Pythagoras - Journal of the Association for Mathematics Education of South Africa
ISSN: (Online) 2223-7895, (Print) 1012-2346

A reflection on the use of artificial intelligence tools for the meaningful learning of mathematics

Author:
Rajendran Govender[1]

Affiliation:
[1]School of Science and Mathematics Education, Faculty of Education, University of the Western Cape, Cape Town, South Africa

Corresponding author:
Rajendran Govender,
editor@pythagoras.org.za

How to cite this article:
Govender, R. (2024). A reflection on the use of artificial intelligence tools for the meaningful learning of mathematics. *Pythagoras, 45*(1), a831. https://doi.org/10.4102/pythagoras.v45i1.831

Introduction

Artificial intelligence (AI), also known as generative AI and large language models, has steadily emerged as a transformative force across various sectors of daily life, including education. Mathematics, a discipline fundamental to fields such as science, engineering, and beyond, has particularly benefitted from this evolution (Harry & Sayudin, 2023; Zreik, 2024). Artificial intelligence's capabilities to personalise learning, automate tasks, and provide real-time feedback have sparked growing interest in its potential to enhance meaningful learning in mathematics at both the school and higher education levels (Darmayanti, 2024). However, the integration of AI into education also raises critical questions regarding its effectiveness, accessibility and ethical implications (How & Hung, 2019). This editorial examines the potential impact of AI tools on fostering deeper understanding in mathematics, while also addressing the challenges associated with their implementation.

Mathematics is a crucial skill that underpins both education and everyday life. It empowers individuals with problem-solving abilities, quantitative literacy and the capacity to navigate an increasingly data-driven world. In addition, mathematics opens doors to career opportunities, enhances critical thinking, nurtures creativity and supports personal development (Harry & Sayudin, 2023; Li et al., 2024). It also fosters mental discipline and plays a key role in many daily activities (García-Martínez et al., 2023; Pedró, 2020). Within education, mathematics provides a foundation for understanding the world and equips individuals for a wide range of academic and professional paths.

However, despite its significance, many students struggle with both internal and external mathematics assessments. Research has identified several reasons for this underperformance (Darmayanti, 2024). These include weak foundational knowledge, teaching methods that fail to address diverse learning styles, insufficient personalised support to match individual learning paces, math-related anxiety, difficulty seeing the real-world relevance of mathematical concepts, inadequate practice leading to poor retention and lower confidence, a curriculum that advances too quickly, limited access to necessary learning resources, a negative mindset and external factors such as personal or family challenges that hinder focus (Grájeda et al., 2024).

Improving students' performance in mathematics requires a comprehensive strategy. This includes tailored instruction, effective teaching techniques, a supportive classroom environment and access to independent learning resources. Encouraging a positive attitude towards mathematics and integrating real-world applications can also significantly enhance student engagement and achievement (How & Hung, 2019; Pedró, 2020). Teachers can further boost students' mathematical skills by identifying learning gaps, using diverse instructional methods, setting clear objectives, making lessons relevant, encouraging active learning, offering plenty of practice opportunities, providing feedback, fostering critical thinking, using formative assessment, cultivating a growth mindset and offering additional resources (Darmayanti, 2024). Creating a positive, supportive atmosphere, setting realistic expectations, incorporating technology, adjusting instruction based on progress, and promoting self-reflection are also important components of an effective teaching approach (Grájeda et al., 2024).

Of particular interest to this study is the role of technology in enhancing mathematics teaching and learning. Technology enriches mathematics education by offering innovative tools, resources and approaches that complement traditional methods (Li et al., 2024). When used effectively, it can improve students' comprehension, retention and ability to apply mathematical concepts, preparing them for success in a technology-driven society. Technology provides the necessary tools, infrastructure and computational power to develop and implement AI systems, which in

turn use these advancements to analyse data, learn from it, and make informed decisions or predictions (Grájeda et al., 2024). Artificial intelligence is increasingly being integrated into educational contexts, particularly in mathematics, to enhance both teaching and learning experiences.

Artificial intelligence tools and their role in mathematics education

One AI tool gaining popularity among mathematics educators is ChatGPT, an advanced conversational AI model developed by OpenAI. Powered by Generative Pre-trained Transformer (GPT) GPT-3.5, ChatGPT has been trained on a vast array of internet text, enabling it to generate human-like responses, answer queries and assist with various tasks (Harry & Sayudin, 2023; Pedró, 2020). With its broad knowledge and strong understanding of context, ChatGPT is highly versatile and can be used for content creation, virtual assistance and education support. Although it possesses expertise across a wide range of topics up until September 2021, it may lack information on events beyond that date. ChatGPT represents a major leap in AI-driven conversation, with the potential to transform human–computer interaction across multiple sectors.

