaei, 2024 Sato et al., 2024
Institutional and policy support	IP, PS	Role of policy, leadership, and systemic support in sustainable, ethical AI integration	Engelbrecht & Borba, 2024 Karsenti, 2019 Kayyali, 2025
Impact on pedagogy and assessment	PA, AS	How AI transforms teaching strategies, assessment, and classroom dynamics in mathematics	Engelbrecht & Borba, 2024 Gabriel et al., 2025 Madaan et al., 2025

Legend: * TR: Teacher Readiness * PD: Professional Development * CF: Competency Framework * ER: Evolving Roles * EQ: Equity * IN: Inclusion * ET: Ethics * CH: Challenges * MB: Mitigating Bias * FR: Fairness * IP: Institutional Policy * PS: Policy Support * PA: Pedagogy * AS: Assessment

Table 2 reflects the seven primary themes derived from the reviewed sources. Each theme was associated with representative codes, concise descriptions, and illustrative references from the research base. This coding system allowed for transparency and analytical rigor, supporting a systematic synthesis of findings across multiple studies (Ayanwale et al., 2022; Cukurova & Miao, 2024).

5. Discussion of Thematic Findings

AI integration in mathematics education is rapidly revolutionizing pedagogical practices, teacher roles, and student learning experiences (Gabriel et al., 2025; McGlone et al., 2025). As AI-powered technologies gain a wide presence in mathematics classrooms, there is an imperative to understand how they impact teaching effectiveness, equity, and ethics in mathematics instruction (Adams et al., 2023; Holstein & Doroudi, 2022).

Recent research has revealed both the transformative potential and challenges of AI adoption, especially teacher preparedness and the need for comprehensive competency frameworks addressing technical, pedagogical, and ethical domains (Filo et al., 2024; Mikeladze et al., 2024). This review examined key studies and frameworks informing mathematics teacher preparation for AI-era requirements, focusing on equity, inclusion, and responsible technology use in diverse contexts (Cukurova & Miao, 2024; Eden et al., 2024; Zreik, 2024). The next section synthesizes key thematic findings from current research, illustrating the evolving demands on teachers and the multifaceted considerations necessary for effective, equitable, and ethical AI implementation in mathematics classrooms (Adams et al., 2023; Cukurova & Miao, 2024).

5.1. Teacher Readiness and Professional Development for AI Integration

Teacher readiness recurs in research, capturing both enthusiasm and apprehension toward AI integration in mathematics education. Studies suggest that while many teachers appreciate AI for enriching instruction, insufficient professional development and institutional support often impedes effective adoption (Ayanwale et al., 2022; Wang et al., 2023). Teacher readiness is shaped by prior exposure to technology, self-efficacy, and access to ongoing training

opportunities. By engaging in professional development programs that are collaborative, context-sensitive, and reflective, teachers gain vital skills for handling the complexities presented by AI-enhanced classrooms (Mouta et al., 2025). These findings underline the essence of systemic efforts that foster teacher capacity building, curriculum reform, and resource support, to equip teachers for effective incorporation of AI tools in diverse mathematics classrooms (Heafner & Ziv, 2024; Karsenti, 2019).

5.2. AI Competency Frameworks and Evolving Teacher Roles

The introduction of AI Competency Frameworks for Teachers has redefined the expectations placed upon mathematics teachers. Frameworks from UNESCO and other bodies outline essential domains, including technical skills, pedagogical adaptation, and ethical accountability (Chiu et al., 2024; Cukurova & Miao, 2024). These frameworks emphasize that teachers should go beyond being proficient with AI tools to incorporating them thoughtfully into instructional design and classroom practices.

Research points to a transition in teacher responsibilities from knowledge transmitters to facilitators, instructional designers, and ethical custodians of AI-mediated learning environments (Filo et al., 2024; Shen & Su, 2020). This evolution obliges teachers to critically evaluate AI's affordances and limitations, encouraging student self-directed learning and ethical digital engagement. As such, competency framework's function both as a benchmark for teacher preparation programs and as a critical direction for professional development, aligning with the requirements of AI-integrated mathematics education (Kim et al., 2021; Mikeladze et al., 2024).

