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A suggested Model to employ AI tools in Math teaching for secondary schools

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Abstract

This study aimed to design and validate a proposed model for employing Artificial Intelligence (AI) tools in mathematics teaching for secondary schools. The model seeks to enhance teaching and learning practices by integrating intelligent systems that support adaptive instruction, data-driven feedback, and problem-solving skills. It responds to the growing demand for innovative approaches that align mathematics education with twenty-first-century learning environments. The model was developed based on educational technology frameworks and pedagogical theories, integrating constructivist, cognitive, and communicative approaches. It consists of four main domains: Inputs, Processes, Outputs, and Evaluation & Continuous Improvement. The *Inputs* domain identifies the human, technical, and curricular resources necessary for AI integration. The *Processes* domain focuses on designing and implementing AI-supported learning activities. The *Outputs* domain reflects the enhancement of students' mathematical understanding, engagement, and creativity. Finally, the *Evaluation & Continuous Improvement* domain ensures sustainability and ethical use of AI through ongoing feedback and performance assessment. Expert validation of the model revealed a high level of agreement (M = 87.03%), indicating its suitability, coherence, and applicability in mathematics education. The study concludes that the proposed model provides a practical and adaptable framework for integrating AI tools to support personalized learning and enhance teaching effectiveness. It further recommends adopting the model to guide curriculum development, teacher training, and policy-making aimed at preparing students for an AI-driven educational future.

Keywords: Artificial Intelligence tools, Mathematics Education, Educational Technology, Secondary Schools.

1. Introduction

Mathematics is a foundational discipline that plays a vital role in both education and everyday life, as it develops individuals' problem-solving abilities, enhances their quantitative literacy, and equips them to navigate an increasingly complex and data-driven world (Nzeadibe et al., 2020). Mathematics fosters mental discipline and is essential in numerous everyday activities. It serves as a cornerstone of education, offering a structured way to interpret the world and equipping individuals with the knowledge and skills needed for diverse academic and professional pathways (Mary et al., 2022).

Mathematics teaching in secondary schools is evolving, with research highlighting a shift from traditional lecture-based methods to more student-centered, innovative, and competency-driven approaches. Effective teaching now emphasizes problem-solving, real-world applications, and the development of core mathematical competencies to better engage students and improve learning outcomes (Oribhabor, 2020).

Enhancing students' mathematics achievement demands a comprehensive strategy (Etcuban et al., 2019), which involves personalized instruction, effective pedagogical approaches, a supportive classroom atmosphere, and opportunities for independent learning (Anshori, 2020). Promoting positive attitudes toward mathematics and integrating practical, real-world experiences further improve students' engagement and outcomes (Arthur et al., 2022). To strengthen mathematical proficiency, teachers should diagnose and bridge learning gaps, employ varied instructional methods, define clear goals, make lessons relevant, encourage active participation, provide sufficient practice, give constructive feedback, cultivate critical thinking, use formative assessments, foster a growth mindset, supply additional resources, maintain a supportive environment, set achievable expectations, integrate technology purposefully, adapt teaching based on progress, and promote self-reflection (Khadjieva & Khadjikhanova, 2019). Collectively, these approaches enable educators to build dynamic, motivating learning environments that help students excel in mathematics—with particular emphasis on the effective integration of technology in teaching and learning.

Digital technology, such as interactive software and online resources, can improve student engagement and facilitate differentiated instruction and comprehension in mathematics. (Okisai & Sripathi, 2025). Integrating computer technology in higher mathematics education significantly improves students' academic performance and fosters positive attitudes towards mathematics, leading to greater engagement and improved understanding of complex concepts (Alali & Wardat, 2024), AI is impacting a wide range of fundamental sciences especially IN mathematics, promoting the growth of novel applications and fueling the sustainable booming of AI. AI then uses these technical advancements to evaluate data, learn from it, and arrive at wise judgements or predictions (Xu et al., 2021) They collaborate to drive the development of intelligent systems with wide-ranging applications across different domains. In education, particularly in mathematics, AI is increasingly being integrated to enrich teaching and learning experiences (McGrath ET AL., 2023; Seo ET AL., 2021)

Artificial intelligence (AI) tools are rapidly reshaping the landscape of mathematics education by introducing innovative ways to personalize instruction, deliver real-time feedback, and support both teachers and learners in achieving deeper mathematical understanding. These technologies encompass a wide spectrum of applications—from intelligent tutoring systems that provide step-by-step guidance, to adaptive learning platforms that adjust content according to individual learners' progress, and generative AI models such as ChatGPT that facilitate interactive problem-solving and explanation-based learning (Li & Manzari, 2025; Elmaadaway et al., 2025). Through such tools, mathematics instruction can become more engaging, responsive, and data-informed, ultimately improving students' performance and motivation. However, despite these promising benefits, educators continue to encounter challenges in effectively integrating AI into classroom practice. Teachers must navigate issues related to time constraints, workload management, technological readiness, and the need for adequate training to ensure that AI-based solutions are used meaningfully rather than mechanically (Wardat et al., 2024). Thus, while AI holds great potential to revolutionize mathematics education, its successful implementation requires thoughtful pedagogical planning, institutional support, and ongoing professional development for teachers.

2. Study problem

In recent years, the rapid advancement of artificial intelligence (AI) has highlighted its growing importance in transforming education, particularly in the teaching and learning of mathematics. With the increasing demand for innovative instructional approaches that enhance students' engagement, problem-solving skills, and conceptual understanding, integrating AI tools into math classrooms has become a pressing necessity. Many schools, however, continue to face challenges in effectively implementing AI-driven technologies due to limited technical infrastructure, insufficient teacher training, and the absence of clear pedagogical frameworks. This situation underscores the need for a comprehensive model that guides the employment of AI tools in mathematics instruction at the secondary level. Hence, the research problem can be formulated as follows: *How can an effective model be designed to guide the integration of AI tools in mathematics teaching in secondary schools?*

3. Study objectives

The primary objective of this study is to develop a suggested model for employing AI tools in mathematics teaching in secondary schools through the following sub-objectives:

1. Identifying the fundamental features and pedagogical requirements of AI-based math teaching at the secondary level.
2. Reviewing existing models and frameworks related to AI integration and technology-enhanced instruction in mathematics education.
3. Proposing a comprehensive model for the effective employment of AI tools in math teaching in secondary schools.
4. Validating the proposed model through expert review and feedback from specialists in mathematics education and educational technology.
5.

