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Position Paper

Teaching Mathematics in the Artificial Intelligence Era: Challenges and Concerns in Higher Education

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Abstract: Problem-solving has been at the core of mathematical education for decades. However, the objectives set for understanding mathematical concepts and developing problem-solving strategies within a realistic and interdisciplinary framework have not been achieved to the expected extent. Over the past decade, the need for persistence in mathematical problem-solving has been emphasized as a process of self-regulation in cognitive behaviour, helping learners overcome obstacles that require flexibility and adaptive actions. Learners often seek external assistance when facing difficulties in solving mathematical problems. Recently it seems that at the secondary and higher education levels, artificial intelligence has taken on this role. Research findings highlight students' willingness and expectation to acquire the necessary knowledge and skills to utilize Artificial Intelligence (AI) tools for learning, developing strategies, and enhancing problem-solving abilities to become more proficient problem solvers. We must acknowledge the advancements in AI and leverage its capabilities in an ethical and effective manner, including adaptive assessment and self-assessment tools, immediate feedback, identification of errors in mathematical thinking, and suggestions for alternative courses of action. The use of appropriate AI tools by cognitively mature individuals can positively contribute to the development of metacognitive skills that improve mathematical ability. The effective use presupposes the relevant teachers' knowledge, skills and high self-efficacy beliefs about the use of AI tools either in teaching or in learning. We present a position paper on the issue and we discuss our main concerns we have to take into consideration, under a pedagogical perspective and the challenges we have to face the following up years.

***Keywords*:** artificial intelligence, mathematical problem solving

1. Introduction

Mathematics is a dynamic science that has evolved over the centuries, shaped by the prevailing socio-cultural context of each period. For example, the transition to non-Euclidean geometry during the Renaissance was not accidental; it resulted from a climate of doubt and inquiry which enforced the development of the scientific thought. Every change, whether in scientific development or, more prominently, in education, is often met with initial resistance. Technology has traditionally viewed as a tool for teaching mathematics (Diego-Mantecon et al., 2022), with discussions focussing on teachers' knowledge, related skills and self-efficacy beliefs to use it fluently and flexibly (Williams et al., 2023). However, the use of technology does not necessarily ensure meaningful learning. The technological tools change rapidly and it is necessary to develop skills for understanding their strengths and limitations. Under the pedagogical

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perspective teachers need to understand the challenges and the possible threats.

Nowadays the rapid advancement and widespread use of Artificial Intelligence (AI), as a rapidly developed technological revolution has raised concerns about its role in education, particularly in upper secondary and higher education. We acknowledge that learners need to acquire AI knowledge and skills to stay competitive (Chiu et al., 2022). At the same time, its reckless use could lead to negative impact in respect to the learning process. Do students find an easy way to overcome the difficulties they face during problem solving by asking the "external contribution" of the AI? What about the persistence and the self-regulatory strategies to insist against the difficulties and the cognitive obstacles?

Resistance to change can have negative consequences, making it crucial to approach AI in education with a balanced and thoughtful perspective. Initially, the primary focus was on establishing strict regulations for AI usage in educational settings. However, in our opinion, the next steps should focus on the rational and constructive integration of AI in education, aiming to help students recognize their strengths and limitations, by understanding the challenges and facing the threats. On the other hand, teachers need to develop knowledge and skills and their self-efficacy abilities for using AI in instruction and pose the appropriate framework for the students' use (Antonenko & Abramowitz, 2022).

Many systematic literature reviews have been presented recently (e.g. Hwang & Tu, 2021; Tan et al., 2025; Wang et al., 2024), and indicated many important aspects of the domain. At the present work, we do not present a systematic literature review. We aim to highlight the strengths and limitations of using the AI as a teaching and learning tool in the case of mathematics education and discuss the main practical implications concerning the next research steps. Mathematics emphasized the problem solving as the basic learning tool for the development of the mathematical thinking. The use of AI during the problem solving can affect negatively the central role of persistence on using fluently and flexible problem-solving strategies and self-regulatory practices to overcome cognitive obstacles (Panaoura, 2017). On the other hand, the use of adaptive tools can offer the appropriate personalized feedback with indications about the necessary cognitive and regulatory actions.