In the educational sphere, ChatGPT can assist teachers by saving time and facilitating the creation of innovative lessons. Mathematics teachers can use ChatGPT to link mathematical topics to real-world contexts and students' interests, as well as to develop a variety of instructional materials (Zreik, 2024). However, there are concerns that over-reliance on AI tools such as ChatGPT might undermine students' ability to develop their own problem-solving skills (Grájeda et al., 2024). Despite these concerns, ChatGPT remains a valuable resource for teachers aiming to craft engaging learning experiences and streamline their workflow.

The application of AI in mathematics education can be seen through various forms, from intelligent tutoring systems to adaptive learning platforms and predictive analytics. Artificial intelligence tools, such as platforms like DreamBox, Aleph and Mathway, allow students to work through problems at their own pace, offering guidance when they encounter difficulties. These systems often rely on machine learning algorithms that analyse a student's performance to predict where they might struggle, thus providing targeted support to strengthen understanding (Darmayanti, 2024).

For instance, adaptive learning platforms adjust the difficulty of problems based on the student's performance, ensuring that they are neither overwhelmed nor under-stimulated. This approach has the potential to create an optimal learning environment, where students are consistently challenged at the right level (Li et al., 2024). Moreover, AI-driven systems can offer immediate feedback, allowing learners to correct their mistakes in real-time and reinforcing key concepts. In this way, AI can help promote a more meaningful engagement with mathematical principles by facilitating personalised, responsive learning experiences.

The concept of meaningful learning in mathematics

Meaningful learning in mathematics goes beyond rote memorisation of formulas or the mechanical application of algorithms. It requires students to develop a deep understanding of mathematical concepts, make connections between different ideas, and apply their knowledge in real-world contexts (Zreik, 2024). The use of AI in mathematics education has the potential to support meaningful learning by offering dynamic, interactive environments where students can experiment with different approaches and receive immediate feedback.

Artificial intelligence tools encourage exploration and active learning, allowing students to experiment with various mathematical operations and see the immediate effects of their choices (Pedró, 2020). For example, AI-based graphing calculators and algebra systems can help students visualise complex functions, manipulate equations and explore geometric transformations. This hands-on approach can enhance students' conceptual understanding by making abstract concepts more tangible (Grájeda et al., 2024).

Furthermore, AI systems can provide opportunities for students to engage in problem-solving activities that mimic real-world scenarios. By solving applied mathematics problems, students can develop a more intuitive grasp of mathematical principles and understand how they relate to everyday life or professional contexts, such as engineering, economics or data science (Li et al., 2024).

Enhancing personalisation and differentiation

One of the primary advantages of AI tools in mathematics education is their ability to personalise learning experiences. Traditional classroom settings often struggle to cater to the individual needs of every student, especially when class sizes are large or resources are limited. Artificial intelligence tools can address this challenge by offering customised learning paths tailored to each student's strengths, weaknesses and learning pace (Grájeda et al., 2024; How & Hung, 2019).

For instance, intelligent tutoring systems, such as Carnegie Learning's MATHia, use AI to adapt lessons based on a student's individual learning progress (Li et al., 2024). This personalisation is essential in fostering meaningful learning, as it ensures that students are working at their appropriate level of challenge (Pedró, 2020). Advanced learners can move forward more quickly, while those needing extra support can receive additional practice and clarification on difficult concepts. This differentiated approach can help close learning gaps and ensure that all students achieve a deeper understanding of the material.

Moreover, AI tools can offer students multiple ways of engaging with mathematical concepts. For example, students

can approach the same problem through visual, auditory or kinaesthetic modes, depending on their preferred learning style (Zreik, 2024). This flexibility can make mathematics more accessible and engaging for a diverse range of learners, promoting a more inclusive learning environment.

Supporting teachers and enhancing assessment

The use of AI in mathematics education not only benefits students but also provides valuable support for teachers. Artificial intelligence tools can reduce the burden of administrative tasks, such as grading, allowing teachers to focus on more meaningful instructional activities. Automated grading systems can quickly assess students' work, providing immediate feedback and analysis of common errors. Teachers can then use this data to identify areas where students are struggling and adjust their teaching strategies accordingly.

In addition, AI can enhance formative assessment by providing continuous feedback throughout the learning process. Traditional assessments, such as end-of-term exams, often fail to capture a student's learning trajectory or identify specific gaps in understanding. Artificial intelligence systems, on the other hand, can track a student's progress in real-time, offering insights into their learning patterns and predicting potential challenges (Zreik, 2024). This data-driven approach allows teachers to intervene early, offering targeted support before misconceptions become deeply ingrained (García-Martínez et al., 2023).