4. Literature review

Systematic reviews confirm that artificial intelligence in education (AIEd) has evolved from early proof-of-concept systems to a robust ecosystem encompassing adaptive learning platforms, intelligent tutoring systems (ITS), automated assessment engines, and conversational agents. These technologies now provide personalized, data-driven support for both learners and educators across K-12 and higher education settings (Zawacki-Richter et al., 2019; Chen et al., 2020). AI's potential for scalable personalization and analytics is well-documented, but its educational value depends on integration with sound pedagogical frameworks. Studies consistently find that AI tools—such as adaptive learning systems, intelligent tutoring, and automated assessment—only improve learning outcomes when their use aligns with established educational theories and curriculum goals. Without this alignment, AI risks becoming a superficial add-on rather than a transformative force (Karroum & Elshaiekh, 2025)

Intelligent tutoring systems have the longest evidence base among AIEd tools in mathematics. Meta-analytic and systematic studies report generally positive but variable effects of ITS on-mathematics learning effects tend to be larger when ITS interventions are well-integrated into curricula, target specific skills, and include teacher facilitation (Steenbergen-Hu & Cooper, 2013; Koedinger et al., 2013).

Intelligent Tutoring Systems (ITS) have the most extensive research base among AI tools in mathematics education. Meta-analyses and systematic reviews consistently report positive, though variable, effects on mathematics learning. Effect sizes range from small to moderate, with ITS interventions typically outperforming traditional classroom instruction, textbooks, and non-adaptive computer-based tools, but showing similar or slightly lower effectiveness compared to individualized human tutoring (Yi et al., 2024; Huang et al., 2025)

Recent reviews of mathematics Intelligent Tutoring Systems (ITS) and adaptive systems highlight advances in student modeling, diagnosis of misconceptions, and scaffolding strategies, but also note persistent limitations in research scale and long-term impact assessment (Harrison & Roberts, 2021), Multiple meta-analyses confirm that ITS use leads to significant, though often modest, improvements in mathematics achievement compared to traditional instruction, with effect sizes ranging from small to moderate (Yi et al., 2024; Kulik & Fletcher, 2016), Gains are most pronounced for procedural skills and structured problem-solving tasks (Paladines & Ramírez, 2020)

Adaptive learning platforms that leverage machine learning to sequence content and tailor tasks to individual learners show strong promise for improving both engagement and retention in mathematics (Xu, 2025). Recent reviews of mathematics Intelligent Tutoring Systems (ITS) and adaptive systems highlight advances in student modeling, diagnosis of misconceptions, and scaffolding strategies, but also note persistent limitations in research scale and long-term impact assessment (Harrison & Roberts, 2021), AI-driven personalization delivers significant learning gains even in low-resource and large-scale educational settings, including via conversational tutors on messaging apps (Henkel et al., 2024), Yet authors caution about variability in algorithms, transparency of adaptation logic, and the need to validate models across diverse curricula and populations (Saeed & Omlin, 2021).

The recent advent of powerful generative models (large language models) has created novel opportunities for mathematical explanation, worked examples, and dialogic problem solving. Initial studies comparing AI responses to student answers indicate that generative models can effectively handle well-structured tasks and provide stepwise explanations, but they may struggle with nuanced proofs, deep conceptual tasks, or domain-specific pedagogy unless carefully constrained and supervised (Ye et al., 2024; Fang et al., 2024), Consequently, generative AI is most useful when used as a scaffold or tutor that operates under teacher guidance and in human-in-the-loop workflows to check correctness and pedagogical appropriateness (Elmaadaway et al., 2025; Alali et al., 2024).

Teacher beliefs, preparation, and workload are decisive factors for successful AI adoption. Numerous recent studies document that teachers appreciate AI's potential for personalized feedback and reduced marking load but express concerns about insufficient training, time to learn new tools, and trustworthiness of AI outputs (Ofem et al., 2025). Policy reports and media coverage have also emphasized the need for AI tools designed specifically to reduce teacher workload and for government/organizational support to supply high-quality training and vetted curriculum resources for model training (Funa & Gabay, 2025). Without sustained professional development and institutional incentives, AI interventions risk being underused or misapplied in mathematics classrooms (Meylani & Kutluca, 2025).

Equity concerns with AI in education are pervasive and multifaceted, centering on access disparities, algorithmic bias, and the risk of amplifying existing educational inequalities. (Alzahrani , 2024), Some rigorous field studies indicate that AI-supported tutoring can help narrow achievement gaps when thoughtfully implemented (e.g., ALEKS evaluations and hybrid human-AI models), but transferring such gains to under-resourced secondary schools requires attention to infrastructure, teacher capacity, and culturally relevant content (Lin et al., 2023; Fang et al., 2018; Henkel et al., 2024).

A growing subfield focuses on using AI to detect student misconceptions and provide targeted formative feedback. Recent benchmark studies demonstrate that AI can reliably identify common algebraic misconceptions when trained and validated with teacher-annotated datasets, enabling automated, timely remediation (Otero et al., 2024; Cosentino et al., 2025). However, the literature stresses the necessity of human oversight: high precision in classification improves when educators are in the loop to validate labels and tune interventions (Te'eni et al., 2023).

The literature points to several gaps that a contextually grounded model should address: (a) most rigorous studies are still short-term or limited in scale—longitudinal, year-long trials in secondary mathematics are scarce; (b) the teacher's mediating role and professional development requirements are insufficiently operationalized in many frameworks; (c) equity and local curricular alignment need prioritization to avoid widening disparities; and (d) the integration of generative AI requires robust guardrails for accuracy, plagiarism, and pedagogical fit (Elnaggar & Sharaf, 2022; Ye et al., 2024, 2025; Monib et al., 2024). These gaps justify the development of a comprehensive, teacher-centred model for employing AI tools in secondary mathematics that specifies technology selection, pedagogical strategies, teacher training, ethical safeguards, and mechanisms for continuous evaluation.