Mathematics in education "plays a key role in the cultivation of students' thinking ability and logical ability. Good education and teaching can develop students' logical thinking ability, so that students can form the quality of independent thinking" (Gao, 2020, p. 2). The focus of the present work is on mathematical thinking at the level of higher education. We present our initial concerns and suggestions based on our preliminary findings regarding the use of AI in higher education and the upper secondary education, specifically in the teaching of mathematics, after the students' first experiences during personal experimentation at the upper levels of secondary education. In recent years, we have studied the beliefs of freshman students about mathematics and its learning process as they began their studies in engineering departments and we proposed teaching and assessment methods either with the use of technological tools or specific interdisciplinary frameworks (Panaoura et al., 2024; Charalambides et al., 2023). More recently, we have also decided to examine their beliefs and dispositions toward the use of AI in learning mathematics. Our initial findings indicated that many of our students have already used AI tools during the secondary education either out of curiosity or to obtain solutions to assigned tasks (Panaoura et al., 2025). However, they were often unable to explain whether they would recommend these tools to others, as they could not justify any positive learning impact. Drawing from this experience, we discuss several important issues related to the potential teaching and learning challenges and threats associated with AI integration in mathematics education. The present work aims to contribute on the theoretical discussion about the application of AI in education either with respect to the curriculum transformation or the implications for the future research on the domain. The present position paper aims to discuss issues arising in both the learning and teaching processes, in an effort to contribute to the global efforts to use AI appropriately in education. In our view, the AI tools can be both a blessing and a curse, depending on how there are used.

2. Artificial intelligence in mathematics education

2.1 *The artificial intelligence*

Artificial intelligence is widely discussed today; however, it is not a new concept. The term was coined in 1956 by McCarthy, building on the work of Turing (Crompton & Burke, 2023). "AI is a process of human intelligence through machines, especially computer systems" (Mohamed et al., 2022, p. 1). In simple terms, AI is a simulation of

human intelligence modelled in a machine and programmed to think like humans. As Opesemowo and Ndlovu (2024) explain, AI involves the study, design, and development of algorithms that make decisions based on data derived from the environment. Its rapid development is driven by significant advancements in capabilities, enhancing the ability of computing systems to engage in human-like processes such as learning, adapting, self-correcting, analysing, and synthesizing. The integration of AI in various contexts can improve our ability to navigate a world increasingly shaped by sophisticated technology.

2.2 *The implementation of AI in education*

UNESCO (2019) has emphasized the importance of implementing AI in education to support teaching and learning. The integration of AI in mathematics education has sparked numerous studies internationally, both disciplinary and interdisciplinary, in recent years (Panqueban & Huincahue, 2024). In the context of higher education, particularly in mathematics, efforts have focused on creating more interactive, efficient, and effective learning environments (Msomi & Mthethwa, 2024), with AI positively influencing the learning process. Zhou (2023) proposed a personalized learning program, and his findings indicated improvements in students' motivation and academic performance.

Vaerenberg and Perez-Suay (2022) propose a taxonomy of AI techniques that are used in digital tools for mathematics education: a) information extractors: AI technologies that take observations from the real world and translate them into a mathematical research (parsing the text of algebraic word problems into equations), b) reasoning engines: automated theorem process whose aim is to verify and generate proofs of mathematical theorems, c) explainers: AI methods that produce understandable explanations, d) data mining and machine learning techniques are used to analyse those data and to convert them into insights and practical models. According to Stefanova and Georgier (2024) the AI systems which are suitable for mathematics education can be divided into two large groups: a) AI-based calculators which are extensively used by students to get help in solving problems and b) Intellectual tutoring systems which are used by the teachers in order to better adapt the teaching methods and the assessment feedback on students' needs and learning styles.

