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LONG-TERM EFFECTS OF AI ASSISTANCE ON MATHEMATICS EDUCATION

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ABSTRACT

The rapid evolution of digital technologies and Artificial Intelligence (AI) has transformed university-level mathematics education, shifting e-learning from passive content delivery to dynamic AI-augmented environments. While generative AI and symbolic computation tools offer significant pedagogical advantages—such as personalized instruction, adaptive assessments, and real-time feedback—they also present profound long-term challenges, including cognitive atrophy, diminished problem-solving resilience, and an "illusion of competence" among learners. This paper critically evaluates the long-term cognitive, psychological, conceptual, and equity-related impacts of AI integration in higher education mathematics. To balance technological capability with human cognitive resilience, this paper proposes a novel proof- and ethics-based assessment framework anchored in three core pillars: reverse-engineered critique assessments, digital viva-voce verifications, and transparent AI-use logging. By shifting assessment paradigms from routine computation to process-oriented reasoning and ethical evaluation, higher education institutions can effectively harness AI to prepare critical, analytical, and adaptive graduates for the digital era.

Keywords: *Artificial Intelligence (AI), AI Tutor, Adaptive learning, Mathematics education, Academic integrity*

Introduction

The rapid advancement of digital technologies has fundamentally shifted the e-learning paradigm from a passive content delivery medium into a dynamic, smart learning environment. Within higher education, the emergence of generative Artificial Intelligence (AI) and symbolic computation engines—such as ChatGPT, Claude, and WolframAlpha—has triggered a new wave of transformation, particularly within Science, Technology, Engineering, and Mathematics disciplines.

Mathematics, a foundational pillar for analytical capability and logical reasoning, now faces unprecedented opportunities and challenges. According to (Ismail et al., 2026) AI-based tutoring systems can be used as structured self-study environments in which students review difficult topics, complete individualized practice sets, receive immediate correction, and track their progress across lessons. The ability of AI tools to solve complex differential equations, generate mathematical proofs, and provide step-by-step solutions instantaneously challenges traditional e-assessment methods that rely heavily on algorithmic memorization and mechanical computation.

Higher education institutions must critically evaluate the long-term implications of AI integration in mathematics education. On one hand, these technologies offer cognitive empowerment through adaptive learning, real-world mathematical modeling, and student-centered pedagogy. On the other hand, unchecked reliance risks eroding foundational reasoning capabilities, inducing cognitive atrophy, and fostering an "illusion of competence" among future graduates. According to (Nguyen & Van Pham, 2025) AI offers many opportunities to improve mathematics education-such as personalizing learning, providing instant feedback, and automating administrative tasks but the integration of AI still faces significant challenges. The integration of AI in mathematics education faces ongoing challenges regarding cognitive over-reliance and data privacy(Stefanova & Georgiev, 2026). In addition, teacher skill shortages and the risk of students becoming over-dependent on technology, which undermines creative thinking and problem-solving, are also challenges that need to be addressed (Nguyen & Van Pham, 2025).

Therefore, this paper examines the long-term positive and negative impacts of AI-assisted e-learning in university mathematics and proposes an innovative assessment framework to steer the future of mathematical education toward a grounded, ethical, and sustainable direction. (Awang et al., 2025) also mentioned that educators and policymakers need to effectively utilize AI technologies to create more adaptive, efficient, and equitable educational experiences. Here are some of the significant advantages and disadvantages of AI based on (Opesemowo, 2024):

The advantages of AI:

1. **Personalized Instruction:** AI algorithms can analyze student data and provide personalized instruction based on individual needs, learning styles, and performance in mathematics. This tailored approach allows students to progress at their own pace, fill knowledge gaps, and receive targeted support, resulting in improved learning outcomes.
2. **Adaptive Assessment:** AI-powered assessment tools can offer adaptive testing, dynamically adjusting the difficulty of questions based on students' responses. This approach provides accurate assessments, identifies areas of weakness, and offers tailored feedback, allowing educators to support student progress better (Opesemowo, 2024). AI-powered adaptive assessment systems can create customized mathematics tests and questions for every student according to their progress and level of knowledge. In order to ensure that students are appropriately challenged and tested, these examinations modify the difficulty of the problems in real-time, producing more accurate evaluations of their mathematical aptitude.
3. **Interactive Learning Environments:** AI technologies like virtual simulations and gamification create engaging learning environments (Bennani et al., 2022). These tools promote active

participation, problem-solving, and critical thinking skills, making mathematics more accessible and exciting for students.

4. **Real-Time Feedback:** AI-based math applications (such as Photomath, Soratic, Mahtway, Maple Calculator, and Microsoft Math Solver) can provide immediate feedback on students' math problem solutions. This quick feedback assists students in identifying and correcting errors, so reinforcing learning and developing problem-solving skills.
5. **Augmented Reality Applications:** Through augmented reality (AR) applications, AI can improve mathematics instruction. AR can bring mathematical concepts to life by superimposing digital information on the real-world environment, making abstract ideas more tangible and understandable for learners without leaving the classroom (Bower et al., 2014). For instance, students might use augmented reality to explore 3D models of mathematical topics or visualize geometric forms in their environment, fostering deeper learning and spatial thinking.