5. Methodology

Given the dynamic, interrelated, and interdependent nature of integrating Artificial Intelligence (AI) tools in mathematics teaching, this research adopted a system-based approach to develop a comprehensive model for employing AI tools in secondary school math instruction. Mejía-Rodríguez & Kyriakides (2022) and Khani et al (2023) summarized the system-based approach in two words—analysis and synthesis—where analysis involves identifying the key components of the system and understanding their interrelationships, while synthesis refers to designing an integrated structure capable of addressing the identified educational needs. Similarly, Lui et al (2025) described the system-based approach as a process through which educational needs are diagnosed, solutions are selected from a range of alternatives, implementation strategies are determined, and feedback is continuously utilized for improvement.

Accordingly, the proposed model was structured around four key components: inputs, processes, outputs, and feedback loops. This systemic perspective ensured that the model accounted for all essential elements influencing the effective employment of AI tools in mathematics education, including technological infrastructure, pedagogical strategies, teacher competencies, and student learning outcomes.

Additionally, thematic analysis was employed as the qualitative analytical method to analyze experts' views and comments regarding the model. As Braun and Clarke (2008) note, "Through its theoretical freedom, thematic analysis provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data."

An inductive approach guided the identification of the fundamental components and features of the proposed AI-based math teaching model. Expert feedback and qualitative data were analyzed following the six phases of thematic analysis developed by Braun and Clarke (2008), which include familiarization with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report.

Model Validation

An analytic questionnaire was designed on the basis of the components of the proposed model.

Although the proposed model has not yet advanced to the implementation and evaluation stages, it was validated through a structured questionnaire reviewed by a panel of experts. The panel included representatives from the Ministry of Education, school leadership, e-learning specialists, and mathematics experts and teachers from Egypt, Qatar, Saudi Arabia, and Bahrain.

The questionnaire, distributed electronically via Google Forms, was sent to 50 experts using a convenience sampling approach. Participants were recruited through professional, academic, and personal networks to ensure diversity in perspectives. The selection aimed to include individuals from different cultural backgrounds and administrative levels within schools, as well as stakeholders from related sectors such as ministries, policy-making bodies, and IT organizations involved in e-learning support — thus ensuring comprehensive feedback on the model.

A total of 25 experts responded, resulting in a 50% response rate. They were asked to assess the importance of each domain, dimension, and item in the model using a five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree). The percentage of agreement was then calculated for each item, dimension, domain, and for the model as a whole.

Students' perspectives were derived from recent research exploring their experiences and expectations regarding the integration of artificial intelligence (AI) tools into digital and mathematics learning environments. Studies have shown that students value the use of technology in learning mathematics but emphasize the need for more engaging and interactive methods that promote active participation and deeper conceptual understanding (Boubker, 2023). Learners highlighted the importance of increasing interaction between teachers and students, as well as among peers, to foster collaboration and motivation. They also expressed the need for diverse and attractive instructional strategies that move beyond traditional teaching approaches and help clarify complex mathematical concepts. In addition, students pointed out the importance of providing guidance and tutorials for using AI applications effectively, along with ensuring equitable access to digital resources and stable internet connectivity—factors that directly influence their learning experiences and outcomes.

Similarly, Sakr & Abdullah (2024) emphasized the potential of AI and virtual reality technologies in enhancing self-directed learning, supporting teacher guidance, and reducing instructional costs. They argued that the successful integration of these technologies requires systematic capacity building for teachers and administrators to ensure readiness and sustainability. Developing educators' digital competence, improving infrastructure, and enhancing students' higher-order thinking and problem-solving skills in mathematics are essential steps toward realizing this goal. Other studies (Zouhri & Mallahi, 2024; Ng et al., 2023) highlighted that interactive and intelligent learning environment, supported by reliable infrastructure, adequate digital resources, and continuous technical support, are key factors for effective AI integration in mathematics teaching.

From a leadership perspective, research has shown that educational leaders play a critical role in creating an enabling environment for the adoption of AI tools in schools. They are responsible for ensuring that teachers receive adequate training, that technology infrastructure is continuously upgraded, and that academic standards are maintained alongside innovation. Strategic planning, investment in digital transformation, and fostering collaboration among teachers, students, and policymakers are essential components of successful AI implementation. These insights informed the design of the proposed model, which aims to promote effective, sustainable, and equitable use of AI tools in mathematics teaching at the secondary school level.

6. Results and Discussion:

a) Quantitative analysis

The importance level (%) of the proposed model components were evaluated by the experts using an analytic questionnaire. Findings are summarized in Table (1) and discussed below.

Table 1.

The importance level (%) of the proposed model components as evaluated by experts.

No.	Domain	Importance (%)
I.	**Inputs** The *Inputs* stage encompasses all foundational elements required for the successful integration of AI tools in mathematics teaching. It includes human, technological, curricular, and institutional resources	**88.13%**
I.1.	**Human Resources**	**90.80%**
I.1.1	Teachers equipped with AI literacy, pedagogical expertise, and technological competence	93.60%
I.1.2	Students prepared to engage in AI-supported, inquiry-based, and adaptive learning experiences	88.80%
I.1.3	Technical and administrative teams responsible for AI infrastructure, maintenance, and troubleshooting	88.00%