5.3. Access, Inclusion and Equity in AI-facilitated Mathematics Education

AI's role in mathematics education brings both promising possibilities and potential challenges for promoting equity and inclusion. On one hand, AI-enabled adaptive learning platforms can tailor instruction to cater for varied learning needs and reduce achievement gaps for underserved students (Kohnke & Zaugg, 2025; Salas-Pilco et al., 2022). On the other hand, unequal technological access and algorithmic bias may present significant challenges if improperly managed (Lata, 2024; Pagliara et al., 2024).

Literature advocates for culturally sensitive AI design and inclusive approaches that accurately represent the unique experiences and cultural backgrounds of all students (Payadnya et al., 2025). Teachers must actively promote equitable access and ensure ethical use of AI tools to foster fairness and social justice. This highlights the critical need for policy reforms and teacher training focused on equity and inclusion in the AI era (Sato et al., 2024).

5.4. Ethical Principles and Challenges in AI Implementation

The core challenges of AI adoption in mathematics education revolve around ethical measures, with privacy, transparency, and accountability pinpointed as critical concerns (Eden et al., 2024). Numerous studies acknowledge the significance of establishing and adhering to ethical frameworks to safeguard the rights of both students and teachers (Adams et al., 2023; Nguyen et al., 2023).

Teachers must be equipped to confront ethical dilemmas surrounding data protection, algorithmic fairness, and possible unforeseen consequences arising from AI usage (Peterson, 2024). Several studies support participatory and inclusive approaches to policy development that engage teachers, students, and community members in determining AI ethics in education (Flores-Viva & García-Peñalvo, 2023). Effectively confronting these challenges calls for continuous teacher training, strong institutional support, and clear ethical frameworks for AI implementation in mathematics classrooms (Kayyali, 2025).

5.5. Minimizing Bias and Promoting Fairness in AI Systems

Reducing bias in AI applications is vital to achieve diversity and fairness in mathematics education. Research cautions that AI algorithms may want to perpetuate or amplify existing social and educational biases, particularly when based on unrepresentative data (Lin et al., 2021; Roshanaei, 2024). Recommended practices for bias reduction include leveraging heterogeneous datasets, maintaining transparent algorithmic processes, and conducting routine reviews of AI technologies (Sato et al., 2024).

Teachers must receive training to recognize and counteract bias, both in AI-generated outputs and their own instructional practices (Cheng, 2025). Literature also stresses the importance of institutional policies and collaborative efforts that promote fairness, equity, and inclusion throughout all AI integration stages in education (Filo et al., 2024; Holstein & Doroudi, 2022).

5.6. Institutional and Policy Support for Sustainable AI Integration

Sustaining AI integration in mathematics education depends fundamentally on robust institutional and policy support. Studies highlight efficient leadership, dedicated resource allocation, and clear implementation guidelines as key factors that facilitate both effective and ethical AI adoption (Engelbrecht & Borba, 2024; Karsenti, 2019). Research further emphasizes that policies must comprehensively address issues of equitable access, targeted professional training, and mechanisms for accountability to ensure that all teachers and students can benefit from AI technologies (Kayyali, 2025; Mikeladze et al., 2024).

Additionally, institutions play a crucial role in creating an innovative environment by providing ongoing professional development opportunities and encouraging collaboration among teachers, policymakers and technology developers (Heafner & Ziv, 2024). These combined measures are critical to overcoming barriers to AI adoption and sustaining its positive impact on teaching and learning processes (Cukurova & Miao, 2024N).

5.7. Impact of AI on Mathematics Pedagogy and Assessment

AI is transforming mathematics pedagogy and assessment by enabling personalized, data-driven, and adaptive learning experiences (Madaan et al., 2025; Mukhibin et al., 2023). The literature highlights how AI tools can support differentiated instruction, formative assessment, and real-time feedback, thereby enhancing student engagement and achievement (Engelbrecht & Borba, 2024; Gabriel et al., 2025). However, these innovations demand that teachers adapt their instructional strategies and deepen their assessment literacy, carefully balancing

technological capabilities with pedagogical integrity (Madaan et al., 2025). They further stress the essentiality of more research and professional development programs to support teachers in integrating AI competently into curriculum design, assessment practices, and classroom management to make AI a facilitator of deeper mathematical understanding rather than a substitute for effective teaching (McGlone et al., 2025; Mukhibin et al., 2023).