The systematic literature review by Msomi and Mthethwa (2024) highlights the value of AI technologies in enhancing mathematics education in higher education. It emphasizes the benefits of AI tools such as intelligent tutoring systems, adaptive learning platforms, and automated assessment and feedback systems. A key advantage, aligned with student-centred pedagogy, is the personalized nature of the teaching process. This includes real-time feedback that addresses students' misconceptions and misunderstandings, as well as diverse teaching and assessment methods tailored to individual proficiency levels. As a result, all students experience success while also being challenged to progress to more advanced levels. In higher education, students have already developed metacognitive abilities that enable them to assess their strengths and limitations accurately (Panaoura & Panaoura, 2006). Using uniform methods and tasks for all students does not promote equal opportunities; rather, it reinforces standardization. To develop persistence and the ability to tackle increasingly complex tasks, each student requires motivation and challenges tailored to their proficiency level (Panaoura, 2016).

One dimension of AI in education is the use of adaptive learning tools, which customize educational content to meet students' needs, learning styles, and cognitive styles. This fosters a more personalized and effective learning environment (Msomi & Mthethwa, 2024). AI-based systems utilize algorithms to analyze students' performance and, based on expected behaviours, provide customized feedback. As Grugeon et al. (2022) explain, in France, the MindMath learning environment was developed to provide students aged 12-16 with adaptive learning paths in algebra and geometry, both in and out of the classroom. The system first conducts a diagnostic assessment of students' knowledge to update their profiles and identify their learning needs. This environment then offers learners relevant tasks and appropriate feedback.

An important dimension of using AI in education is related with teachers' conceptions. While extensive literature exists on the integration of AI in education, less emphasis has been placed on the critical role of teachers and their respective professional development. According to Yau et al. (2023), very few studies investigated teachers' perceptions of AI education. Their study investigated teachers' conception of teaching AI using a phenomenographic approach. Six categories of conceptions were identified: technology bridging, knowledge delivery, interest stimulation, ethics establishment capacity cultivation and intellectual development. Egara and Mosimege (2024) emphasize the significance and ongoing support for teachers to integrate AI-based ChatGPT into mathematics instruction.

Mathematics teaching and learning are highly complex processes involving many interrelated variables, both external and internal. Major goals are set concerning the expected learning outcomes in mathematics, and various teaching tools are employed in an attempt to achieve them. However, these tools do not always fulfil those goals. A key objective in mathematics education is the development of mathematical reasoning skills, whereas AI systems are designed to perform reasoning tasks in an automated way. In 2014, the mobile phone application Photomath was released and quickly became popular among students. It allows users to point a phone camera at an equation in a textbook and instantly obtain the solution along with the corresponding steps of reasoning.

3. Concerns and challenges

The implementation of AI in mathematics education, particularly in higher and the upper secondary education, offers numerous benefits and paves the way for new directions in learning. However, each innovation also introduces challenges and potential threats, often stemming from problematic implementation. According to Jaiswal and Arun (2021), the most significant advantage of using AI tools is individualized learning. When used rationally, AI tools provide benefits in two key areas: teaching and learning. These benefits are essential for achieving the goals outlined in the curriculum and the corresponding learning outcomes. We present in a structured way the benefits (Table 1) and the threats (Table 2) which can be the expected consequences of using the AI in mathematics education. Both tables are conceptual in nature and are derived from our initial insights and practical experiences. We believe that presenting the associated challenges and concerns can contribute meaningfully to the ongoing discourse on the appropriate use of AI in education. We acknowledge that a potential limitation of both the tables is that there are based on early-stage theoretical and practical insights, which may not fully capture the complexity or diversity of AI implementation in varied educational contexts.

Table 1 presents an analysis of the major benefits of teaching and their corresponding positive impact on learning. From a teaching perspective, an intelligent tutoring system is a computer-based learning tool that leverages AI to create an adaptive educational environment tailored to learners' needs and instructional objectives (Vaerenbergh & Perez-Suay, 2022).