No.	Domain	Importance (%)
I.1.4	Curriculum designers ensuring AI integration aligns with national learning standards and math competencies	89.60%
I.1.5	Teacher trainers and instructional coaches providing ongoing professional development in AI pedagogy.	95.20%
I.1.6	Educational leaders and policymakers supporting strategic implementation and ethical use of AI tools	89.60%
I.2.	**Technological Infrastructure**	**87.33%**
1.2.1	AI-based learning platforms such as ChatGPT, Mathway, GeoGebra AI, and Wolfram Alpha for dynamic problem solving	88.80%
1.2.2	Learning Management Systems (LMS) integrated with analytics and adaptive feedback (e.g., Moodle with AI plugins)	90.40%
1.2.3	Hardware and connectivity including tablets, laptops, smartboards, and stable internet access for all students	79.20%
1.2.4	Cloud storage and data environments ensuring security, accessibility, and interoperability of learning data	88.80%
1.2.5	AI analytics dashboards for tracking performance, engagement, and personalized learning trajectories	87.20%
1.2.6	Assistive technologies supporting students with learning difficulties or special educational needs	89.60%
I.3.	**Curricular and Instructional Resources**	**86.27%**
I.3.1	Curriculum frameworks aligned with AI-enhanced learning objectives and 21st-century skills	88.80%
I.3.2	AI-supported learning materials, such as intelligent problem generators, virtual manipulatives, and simulations	84.80%
I.3.3	Adaptive assessment instruments designed for automated grading and feedback personalization	89.60%
I.3.4	Digital repositories of AI-enhanced tasks and exemplars linked to mathematical standards	89.60%
I.3.5	Lesson templates and blueprints demonstrating effective AI integration in different mathematical domains (e.g., algebra, geometry, statistics)	80.00%
I.3.6	Ethical and digital literacy content embedded into the math curriculum to foster responsible AI use	84.80%
2.	**Processes** The *Processes* stage represents the systematic procedures and pedagogical actions through which AI is integrated into teaching, learning, and classroom management	**85.65%**
2.1.	**Instructional Design**	**86.00%**
2.1.1	Align learning objectives with AI functionalities that promote conceptual understanding and problem-solving	77.60%

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No.	Domain	Importance (%)
2.1.2	Adopt design frameworks such as TPACK and SAMR to integrate AI meaningfully into lesson planning	90.40%
2.1.3	Identify suitable AI tools for specific mathematical skills (e.g., visualization, computation, reasoning)	89.60%
2.1.4	Develop adaptive lesson plans incorporating AI feedback loops and formative assessments	89.60%
2.1.5	Design differentiated instruction supported by AI algorithms for personalized learning paths	88.80%
2.1.6	Incorporate real-world data and modeling tasks supported by AI analysis to enhance mathematical relevance	80.00%
2.2.	**Teaching and Learning Implementation**	**86.29%**
2.2.1	Facilitate adaptive learning through AI systems that adjust difficulty and content based on performance	79.20%
2.2.2	Use Intelligent Tutoring Systems (ITS) to provide step-by-step guidance and instant feedback	88.80%
2.2.3	Employ AI chatbots or digital assistants to answer students' mathematical inquiries in real time	87.20%
2.2.4	Integrate gamified AI applications to increase motivation and engagement in math learning	82.40%
2.2.5	Encourage collaborative learning through AI-driven discussion forums and shared problem-solving tools	87.20%
2.2.6	Blend AI-supported learning with traditional instruction to create hybrid, student-centered classrooms	89.60%
2.2.7	Foster inquiry-based exploration using AI simulations and predictive modeling tasks	89.60%
2.3.	**Monitoring and Data Management**	**84.67%**
2.3.1	Collect and analyze learning analytics from AI platforms to detect trends, gaps, and misconceptions	77.60%
2.3.2	Apply predictive analytics to anticipate learning challenges and suggest interventions	94.40%
2.3.3	Generate individualized learning reports for teachers and students based on AI data interpretation	89.60%
2.3.4	Track engagement levels and identify at-risk learners for targeted support	71.20%
2.3.5	Ensure data privacy and ethical compliance in all AI-related monitoring practices	87.20%
2.3.6	Use data visualization dashboards to guide instructional adjustments and curriculum refinement	88.00%
3.	**Outputs** The *Outputs* stage focuses on the tangible and intangible outcomes resulting from the integration of AI tools in mathematics classrooms	**86.66%**

No.	Domain	Importance (%)
3.1.	**Student Learning Outcomes**	**86.13%**
3.1.1	Improved conceptual understanding through visual, interactive, and adaptive representations of mathematical ideas	77.60%
3.1.2	Enhanced reasoning, problem-solving, and analytical thinking supported by AI feedback and scaffolding	90.40%
3.1.3	Increased learner engagement through interactive, personalized, and gamified activities	89.60%
3.1.4	Development of self-regulated learning skills as students take ownership of their progress with AI support	88.80%
3.1.5	Greater inclusivity and accessibility for diverse learners through adaptive AI technologies	80.00%
3.1.6	Improved performance on standardized math assessments due to personalized learning paths	90.40%
3.2.	**Teacher Development**	**86.00%**
3.2.1	Enhanced pedagogical skills in using AI tools for differentiated instruction	89.60%
3.2.2	Ability to interpret AI-generated data for formative and summative assessment purposes	77.60%
3.2.3	Increased efficiency in feedback delivery, grading, and student tracking	90.40%
3.2.4	Stronger confidence in integrating technology meaningfully into teaching	89.60%
3.2.5	Participation in AI-focused professional learning communities for ongoing development	88.80%
3.2.6	Innovative instructional design practices informed by data-driven insights	80.00%
3.3.	**Institutional Impact**	**87.84%**
3.3.1	Improved teaching quality through evidence-based and technology-enhanced practices	88.80%
3.3.2	Optimized decision-making supported by analytics and performance tracking	80.00%
3.3.3	Strengthened alignment between institutional goals and digital transformation initiatives	90.40%
3.3.4	Scalable AI-integrated teaching models that can be replicated across subjects and schools	89.60%
3.3.5	Sustainable innovation culture that encourages experimentation and continuous growth	90.40%
4.	**Evaluation and Continuous Improvement** This final stage ensures that AI integration remains adaptive, effective, and evidence-based through regular assessment, stakeholder input, and iterative refinement	**87.68%**
4.1.	**Evaluation**	**87.68%**
4.1.1	Conduct ongoing evaluations of student outcomes, teaching performance, and AI tool efficacy	90.40%
4.1.2	Assess both cognitive and affective learning domains (e.g., motivation, confidence, collaboration)	89.60%
4.1.3	Evaluate AI algorithms for accuracy, fairness, and relevance to educational objectives	88.80%
4.1.4	Review curriculum alignment to ensure AI-supported activities meet learning standards	80.00%