5.8. Reflections on Thematic Findings

The thematic findings indicate that preparing mathematics teachers for the AI era requires a holistic, collaborative approach that addresses readiness, competency development, equity, ethics, and sustained institutional support. The literature highlights AI integration as offering both transformative opportunities and complex challenges, reinforcing the critical role of ethical frameworks, focused professional learning, and comprehensive competency development (Adams et al., 2023; Cukurova & Miao, 2024; Filo et al., 2024).

Resolving issues of bias, inclusion, and teacher agency entails establishing ongoing cooperation among teachers, policymakers, and technology developers (Engelbrecht & Borba, 2024). These insights expose gaps in current teacher preparation programs and affirm the need for frameworks that encompass technical, pedagogical, and ethical domains – ultimately advancing the agenda of preparing teachers for evolving classroom requirements (Nguyen et al., 2023).

Explaining these findings through the integrated application of Activity Theory and AI Competency Framework for Teachers reveals both alignment with existing theory and significant areas of unresolved tensions warranting critical reflection. Activity Theory emphasizes the interdependence of subjects (teachers), mediating tools (AI technologies), governing rules, and the broader community for meaningful transformation (Abboud et al., 2018; Engeström, 1987).

Yet, the findings indicate that teacher readiness (Theme 1) frequently develops ahead of institutional and policy support (Theme 6), creating imbalances within the activity system that hinder sustained change. Professional development opportunities, for example, are sometimes fragmented and poorly connected with school-level policies or assessment reforms (Theme 7), leaving teachers unsure of how to apply AI in pedagogically sound and ethically responsible ways (Theme 4). Similarly, equity and inclusion goals (Theme 3) are compromised by uneven access to AI infrastructure, undermining Activity Theory's principle that tools should facilitate learning equitably across all students.

Furthermore, examining the findings against AI Competency Frameworks for Teachers presents another layer of complexity. While the frameworks precisely articulate technical, pedagogical, and ethical capacities that teachers must cultivate (Cukurova & Miao, 2024; Filo et al., 2024), they implicitly assume that schools already possess the infrastructure and systemic supports to make these competencies attainable.

Additionally, teachers struggle with mitigating algorithmic bias (Theme 5) and upholding ethical principles (Theme 4) without clear guidelines or shared institutional protocols, thus shifting systemic responsibilities to individuals. Moreover, the frameworks highlight the importance of teachers' evolving roles (Theme 2), yet the findings indicate that role redefinition is often accompanied by increased workload and cognitive burden, suggesting that teacher agency may be compromised rather than enhanced.

Together, these comparative insights demonstrate that a holistic approach to AI integration in mathematics education must move beyond building individual competencies to reconfiguring institutional structures, policies, and collaborative networks. Only by aligning teacher preparation programs, supportive policies, and equitable infrastructure can AI's pedagogical potential (Theme 7) be realized in a sustainable, inclusive, and ethically robust manner.

6. Synthesizing Findings for Precise Answers to the Research Questions

The thematic insights from the literature shed light on AI's impact on mathematics education and the evolving demands placed on teachers. The following section consolidates these insights to directly respond to the study's research questions.

6.1. RQ-1: How can AI integration in mathematics education foster equity and reduce systemic bias?

AI integration in mathematics education presents significant opportunities for advancing equity and reducing systemic bias, provided that implementation is consciously designed and closely monitored. Studies highlight that AI-enabled adaptive learning systems can personalize instruction, allowing teachers to meet diverse learning needs and bridge achievement gaps for marginalized students (Kohnke & Zaugg, 2025; Salas-Pilco et al., 2022). However, the literature also cautions that if the AI systems are built on biased data or lack cultural responsiveness, they may inadvertently reinforce existing disparities (Lin et al., 2021; Pagliara et al., 2024).

In light of this, effective integration warrants that teachers be equipped with the skills to critically evaluate AI tools, recognize potential sources of bias, and advocate for equitable access to technology (Cheng, 2025; Payadnya et al., 2025). Additionally, institutional policies must support inclusive practices and make sure AI is leveraged as a catalyst for social justice rather than perpetuating inequity (Sato et al., 2024).

