Annual of Konstantin Preslavsky University of Shumen
Faculty of Mathematics and Informatics
vol. XXVI C, 2025, pp. 139– 148, https://doi.org/10.46687/YAUI8030

ARTIFICIAL INTELLIGENCE IN TEACHING GEOMETRY TO STUDENTS: OPPORTUNITIES AND WARNINGS

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ABSTRACT: *Education today, particularly mathematics education, requires a deep understanding of how to apply AI technologies in teaching, making optimal use of their advantages while preventing negative effects on the quality of the educational process. In the modern context of rapid digital technology development, a mathematics teacher can and should serve as a model of competent, active, and balanced use of AI in teaching mathematics, especially geometry. Methodological science must provide teachers who teach geometry with well-grounded methodological guidelines and recommendations for the effective use of AI. The article proposes a systematization of selected methodological recommendations for the effective integration of AI in teaching geometry to students.*

KEYWORDS: *artificial intelligence, digital technologies, teaching geometry;*

2010 Math. Subject Classification: *97M10*

1 Introduction

According to the Concept for the Development of Artificial Intelligence until 2030, adopted in Ukraine in December 2020, artificial intelligence (AI) is planned to be used in nine areas, including education. However, the use of tools such as ChatGPT by students in the educational process has currently caused some confusion and uncertainty within the educational community regarding such collaboration. In this context, the growing attention of education researchers to identifying the benefits and challenges of using AI in teaching is understandable.

2 Analysis

An analysis of several related publications [5, 6, 10–15] allows us to recognize the following advantages of using AI in education:

– AI improves access to education for students with disabilities, particularly through specialized applications that enhance material perception. For example, for students with visual impairments, AI can convert written text into speech or provide real-time audio descriptions of images;

– AI can assist in creating lesson plans by extracting resources from across the Internet, aligning them with curriculum requirements, taking into account the characteristics of a particular class, and adapting to a teacher's individual style;

– AI can reduce the excessive workload of teachers by helping to adjust curricula and assist in student assessment;

– AI can respond quickly to students' actions, helping them to promptly correct mistakes or analyze their own ideas;

– AI can adapt to each learner's unique learning style and pace, providing a qualitatively new level of personalization;

– AI can systematically and comprehensively analyze learning outcomes by collecting data on students' performance, identifying their strengths and weaknesses, and suggesting tasks for further learning and development.

Researchers [7, 13] also identify current challenges in using AI in education, including:

– Privacy concerns, since the collection and processing of large amounts of personal data for analysis always carry the risk of unauthorized data leakage;

– Lack of human ethical understanding, as AI cannot always consider ethical aspects and the moral significance of issues in teaching and counseling;

– Absence of spontaneity and intuition in AI systems, which can limit their ability to respond flexibly and intuitively in educational situations.

Researchers of AI technologies in education emphasize that before implementing AI into the educational process, teachers should undergo professional development and acquire skills to apply these technologies without compromising the quality of education. In particular, I. Bubnov [2] identified relevant tasks to clarify the potential of AI technologies in education:

– use of various AI-based tools to detect plagiarism and dishonest copying;

– development of tasks that require creativity, critical thinking, and an individual approach—tasks that AI cannot easily automate;

– motivating students to use AI technologies for conducting research and solving real-world problems rather than distorting the learning process;

– applying diverse types of assessment (open and closed tests, discussions, practical tasks) that would complicate the possibilities of cheating with AI assistance.

Thus, modern education—particularly mathematics education—requires a deep understanding of how to apply AI technologies in teaching, making optimal use of their benefits while preventing negative effects on the quality of education.

Our analysis of international publications shows that foreign researchers focus on three key aspects: the benefits, the cautions, and the ethics of using AI. Some predict that AI might eventually replace teachers in schools. However, through an analysis of global research, we found substantial arguments from scholars across different continents emphasizing the irreplaceable role of human teachers in AI-supported learning. This underscores the importance of creating an educational environment in which AI and teachers collaborate, utilizing the strengths of both.

In the current era of rapid digital development, mathematics teachers can and should serve as models of competent, active, and balanced use of AI in teaching mathematics, particularly geometry. Geometry remains one of the few intellectual domains where humans still outperform computers. On the other hand, computers can serve as valuable tools for solving certain methodological problems in teaching geometry [8].

Methodological science must provide geometry teachers with well-grounded, research-based guidelines and recommendations for the effective and pedagogically sound use of AI. Researchers in the field of geometry education are already addressing this issue. For instance:

Gladys Sunzuma [13] conducted a systematic literature review on the integration of digital technologies into the teaching and learning of geometry published between 2010 and 2022. The number of such studies was relatively high, with the peak in 2015. Among the most frequently mentioned technologies were GeoGebra, augmented reality (AR), computer animation packages, video-based cooperative learning, graphic calculators, Flash animation, Powtoon, learning management systems (LMS), interactive whiteboards, digital simulations (applets), iPads, and tablets. Most studies focused on evaluating the effectiveness of these technologies in geometry teaching and learning.