No.	Domain	Importance (%)
4.1.5	Benchmark performance against national or international STEM frameworks	89.60%
4.2.	**Feedback and Reflection**	**87.68%**
4.2.1	Use AI analytics to generate real-time feedback for both teachers and students	89.60%
4.2.2	Facilitate reflective teaching practices using AI dashboards and lesson performance summaries	90.40%
4.2.3	Conduct regular stakeholder consultations (teachers, students, administrators, parents)	89.60%
4.2.4	Incorporate peer review mechanisms to assess the quality of AI-based instructional design	88.80%
4.2.5	Promote reflective journals or portfolios documenting teachers' experiences with AI integration	80.00%
4.3.	**Continuous Improvement**	**87.68%**
4.3.1	Iteratively update AI tools and teaching materials based on feedback and new research	89.60%
4.3.2	Integrate insights from evaluation into teacher training and curriculum development	90.40%
4.3.3	Promote innovation cycles where AI strategies are tested, revised, and redeployed	89.60%
4.3.4	Establish long-term partnerships with EdTech developers to sustain system updates	88.80%
4.3.5	Ensure sustainability and scalability through policy support, training, and continuous investment	80.00%
Total Percentage		**87.03%**

As shown in Table (1), the Inputs domain ranked as the most important component of the proposed model, achieving a relative importance level of 88.13%. Within this domain, the Human Resources dimension recorded the highest value (90.80%), emphasizing the central role of teachers' AI literacy, pedagogical expertise, and continuous professional development (95.20%), followed by students' preparedness for AI-supported learning (88.80%), and the contribution of curriculum designers, administrators, and policymakers to ensure strategic and ethical implementation (ranging between 88.00% and 89.60%). The Technological Infrastructure dimension followed with 87.33%, highlighting the necessity of AI-based platforms such as ChatGPT, Mathway, and GeoGebra AI, integrated LMS analytics, and assistive technologies that promote accessibility. Meanwhile, the Curricular and Instructional Resources dimension achieved 86.27%, underscoring the importance of AI-aligned curricula, adaptive assessments, and ethical AI literacy within mathematics education.

The Processes domain ranked second with an overall importance of 85.65%, reflecting the model's operational mechanisms for embedding AI into instructional practice. The Instructional Design dimension (86.00%) stressed the alignment of learning objectives with AI capabilities and the adoption of frameworks such as TPACK and SAMR. The Teaching and Learning Implementation dimension (86.29%) emphasized adaptive, collaborative, and inquiry-based learning experiences supported by AI-driven tutoring systems, chatbots, and simulations. The Monitoring and Data Management dimension (84.67%) highlighted the role of predictive analytics (94.40%) and ethical data monitoring for refining instructional strategies.

The Outputs domain followed with an importance level of 86.66%, representing the tangible educational impacts of AI integration. Within this domain, Student Learning Outcomes (86.13%) included enhancements in reasoning, problem-solving, engagement, and inclusivity. The Teacher Development dimension (86.00%) reflected growth in pedagogical innovation, feedback efficiency, and participation in AI-focused professional communities. Furthermore, the Institutional Impact dimension (87.84%) underscored evidence-based decision-making, sustainable innovation, and the scalability of AI-integrated practices across educational contexts.

Finally, the Evaluation and Continuous Improvement domain achieved 87.68%, ensuring the model's sustainability and adaptability. It encompasses three interrelated dimensions: Evaluation, focusing on assessing learning outcomes, AI performance, and curriculum alignment; Feedback and Reflection, emphasizing data-informed instructional reflection and stakeholder collaboration; and Continuous Improvement, promoting iterative enhancement, innovation cycles, and long-term partnerships for sustaining AI integration. The total mean agreement of the model reached 87.03%, reflecting a high level of consensus on its validity, comprehensiveness, and applicability in guiding effective AI integration in mathematics teaching at the secondary school level.

b) Qualitative analysis:

Based on the thematic analysis approach, data were coded and clustered into major themes and sub-themes reflecting expert feedback on the proposed model for employing AI tools in mathematics teaching at the secondary school level. Less frequent or irrelevant codes were discarded. Experts' insights focused on the requirements, enablers, and limitations of the model's domains and dimensions to ensure feasibility, quality, and sustainability.

Thematic analysis revealed six major themes—Context, Learning Approaches, Sustainability, Equity, Quality, and External Efficiency—which correspond to the four stages of the model (*Inputs, Processes, Outputs, and Evaluation & Continuous Improvement*) as follows:

First Stage: Inputs

(Related Themes: Context, Equity, and Quality)

a) Context

Experts emphasized that contextual readiness is foundational for the successful integration of AI tools in mathematics teaching. Stakeholders—including teachers, students, school leaders, parents, and policymakers—must be aware of and involved in planning, resource allocation, and policy formulation to ensure model alignment with national educational priorities. The presence of reliable technological infrastructure (hardware, connectivity, AI-supported platforms) both inside and outside school settings was viewed as critical for equitable model implementation. Institutional policies also need to address data ethics, privacy, and responsible AI use to ensure a trustworthy learning environment.

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d) Equity

Equity considerations emerged as essential within the Inputs stage, as experts cautioned against the digital divide that may arise from unequal access to devices, connectivity, and technical support. They highlighted the need for inclusive design principles, ensuring that AI-based platforms accommodate students with different socioeconomic, linguistic, and cognitive backgrounds. Additionally, experts stressed the importance of gender-sensitive design in AI-generated learning materials to avoid bias or stereotyping. Data analytics systems were recommended to monitor participation, accessibility, and performance trends among diverse learner groups, supporting evidence-based equity policies.

e) Quality (as part of Inputs)

Experts asserted that the quality of initial resources—including teacher training, technological readiness, and curriculum integration—is decisive for the model's effectiveness. Teacher preparation programs should embed AI literacy, ethical awareness, and adaptive pedagogical strategies to ensure competent use of AI tools. Quality assurance mechanisms should also be established for selecting and maintaining AI systems that align with educational objectives, content validity, and accessibility standards.