Furthermore, AI tools can support differentiated instruction by offering teachers insights into each student's unique learning needs. For example, platforms like Century Tech provide analytics that highlight how individual students are progressing and which topics require additional attention (García-Martínez et al., 2023). These insights can inform lesson planning and ensure that instruction is tailored to the needs of the class, thereby fostering a more meaningful learning environment (Darmayanti, 2024).

Challenges and considerations

While the potential benefits of AI in mathematics education are significant, there are also important challenges and considerations that must be addressed. One concern is the potential for over-reliance on AI tools, which may lead to a diminished role for teachers (Harry & Sayudin, 2023). While AI can automate certain tasks, the human element of teaching – such as providing emotional support, fostering critical thinking and encouraging collaboration – remains irreplaceable (García-Martínez et al., 2023). Therefore, AI should be seen as a tool that complements, rather than replaces, the teacher's role in facilitating meaningful learning.

Another challenge is the issue of accessibility. Not all schools or higher education institutions have the resources to invest in sophisticated AI tools (Zreik, 2024). The digital divide could exacerbate existing educational inequalities, particularly in under-resourced communities. Ensuring equitable access to AI technology is essential if it is to have a positive impact on meaningful learning in mathematics (How & Hung, 2019; Li et al., 2024).

In addition, there are ethical concerns related to data privacy and the use of AI in education. Artificial intelligence tools often collect large amounts of data on students' performance and behaviour, raising questions about how these data are used and who has access to it (Pedró, 2020). Protecting students' privacy and ensuring that data are used responsibly is critical in the implementation of AI technologies in education.

The future of artificial intelligence in mathematics education

As AI technology continues to evolve, its potential to enhance mathematics education will likely expand. Future developments in AI could lead to even more sophisticated tools that can analyse students' thought processes, offer nuanced feedback, and support collaborative learning. For example, AI systems might be able to facilitate peer tutoring or group work by matching students with complementary skills and providing real-time feedback on their collaborative efforts (Li et al., 2024).

Moreover, AI could play a role in bridging the gap between school and higher education by offering continuous learning pathways. Artificial intelligence-driven platforms could support students as they transition from one level of education to the next, ensuring that they build on their previous knowledge and are adequately prepared for more advanced mathematical concepts.

The potential impact of AI tools on the meaningful learning of mathematics in schools and higher education is vast. Artificial intelligence has the capacity to personalise learning, enhance problem-solving skills and provide real-time feedback that fosters deeper understanding (Grájeda et al., 2024). However, for AI to truly enhance meaningful learning, it must be implemented thoughtfully, with careful consideration of its limitations and ethical implications. By complementing, rather than replacing, traditional teaching methods, AI can play a significant role in transforming mathematics education for the better, helping to create more dynamic, inclusive and effective learning environments for all students.

References

Darmayanti, R. (2024). Programmed learning in mathematics education before and after the pandemic: Academics integrate technology. *Assyfa Learning Journal, 2*(1), 40–56.

Harry, A., & Sayudin, S. (2023). Role of AI in education. *Interdiciplinary Journal and Hummanity (INJURITY), 2*(3), 260–268. https://doi.org/10.58631/injurity.v2i3.52

How, M.L., & Hung, W.L.D. (2019). Educing AI-thinking in science, technology, engineering, arts, and mathematics (STEAM) education. *Education Sciences, 9*(3), 184. https://doi.org/10.3390/educsci9030184

García-Martínez, I., Fernández-Batanero, J.M., Fernández-Cerero, J., & León, S.P. (2023). Analysing the impact of artificial intelligence and computational sciences on student performance: Systematic review and meta-analysis. *Journal of New Approaches in Educational Research, 12*(1), 171–197. https://doi.org/10.7821/naer.2023.1.1240

Grájeda, A., Burgos, J., Córdova, P., & Sanjinés, A. (2024). Assessing student-perceived impact of using artificial intelligence tools: Construction of a synthetic index of application in higher education. *Cogent Education, 11*(1), 2287917. https://doi.org/10.1080/2331186X.2023.2287917

Li, X., Gould, T., & Zaki, R. (2024). The impact of artificial intelligence on learners and teachers: A mathematics education perspective. In S. Papadakis & M. Kalogiannakis (Eds.), *Education, development and intervention: Toward participatory and integrated solutions* (pp. 133–148). Springer Nature Switzerland.

Pedró, F. (2020). Applications of artificial intelligence to higher education: Possibilities, evidence, and challenges. *IUL Research, 1*(1), 61–76. https://doi.org/10.57568/iulres.v1i1.43

Zreik, M. (2024). Redefining mathematics education in the age of artificial intelligence: Challenges and opportunities. In E. Njurai & A. Uworwabayeho (Eds.), *Impacts of globalization and innovation in mathematics education* (pp. 19–40).