In many countries, the aim of studying geometry in school is to develop learners' skills in problem solving, visualization, intuition, critical thinking, hypothesis formulation, logical reasoning, and deductive thinking. The goal is for students to use visualization, develop spatial imagination, and acquire skills in geometric modeling for solving applied problems. However, it has been found that these intended learning goals are often not achieved, and conceptual understanding of geometric ideas remains insufficient [5]. Despite geometry's importance and popularity, researchers have reported numerous challenges in its teaching and learning [11, 14]. One innovative approach proposed by foreign scholars is the qualitative integration of digital technologies into the teaching process, which can

increase learning motivation, improve outcomes, and enhance student engagement [10].

Studies show that learning geometry with computer technologies improves student achievement compared to traditional textbook-based methods [1]. Integrating digital technologies into geometry learning is crucial, as it helps students better understand problem-solving processes. In particular, using software that allows manipulation of 3D geometric objects significantly enhances visualization and comprehension. Moreover, digital tools enable learners to use various resources for solving geometry problems, such as computer animation, video-based collaboration, graphic calculators, Micromedia Flash, Powtoon Animation, learning management systems, interactive boards, and simulation applets. AI, in particular, can make geometry learning more interactive. Limited use of these technologies is often linked to insufficient teacher preparation. Dockendorff and Solar [4] noted that many educators lack the professional training required for effective technology integration in mathematics instruction.

Based on a comprehensive analysis of Ukrainian and international studies, as well as our own experimental research, we have systematized and developed specific recommendations for mathematics teachers on how to use AI technologies in teaching geometry:

- Generative AI models can facilitate distance learning by providing automated feedback, personalized lessons, and interactive problem-solving support, making geometry education more accessible.
- Generative AI is particularly advantageous in geometric design and architectural tasks, where it can generate new geometric patterns. Such AI-generated visuals can assist both teachers and students in solving geometry problems.
- When teachers ask students to prompt generative AI models to produce two contradictory solutions to a geometry problem, it helps them realize that AI can make mistakes, thereby fostering critical thinking.

- One strategy for using AI in geometry problem-solving is to teach students to compare geometric shapes with real-world objects and determine their heights by visualizing them using AI tools such as Canva or GeoGebra.
- Augmented Reality (AR) is a valuable tool for supporting geometry teaching and learning, helping students better understand composition, spatial representation, and other geometric aspects.
- Intelligent tutoring systems that integrate AR can serve as effective learning environments for helping middle and high school students study complex geometry topics.
- Overall, the use of AI in geometry teaching (including computer programs, virtual environments, and robotics) offers students great opportunities for developing creativity and optimizing the learning process.
- Generative AI enhances visualization in geometry, especially through immersive and interactive 3D modeling. The integration of generative AI with extended reality (XR) technologies enables teachers to design more engaging learning experiences that go beyond traditional instruction.
- Combining traditional teaching methods with AI-based tools such as ChatGPT can provide substantial benefits, particularly for students whose cognitive styles align with interactive and exploratory learning, promoting higher-order skills like problem-solving and critical analysis.
- Using AI, teachers can design more effective learning materials for students with intellectual disabilities. In geometry lessons for children with mild intellectual impairments, AI can be applied through visual objects or multimedia formats such as videos and quizzes.
- In its current form—using ChatGPT—and undoubtedly in its future iterations, AI can enhance learning effectiveness by helping to overcome three barriers: lack of applied learning orientation,

illusion of deep understanding, and inability to critically assess content.

- The fact that AI-generated examples may sometimes be inaccurate, irrelevant, or fabricated can be pedagogically leveraged. Teachers can encourage students to compare, analyze, and correct such examples, turning AI's fallibility into a learning opportunity that promotes reflection and critical inquiry.
- Geometry learning requires practice in reinforcing new knowledge and applying it in varied contexts. One powerful way to practice is teaching others. The processes involved in explaining material to someone else deepen understanding and highlight gaps in comprehension. AI opens new possibilities for this kind of interaction.
- Generative AI contributes to automated assessment in geometry, providing immediate feedback essential for student development. Unlike traditional assessment methods that delay feedback, AI-based systems can offer real-time performance analysis, identifying students' strengths and weaknesses.

3 Conclusion

One of the most effective ways to enhance the learning of geometry is the methodically balanced and pedagogically sound integration of digital technologies into the educational process. Through the thoughtful use of artificial intelligence (AI) in geometry instruction, students can explore and explain geometric concepts in multiple forms within a technology-rich environment. Researchers from various countries associate the limited use of modern digital technologies with the insufficient preparation of mathematics teachers for their effective implementation. Methodological science must provide teachers who teach geometry with well-grounded, research-based methodological guidelines and recommendations for the effective use of AI. The systematization and development of methodological recommendations

for the efficient application of AI in teaching geometry represent a key objective of our research

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