Second Stage: Processes

(Related Themes: Learning Approaches, Quality, and Sustainability)

c) Learning Approaches

Experts noted that successful implementation of AI in mathematics teaching depends on adopting student-centered, inquiry-based, and competency-oriented learning approaches. AI-driven adaptive systems, intelligent tutoring tools, and predictive analytics should be integrated into lesson design to personalize learning experiences. Theoretical underpinnings such as constructivism, cognitive apprenticeship, and multiple intelligences were seen as necessary for designing AI-supported environments that address diverse learning styles (visual, logical, kinesthetic, and linguistic). Experts further emphasized aligning AI-based tasks with real-world mathematical applications to strengthen students' analytical reasoning and problem-solving competencies.

e) Quality (as part of Processes)

Quality assurance was also viewed as integral to instructional design and classroom implementation. Experts recommended embedding internal review cycles to ensure that AI applications meet pedagogical, cognitive, and ethical standards. They advised that teachers use AI analytics dashboards to continuously assess student performance, engagement, and feedback quality, thereby refining teaching strategies in real time.

c) Sustainability (as part of Processes)

Experts underscored the importance of sustaining the model operationally and institutionally. This involves continuous professional development for teachers, instructional designers, and administrators to stay updated on evolving AI tools. Schools should establish innovation hubs or AI learning labs to encourage experimentation with emerging technologies.

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Strategic partnerships with EdTech providers and policymakers were also suggested to support long-term maintenance, updates, and cost-effectiveness of AI systems.

Third Stage: Outputs

(Related Themes: Equity, Quality, and External Efficiency)

d) Equity (as reflected in Outputs)

Experts emphasized that the expected outcomes of AI integration should include greater inclusivity and fairness in learning opportunities. AI tools must generate measurable improvements in participation and performance among underrepresented or disadvantaged students. Accessibility indicators—such as platform usage frequency, progress tracking, and digital resource reach—should be monitored to ensure equitable educational outcomes.

e) Quality (as reflected in Outputs)

The quality of learning outcomes was another focus of expert commentary. They observed that AI tools can significantly improve students' conceptual understanding, reasoning skills, and engagement when effectively implemented. Similarly, teachers' professional growth in AI pedagogy, data interpretation, and adaptive instruction was seen as a key output of the model. Experts highlighted the institutional benefits of the model, including the development of evidence-based decision-making practices, enhanced teaching quality, and scalable innovation across mathematics departments.

f) External Efficiency

External efficiency was identified as a distinct outcome area where experts recommended establishing mechanisms to gather feedback from external stakeholders—such as higher education institutions and employers—to measure the model's broader impact. They advised assessing whether students exposed to AI-integrated mathematics teaching demonstrate improved readiness for STEM pathways, problem-solving in real-life contexts, and digital fluency compared to traditional methods. The inclusion of national benchmarking and participation in international comparative assessments was also proposed to ensure the model's external validity and competitiveness.

Fourth Stage: Evaluation and Continuous Improvement

(Related Themes: Sustainability and Quality)

e) Sustainability (as part of Evaluation)

Experts viewed sustainability as an ongoing cycle of reflection, redesign, and reimplementation. They recommended continuous capacity-building initiatives, integrating lessons from evaluation into teacher training, curriculum updates, and institutional policies. Financial sustainability should be secured through dedicated budgets for AI maintenance, software upgrades, and infrastructure renewal.

e) Quality (as part of Evaluation)

Continuous evaluation mechanisms must ensure that all AI-related activities remain aligned with learning objectives, ethical standards, and policy frameworks. Experts suggested incorporating both quantitative analytics (e.g., performance metrics) and qualitative feedback (e.g., teacher reflections, student experiences) into periodic reviews. Iterative improvement cycles should allow the model to evolve in response to new research findings, technological advancements, and contextual changes.

7. Description of the Proposed Model for employing AI tools in Math teaching

Since the intended outcome of AI integration in mathematics education is the development of students' conceptual understanding, problem-solving abilities, and higher-order thinking skills, the proposed model extends beyond tool adoption to encompass pedagogical design, instructional implementation, and evaluation processes that ensure the achievement of the intended learning objectives (ILOs).

The model's domains, dimensions, and components were designed based on frameworks and models highlighted in the literature review, combined with the researcher's practical experience in technology-enhanced and AI-supported teaching. Subsequently, several dimensions and items were refined based on expert feedback. For instance, experts emphasized the importance of ensuring inclusivity, data ethics, and stakeholder engagement across all stages of AI integration. Accordingly, additional components addressing ethical governance, digital equity, and quality assurance were incorporated into the model to ensure balanced, responsible, and sustainable implementation.

The proposed Model for Employing AI Tools in Mathematics Teaching is a comprehensive, adaptive framework applicable to both in-person and blended learning environments. It consists of four main domains: (a) Inputs, which encompass human, technological, and curricular resources; (b) Processes, which outline instructional design, implementation, and data management mechanisms; (c) Outputs, which capture the outcomes and impacts of AI integration on students, teachers, and institutions; and (d) Evaluation and Continuous Improvement, which ensures ongoing refinement through systematic assessment, reflection, and innovation cycles.

Each of these domains interacts dynamically to support the effective and ethical use of AI in mathematics education, fostering innovation, equity, and continuous pedagogical enhancement.