Table 1. The benefits of using the AI tools in teaching and learning

Teaching	Learning
AI can analyse students' strengths, weaknesses, learning and cognitive styles to generate customized teaching methods.	By understanding their strengths and limitations, students develop metacognitive and self-regulatory abilities.
AI can provide automatically grade assessments, quizzes and exams. Mainly it can detect patterns in student errors and suggest areas for improvement.	Students receive instant feedback on their answers, including mistake identification, hints, and explanations.
AI can create activities of gamification, simulations and adaptive activities. Those activities adapt in difficulty based on their performance.	AI learning platforms personalize quiz difficulty based on past responses, ensuring progressive improvement.
AI powered tutoring systems that analyse students' responses and offer step by step guidance.	AI tools encourage students to set learning goals, track progress, and receive personalized recommendations, fostering ownership of their education.
AI chatbots and virtual assistants can answer student queries, explain concepts and suggest appropriate materials.	Students can ask questions, clarify doubts, and receive immediate explanations.
AI can recommend appropriate resources and materials to teachers, helping them tailor instruction to students' needs and enhance the overall learning experience.	Learning materials are personalized based on students' needs and interests.
AI can track students' performance over time, identifying areas where they have to insist. Teachers receive detailed reports permitting them to adjust their teaching methods accordingly.	Students can use AI-driven analytics to monitor their learning progress and identify areas for improvement.
AI tools can help teachers design problem-solving activities that encourage students to engage in critical thinking.	AI-powered platforms can pose challenging, real-world problems and guide students through step-by-step reasoning, promoting deeper understanding.

In higher education, students are expected to have already developed a precise self-image regarding their strengths and weaknesses. However, individuals sometimes overestimate their abilities or struggle to manage difficulties through self-regulation of their cognitive performance. Teachers require time and various assessment tools to construct an accurate profile of each student. AI tools, on the other hand, rely on students' responses to analyse their learning and cognitive styles and provide appropriate feedback. Through this individualized and continuous feedback, students recognize their mistakes and misunderstandings, gain a clearer understanding of their strengths and limitations, and receive suggestions on how to overcome challenges. At the same time, the use of adaptive tools, based on an analysis of students' understandings and misunderstandings, ensures that all students experience success, which serves as motivation for subsequent learning steps.

From the teachers' perspective, AI tools offer creative ideas through open-access resources, allowing them to adapt their teaching processes based on students' responses. It is important to recognize that teachers must continuously expand their knowledge and refine their teaching methods. Teaching is a challenge that should be enriched with interdisciplinary and realistic tasks, which AI tools can help propose. However, each tool must be critically evaluated by teachers to determine whether it aligns with learning goals. Through a critical perspective, teachers must also identify and address potential challenges associated with AI implementation. Moreover, mathematics education should allocate adequate time to each aspect of the learning process, placing greater emphasis on conceptual understanding and real-world applications, rather than solely focusing on calculations and the use of digital tools (Martínez-Sevilla & Alonso, 2022). In Table 2 we summarize the main threats that we need to have in mind concerning the use of AI in teaching and learning.

Table 2. Threats on teaching and learning by the use of AI tools

Teaching	Learning
Over-reliance on AI tools may reduce teachers' autonomy and critical decision-making in lesson planning and assessment.	AI-driven instruction may lead to routine learning processes, limiting inquiry-based or project-based learning opportunities
AI algorithms are trained on existing data, which may contain biases, leading to unfair recommendations or assessments.	AI systems may prioritize "typical" cases, potentially overlooking inclusivity and accessibility for diverse learners.
AI-based learning may decrease face-to-face interactions between students and teachers, which are crucial for social and emotional development.	Increased reliance on chatbots for communication may hinder students' ability to express emotions and engage in meaningful discussions.
AI-driven grading and feedback systems may not always accurately capture a student's understanding, creativity, or reasoning process.	A strong emphasis on final answers may discourage students from using diverse representations, which are essential for deep mathematical understanding.
Over-reliance on AI-generated lesson plans and materials may limit teachers' creativity and professional judgment.	AI-driven curricula might not encourage personalized and innovative teaching strategies that accommodate different student needs.
AI-assisted tools may promote procedural learning over conceptual understanding, leading teachers to emphasize computational efficiency rather than problem-solving strategies.	Students may become passive learners, relying on AI-generated solutions rather than developing independent problem-solving skills.
AI tools collect and analyse student data, raising concerns about privacy, ethical use, and potential misuse of personal information.	Students' data may be used for profiling, potentially leading to biases in learning pathways and limiting opportunities for personalized education.
AI systems may reinforce rigid, standardized learning models that do not adapt to the diverse cognitive and emotional needs of students.	AI-generated content might limit creativity and exploration by focusing on predefined learning pathways rather than fostering open-ended inquiry.