The disadvantages of AI:

1. **Lack of creativity and problem-solving skills:** Mathematics education is more than just answering routine problems; it is also about cultivating creativity and problem-solving abilities. AI algorithms are excellent at pattern detection and optimization but lack human-like creativity (Opesemowo, 2024) and the ability to think outside the box.
2. **Overemphasis on computational skills**: Since AI can automate calculations, overemphasizing computational abilities and basic procedures may discourage learners from engaging their brains when dealing with routine problem-solving tasks. While these abilities are necessary, a well-rounded mathematics education should emphasize conceptual understanding, mathematical reasoning, critical thinking, metacognition, and mathematical applications in real-world contexts and other areas where AI cannot fully replace human instruction.
3. **Lack of emotional intelligence:** Mathematics education entails more than just delivering knowledge; it also entails creating a welcoming learning atmosphere. Because AI lacks emotional intelligence and it cannot provide the same level of empathy, encouragement, and emotional support human teachers can.
4. **Lack of real-time interaction:** Traditional classroom environments encourage direct interaction between students and teachers, allowing teachers to assess students' comprehension and alter their instruction accordingly. AI may lack the real-time reaction required for dynamic classroom interactions, making it impossible to properly handle urgent inquiries or concerns (Almaiah et al., 2022).

5. **Oversimplification of concepts:** AI algorithms may provide quick answers and solutions without fostering deep conceptual understanding. Students may become overly dependent on AI for problem solving without fully comprehending the underlying mathematical principles.

Comprehensive long-term impact analysis

Table 1 shows the long-term impact of AI for higher education students in mathematics fields. There are four learning dimensions with positive and negative impacts and assessment implications that should be considered to overcome the risks.

Table 1: Long-Term Impacts of AI Integration in Higher Education for Mathematics' students

Learning Dimension	**Long-Term Positive Impact (Opportunities & Empowerment)**	**Long-Term Negative Impact (Risks & Cognitive Threats)**	**Assessment Implication**
Cognitive & Thinking Skills	The focus of students shifts from simple computations to more complex data analysis, mathematical modeling, and problem framing.	Erosion of "number sense" and intuitive error detection due to a lack of manual, foundational problem-solving practice.	Shift focus from grading final numeric answers to evaluating logical reasoning processes and critical analysis of AI outputs.
Learning Psychology & Attitude	24/7 adaptive AI tutoring reduces math anxiety and fosters self-directed learning behaviors.	Instant answer retrieval degrades mental stamina when students encounter novel problems lacking immediate AI solutions.	Design open-ended, project-based assignments requiring sustained inquiry over short, static quizzes.
Conceptual Mastery & Metacognition	Enables real-time hypothesis testing, multi-dimensional graph visualization, and immersive data simulations.	Passive comprehension occurs when students mistake watching an AI solve a problem step-by-step for actual independent capability.	Incorporate digital viva-voce assessments to verify genuine conceptual comprehension.

Learning Dimension	Long-Term Positive Impact (Opportunities & Empowerment)	Long-Term Negative Impact (Risks & Cognitive Threats)	Assessment Implication
Inclusivity & Learning Gaps	Bridges learning gaps across diverse backgrounds through personalized pedagogical assistance tailored to individual learning paces.	Over-reliance on proprietary AI tools that may contain algorithmic biases, hallucinated logic, or privacy concerns.	Mandate transparent AI declaration logs and critical AI literacy training within every learning module.

Proposed innovative assessment framework

To harness the benefits while mitigating long-term cognitive risks, universities must do a transition from static, traditional testing to a Proof- and Ethics-Based Assessment Framework. This framework relies on three core pillars:

1. Reverse-Engineered Assessments (Critique & Verification)

Implementation: Rather than banning AI, educators deliberately utilize AI-generated responses—including those containing intentional logical fallacies or hallucinated steps—as learning materials.

Student Role: Students are evaluated on their ability to audit the solution, identify mathematical errors, critique flawed reasoning, and construct a corrected, mathematically sound justification.

2. Verification Through Digital Viva-Voce

Implementation: Written online submissions are complemented by synchronous or asynchronous video-recorded oral defenses.

Student Role: Students must verbally defend their mathematical reasoning, justify their choice of theorems or formulas, and explain how AI tools were utilized during their problem-solving workflow.

3. Transparent AI Integration & Ethical Logging

Implementation: E-learning platforms establish clear protocols for acceptable AI usage.

Student Role: Submissions must include an AI-Use Log (documenting prompts and outputs) alongside a reflective commentary evaluating how AI assisted or potentially misdirected their cognitive process

Conclusion

The integration of Artificial Intelligence into mathematics e-learning should not be viewed as an existential threat to academic integrity, but rather as a catalyst for transforming higher education pedagogy and assessment. While cognitive atrophy and the illusion of competence are valid concerns stemming from over-reliance, AI's potential to shift focus from routine computation to critical thinking and complex modeling offers an unprecedented opportunity to prepare quality graduates for the future.

Steering the future of innovative e-learning requires institutional courage—not to prohibit technology, but to construct learning environments that balance artificial intelligence with human cognitive resilience. By implementing assessment frameworks centered on logical reasoning, ethics, and process-oriented evaluation, universities can ensure that mathematics remains a vital discipline for nurturing critical, analytical, and adaptive minds in the digital era.

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