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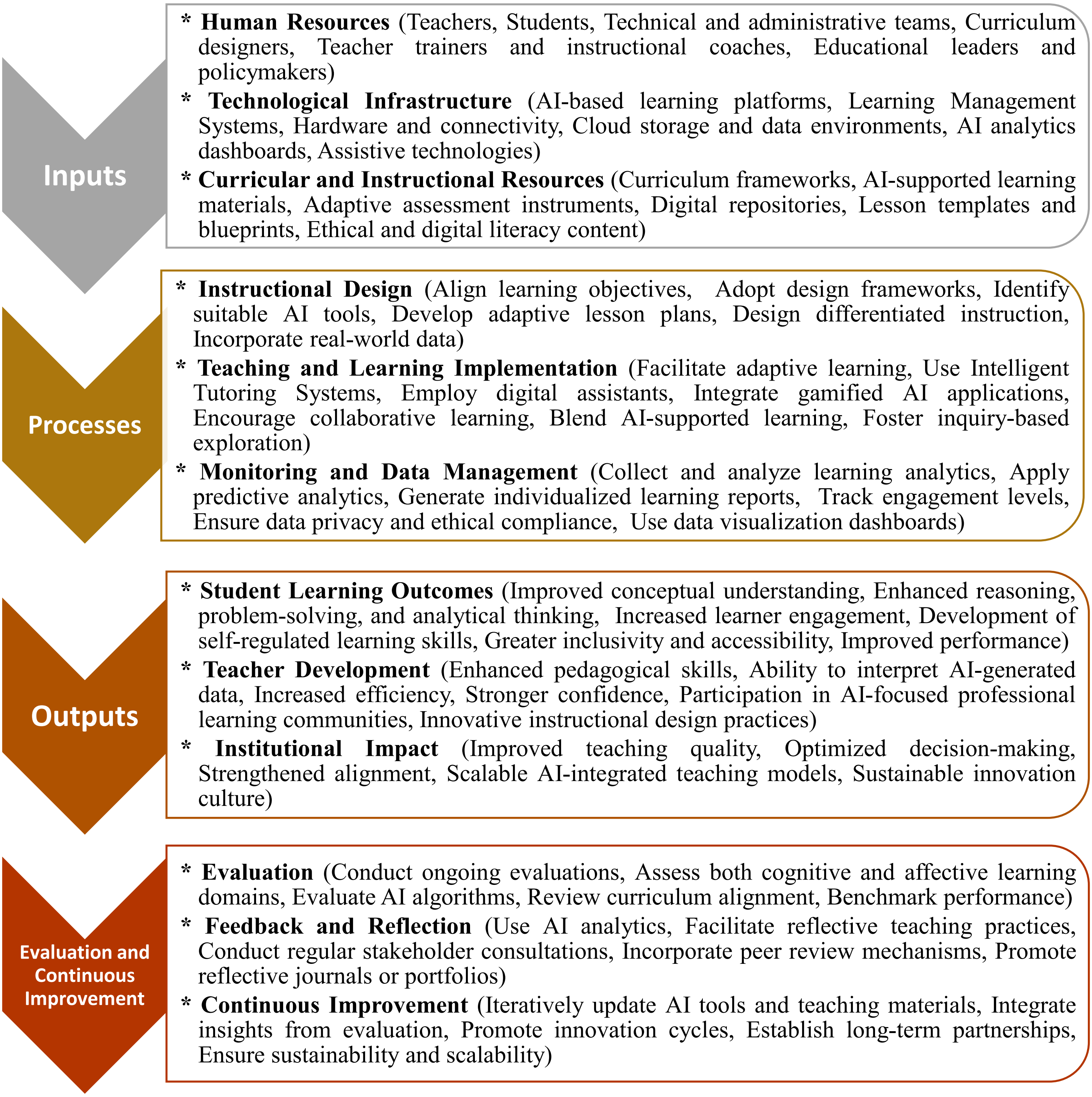
Figure 1.

The Proposed Model for employing AI tools in Math teaching



The Model elaborates and stages of employing AI tools in Math teaching as the following:

a) Inputs

This domain focuses on preparing all essential resources for the successful integration of AI tools in mathematics teaching. It includes the identification of human, technological, and curricular requirements. Teachers should possess AI literacy and pedagogical competence to design adaptive, inquiry-based lessons, while students must be prepared for interactive and data-driven learning. Technological infrastructure such as AI-enabled platforms, learning management systems, and stable internet connectivity ensures smooth implementation. Curriculum alignment with AI-supported objectives and the inclusion of intelligent exercises and adaptive assessment tools further strengthen this domain.

b) Processes

This domain represents the systematic procedures through which AI is embedded into mathematics instruction. It begins with instructional design, where AI tools are aligned with mathematical objectives and teaching strategies such as visualization, exploration, and reasoning. During teaching and learning implementation, AI is employed to provide adaptive instruction, real-time feedback, and intelligent tutoring support. Data management is an integral part of this domain, involving continuous analysis of student performance through AI dashboards to inform pedagogical adjustments and enhance decision-making.

c) Outputs

The Outputs domain captures the outcomes of AI integration in mathematics classrooms. These include improved conceptual understanding through visualization and adaptive learning, enhanced problem-solving and analytical skills, and increased student engagement and autonomy. For teachers, outputs include strengthened capacity for data-informed decision-making, improved instructional efficiency, and innovative lesson design. At the institutional level, outputs are reflected in enhanced teaching quality, technology-driven innovation, and sustainable digital learning ecosystems.

d) Evaluation and Continuous Improvement

This domain ensures that the model remains dynamic and evidence-based. Evaluation involves ongoing assessment of learning outcomes, AI tool performance, and teaching effectiveness. Feedback mechanisms—such as AI analytics, teacher reflection, and stakeholder input—inform necessary refinements. Continuous improvement relies on updating instructional materials, upgrading AI tools, and sustaining innovation through professional development and policy support to guarantee long-term model relevance and impact.

8. Conclusion

Current study was undertaken to develop, validate, and propose a comprehensive model for employing Artificial Intelligence (AI) tools in mathematics teaching for secondary schools. It arose from the recognition that traditional mathematics instruction, though rich in content, often fails to respond to the dynamic learning needs of twenty-first-century students who live in a world increasingly driven by intelligent technologies and data-based decision-making. The study thus sought to design a pedagogically sound and technologically feasible framework that would integrate AI tools into the teaching and learning of mathematics, fostering both conceptual understanding and adaptive problem-solving skills. The ultimate goal was not to replace the teacher but to empower educators with intelligent support systems that can personalize instruction, enhance student engagement, and ensure equitable access to quality learning.