All the potential threats to teaching and, consequently, to learning stem from the problematic use of AI tools. It is essential to always remember that technological tools, including AI, serve as alternative resources to support and enhance learning goals. However, if these tools are used as a substitute for the teacher rather than as a complement, the consequences will undoubtedly be negative.

4. Conclusions

Last decades technology enriches mathematics education by providing innovative tools, resources and methods. Nowadays AI is increasingly integrated into educational settings to enhance teaching and learning experiences in mathematics (Egara & Mosimege, 2024). Undoubtedly AI has great potential to revolutionize mathematics education, but it requires attention to the challenges that exist to ensure effective and equitable implementation (Qothrunnada & Maghfiroh, 2025). The application of AI in education will be increasingly recognized as a key driver of educational innovation (Tan et al., 2025). AI supports personalized learning for students and assists mathematics teachers in their efforts encompassing many learning aspects (Thanasi & Mema, 2024).

As AI continues to reshape mathematics education, it is crucial to maintain a balance between technological advancements and the human element in teaching. Recent curriculum and teaching tools especially in higher education and the upper secondary education cannot ignore the use of AI by both teachers and learners. We need to discuss the rational use of AI as a teaching and learning tool, by having mainly in mind the purpose of developing the problem-solving ability and the persistence to encounter difficult and unexpected situations. The present work aims to shed light on this discussion. While the paper highlights key challenges and concerns, it does not exhaust the full range of ethical, pedagogical and technical implications surrounding AI in education. We have already underlined that although the presented analysis aims to contribute to the broader discussion on the issue, its relevance may be affected by the specific educational systems and contexts.

4.1 *Practical implications*

While AI tools offer personalized learning and adaptive feedback, they should complement rather than replace traditional pedagogical approaches. Ethical considerations also play a significant role, as AI systems must be designed to ensure fairness, accessibility, and data privacy, preventing potential biases that could exacerbate educational inequalities. Additionally, both educators and students need to develop AI literacy, equipping them with the knowledge to critically assess and effectively integrate AI tools in the learning process. Another important aspect to consider is the long-term impact of AI on mathematical reasoning-over-reliance on automated solutions may weaken students' ability to develop problem-solving skills, making it essential to design AI-enhanced learning experiences that promote deeper conceptual understanding. Thoughtful integration of AI in mathematics education has the potential to transform teaching and learning, but careful consideration of these factors is necessary to maximize its benefits while mitigating possible challenges.

Educators must be prepared to harness AI tools not only to personalize learning and offer adaptive feedback, but also to cultivate students' self-regulatory skills and persistence in problem-solving. This requires targeted professional development that enhances teachers' confidence and competence in using AI effectively and ethically. Moreover, curriculum designers should embed AI-supported learning experiences that reinforce conceptual understanding rather than mere procedural efficiency. Especially universities must develop clear policies ensuring the ethical use of AI, protecting data privacy and promoting equity. These measures can support a balanced educational ecosystem where AI augments rather than replaces the human dimension of mathematical reasoning and instruction.

4.2 *Future studies*

Future research should explore how AI influences student engagement, fosters creativity in mathematical problem-solving, and compares with traditional assessments in evaluating learning outcomes. On the other hand, the future research should increase the focus on teacher professional development with respect to the use of AI. Bridging the gap in understanding how teachers can effectively integrate AI into their practices and enhance their AI competencies is essential for empowering teachers. Similarly, studies are needed about the accountability of the professional development programs which evolve skill requirements associated with AI integration. The future directions emphasize the need for studies on the impact of AI (Awang et al., 2025) and how AI can best complement the current or traditional teaching methods.

Conflict of interest

The author declares there is no conflict of interest at any point with reference to research findings.

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