6.2. RQ-2: What competencies do teachers need for ethical AI use in inclusive mathematics instruction?

The literature consistently underscores the necessity for a comprehensive set of teacher competencies to enable ethical and inclusive adoption of AI in mathematics classrooms. Competency frameworks developed by UNESCO and other similar organizations emphasize three core domains: technical proficiency with AI tools, pedagogical adaptation for AI-mediated instruction, and ethical consciousness to guide responsible technology use (Chiu et al., 2024; Cukurova & Miao, 2024). Teachers are expected to possess critical data literacy, the capacity to

interpret and act on AI-generated insights, and the skills to create inclusive, culturally responsive learning environments (Filo et al., 2024; Kim et al., 2021).

Furthermore, professional development programs should promote reflective practice, teacher agency, and collaboration to address the dynamic challenges of AI integration (Heafner & Ziv, 2024; Mouta et al., 2025). By equipping teachers with these competencies, educational systems can deliver quality mathematics instruction while ethically managing AI technologies.

6.3. RQ-3: What ethical principles should be adopted for AI design and deployment in mathematics classrooms to protect student privacy, promote fairness, and uphold teacher and student rights?

Ethical standards are foundational to the responsible AI design and deployment in mathematics education. The literature identifies key principles – transparency, privacy, accountability, inclusivity, and fairness – as essential for protecting the rights of students and teachers (Adams et al., 2023; Nguyen et al., 2023). Teachers must be prepared to navigate ethical dilemmas around data privacy, algorithmic decision-making, and the unintended consequences of using AI (Eden et al., 2024; Peterson, 2024).

Participatory approaches that involve teachers, students, and communities in the development of ethical guidelines are recommended to ensure relevance and trust (Flores-Viva & García-Peñalvo, 2023). In addition, ongoing professional learning and institutional support are necessary to keep pace with evolving ethical standards and technological advancements (Kayyali, 2025). Emphasizing these principles enable mathematics teachers to utilize AI effectively while upholding equity and human dignity.

7. Implications of the Study for Policy and Practice

This study contributes to mathematics education in the AI era essentially across three domains: instructional quality, curriculum design, and scholarly inquiry.

- The findings demonstrate that embedding AI literacy, ethical reasoning, and inclusive pedagogy in teacher preparation strengthens instructional quality. They also stress the importance of sustained professional development to support teachers in adapting responsibly to technological change (Ayanwale et al., 2022; Karsenti, 2019; Wang et al., 2023).
- By identifying the competencies teachers require for ethical and effective AI use, the study offers a framework for reforming teacher education and mathematics curricula. It further highlights the value of equity-focused, culturally responsive AI tools in reducing systemic bias and expanding student access (Cheng, 2025; Cukurova & Miao, 2024; Payadnya et al., 2025).
- The study combines Activity Theory with AI competency frameworks, offering a new analytical perspective on pedagogy, technology, and ethics. It also articulates guiding ethical principles – privacy, fairness, and accountability – that open new avenue for scholarly debate and empirical research (Abboud et al., 2018; Adams et al., 2023; Nguyen et al., 2023).

8. Conclusion and Recommendations

This conceptual study has synthesized a wide range of research on AI integration in mathematics education, stressing the urgent need for teacher readiness, robust AI competency frameworks, and the prioritization of equity and ethics. Thematic findings reveal that, while AI tools have the potential to personalize instruction and reduce systemic bias, its success is contingent on teachers' capacity to critically evaluate, ethically implement, and inclusively adapt them.

Furthermore, institutional support, continuous professional development, and clear ethical guidelines are essential for maximizing AI's positive impact in mathematics classrooms. By reviewing recent literature and synthesizing thematic findings, this study has enriched understanding of the evolving responsibilities teachers face in the AI era. It stresses the importance of integrating ethical, technical, and pedagogical competencies into teacher preparation programs and policy frameworks.

The study also provides practical recommendations for fostering equity and inclusion through AI, offering a foundation for future curriculum design, institutional policy, and professional learning initiatives in mathematics education. While this conceptual study has drawn extensively on international research works, it is restricted by its reliance on published literature and the absence of primary empirical data. Contextual factors, such as differences in infrastructure, policy contexts, and cultural responsiveness, may influence the findings' generalizability.

Future inquiries should focus on mathematics teachers' firsthand experiences with AI, conduct longitudinal evaluations of professional learning outcomes and engage diverse educational stakeholders in the joint formulation of ethical guidelines. Expanding these research areas will strengthen the foundation for responsible and effective AI usage in mathematics education.

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