The proposed model, entitled "A Suggested Model for Employing AI Tools in Mathematics Teaching for Secondary Schools," is structured around four major stages: Inputs, Processes, Outputs, and Evaluation & Continuous Improvement. Each stage plays a critical role in ensuring a systematic and evidence-based integration of AI technologies into the mathematics curriculum. The Inputs stage establishes the foundational resources — human, technological, and curricular — necessary for the effective implementation of AI-driven pedagogy. It emphasizes the need for teachers to develop AI literacy and pedagogical expertise that enable them to use intelligent systems such as ChatGPT, Mathway, and GeoGebra AI effectively. It also underscores the importance of robust technological infrastructure, including high-speed internet, cloud storage, and adaptive learning management systems (LMS) that can support real-time data analysis and personalized feedback. Furthermore, this stage calls for curriculum designers to embed AI-enhanced content and ethical digital literacy into mathematics frameworks to ensure alignment with national and international educational standards.

Building upon these inputs, the Processes stage delineates the operational mechanisms through which AI is systematically integrated into classroom instruction. This stage embodies the pedagogical heart of the model, where AI tools are used to transform traditional teaching into a more adaptive, data-driven, and student-centered process. Instructional design plays a pivotal role here, guided by frameworks such as TPACK and SAMR, which help educators balance technological, pedagogical, and content knowledge in lesson planning. Through the use of intelligent tutoring systems (ITS), AI chatbots, and predictive analytics, teaching becomes more responsive to individual student performance and cognitive patterns. The model thus envisions a dynamic classroom environment where teachers use AI to facilitate inquiry-based learning, foster collaborative problem-solving, and continually refine instructional strategies based on real-time feedback from data analytics dashboards.

The Outputs stage reflects the measurable and observable transformations that result from implementing AI tools in mathematics classrooms. At the student level, AI integration leads to improved comprehension of abstract mathematical concepts through visualization, simulation, and adaptive feedback. Learners demonstrate enhanced critical thinking, reasoning, and metacognitive awareness, as AI tools encourage them to explore, test, and revise their understanding actively. Teachers, in turn, benefit from reduced workload in assessment and grading, greater confidence in using data to inform instruction, and a heightened capacity for innovation in lesson design. At the institutional level, schools experience improved teaching quality, stronger alignment with digital transformation goals, and more sustainable models of technology-enhanced education. The outputs thus validate the hypothesis that AI can serve as both a cognitive partner for learners and a decision-support tool for educators.

Finally, the Evaluation and Continuous Improvement stage ensures that the model remains a living, adaptable framework rather than a static design. Through systematic evaluation of student outcomes, teaching performance, and AI system efficacy, schools can identify strengths, weaknesses, and emerging opportunities for refinement. Regular feedback loops involving teachers, students, administrators, and external stakeholders (including employers and policymakers) are crucial for sustaining innovation and accountability. Ethical considerations — such as data privacy, fairness in AI algorithms, and inclusivity in learning design — are integrated into the evaluation process to guarantee responsible and equitable use of technology. The emphasis on continuous improvement reinforces the notion that AI integration is not a one-time initiative but an evolving process that requires ongoing reflection, research, and capacity development.

The validation of the model by educational technology and mathematics experts across several countries confirmed both its practicality and theoretical robustness. Experts agreed on the coherence and balance between the pedagogical and technological dimensions, with an overall mean agreement level of 87.03%, which indicates strong support for its feasibility and applicability. Thematic analysis of expert feedback revealed essential considerations that shaped the final refinement of the model, including contextual awareness, sustainability, equity, quality assurance, and external efficiency. These themes reflect the recognition that effective AI integration must extend beyond classroom instruction to encompass broader institutional and societal contexts, addressing issues such as infrastructure equity, gender sensitivity, and alignment with labor market needs.

In conclusion, the proposed model represents a significant step toward reimagining mathematics education in the era of artificial intelligence. It offers a holistic, data-informed, and pedagogically grounded roadmap for transforming mathematics teaching into a more personalized, engaging, and equitable experience. The study affirms that AI, when thoughtfully integrated, can augment rather than replace human intelligence—enabling teachers to focus on creativity, mentorship, and higher-order thinking, while allowing students to learn at their own pace and according to their unique cognitive profiles. This model not only provides a blueprint for current implementation but also serves as a foundation for future research and policy development in the field of AI-driven education. It envisions a new paradigm in which technology and pedagogy coexist harmoniously to advance the cognitive, emotional, and ethical dimensions of learning, ultimately preparing students to thrive in a future defined by intelligence—both human and artificial.

9. Implications

The model holds significant implications for educational policy, teacher training, and curriculum development.

1. For policymakers, it provides a structured foundation for designing national strategies that promote AI integration in mathematics curricula while ensuring equity and access across schools.
2. For teachers, the model emphasizes the need for continuous professional development in AI literacy, data analytics, and adaptive teaching design.
3. For curriculum developers, it offers a framework for embedding AI-supported activities that promote visualization, reasoning, and problem-solving across mathematical domains.
4. For researchers, it opens avenues for empirical studies on how AI can reduce cognitive load, personalize learning pathways, and improve long-term retention of mathematical concepts.

5. For students, it creates opportunities for active engagement, autonomy, and enhanced motivation through intelligent tutoring and interactive simulations.

10. Recommendations

Based on the findings and framework design, the following recommendations are proposed:

1. Policy and Infrastructure: Ministries of Education should invest in scalable AI infrastructure and ensure reliable connectivity to support AI-based instruction, particularly in underserved regions.
2. Teacher Development: Implement structured training programs focused on AI literacy, ethical use of data, and the pedagogical integration of AI tools such as ChatGPT, Mathway, and GeoGebra AI.
3. Curriculum Integration: Align mathematics curricula with AI-supported pedagogical models to foster critical thinking, collaboration, and real-world problem-solving.
4. Monitoring and Evaluation: Establish continuous monitoring systems using AI analytics to evaluate both student progress and teaching effectiveness, ensuring evidence-based improvement.
5. Ethical and Inclusive Use: Develop ethical guidelines to ensure data privacy, fairness, and gender equity in AI-based mathematics learning environments.
6. Future Research: Encourage longitudinal and comparative studies to evaluate the long-term effects of AI integration on students' mathematical achievement, motivation, and cognitive load.

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