FOSTERING STUDENTS' CREATIVE PROBLEM-SOLVING SKILLS IN MATHEMATICS THROUGH GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS

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Annotation: The rapid advancement of digital transformation processes and the integration of generative artificial intelligence (AI) technologies into education are creating new opportunities for improving the content and methodology of mathematics education. In particular, generative AI tools such as ChatGPT, Gemini, Claude, and Copilot expand students' opportunities to engage in independent thinking, develop multiple solution strategies, and demonstrate creative approaches while solving mathematical problems. Contemporary research indicates that, alongside its positive impact on learning outcomes, the effective implementation of generative AI requires the development of appropriate pedagogical mechanisms and instructional frameworks. This article analyzes the theoretical and pedagogical foundations for fostering students' creative approaches to solving mathematical problems through the use of generative AI tools and proposes an innovative methodological model aimed at enhancing creative problem-solving competencies in mathematics education.

Keywords: generative artificial intelligence, mathematics education, creative thinking, mathematical problem solving, creative competence, ChatGPT, innovative educational technologies.

Introduction

In recent years, artificial intelligence (AI) technologies have been widely integrated into nearly all spheres of society and have become an essential component of human activity. In particular, the rapid development of generative artificial intelligence tools has significantly simplified the processes of information retrieval, analysis, and problem-solving. As a result, users increasingly tend to accept AI-generated responses as reliable and unquestionably accurate information, often without conducting independent analysis or verification.

This phenomenon is especially evident in the field of education, particularly in students' approaches to solving mathematical problems. Practical observations indicate that some students are becoming inclined to accept solutions proposed by artificial intelligence without critically analyzing them, verifying their mathematical validity, or comparing them with alternative solution methods. However, generative AI models may, in certain cases, produce inaccurate, incomplete, or erroneous results. Therefore, unquestioning reliance on AI-generated solutions may negatively affect the development of students' critical thinking, analytical reasoning, and independent problem-solving skills.

Such a tendency may adversely affect the development of students' competencies in independent thinking, critical analysis, evidence-based decision-making, and creative problem-solving. From this perspective, fostering students' digital literacy, algorithmic thinking, and the ability to critically evaluate outcomes generated by artificial intelligence has become one of the most pressing pedagogical challenges.

In twenty-first-century education, the development of students' abilities to think creatively, solve complex problems, engage in critical analysis, and generate innovative ideas is recognized as a key educational priority. Therefore, when integrating artificial intelligence technologies into the educational process, it is essential to employ them not merely as tools for providing ready-made answers, but rather as educational instruments

that stimulate students' intellectual engagement and support processes of analysis, reflection, and reasoning.

Accordingly, the effective and pedagogically sound use of artificial intelligence in education requires the implementation of instructional approaches that encourage learners to question, evaluate, and validate AI-generated outputs, thereby promoting deeper learning and the development of higher-order cognitive skills.

Mathematics plays a crucial role in the development of these competencies, as mathematical activity is fundamentally based on processes such as analysis, modeling, generalization, and the discovery of novel solutions.

In recent years, the advancement of generative artificial intelligence technologies has created new pedagogical opportunities within the field of education. Generative AI has emerged not only as a tool for providing information but also as an intellectual partner that supports students in idea generation, problem analysis, and the development of alternative solution strategies.

At the same time, a growing body of research suggests that the inappropriate or excessive use of generative artificial intelligence may reduce students' engagement in independent thinking and cognitive activity. Therefore, the scientific investigation of the pedagogical potential, benefits, and limitations of these technologies has become an increasingly important and relevant research priority.

Problem Statement

In traditional mathematics education, students often rely on predetermined algorithms and standard solution procedures. As a result, opportunities for developing non-standard thinking and generating creative solutions are frequently limited.

At present, the following contradiction can be observed:

- There is an increasing demand for professionals who possess creative thinking skills and the ability to solve complex problems innovatively;

- Mathematics education provides significant opportunities for fostering creativity and developing innovative approaches to problem-solving;
- However, scientifically grounded methodological approaches for the purposeful integration and effective use of generative artificial intelligence tools in mathematics education remain insufficiently developed.

Taking these circumstances into account, the present study aims to develop a pedagogical mechanism for fostering students' creative approaches to solving mathematical problems through the use of generative artificial intelligence tools and to substantiate its effectiveness within the educational process.

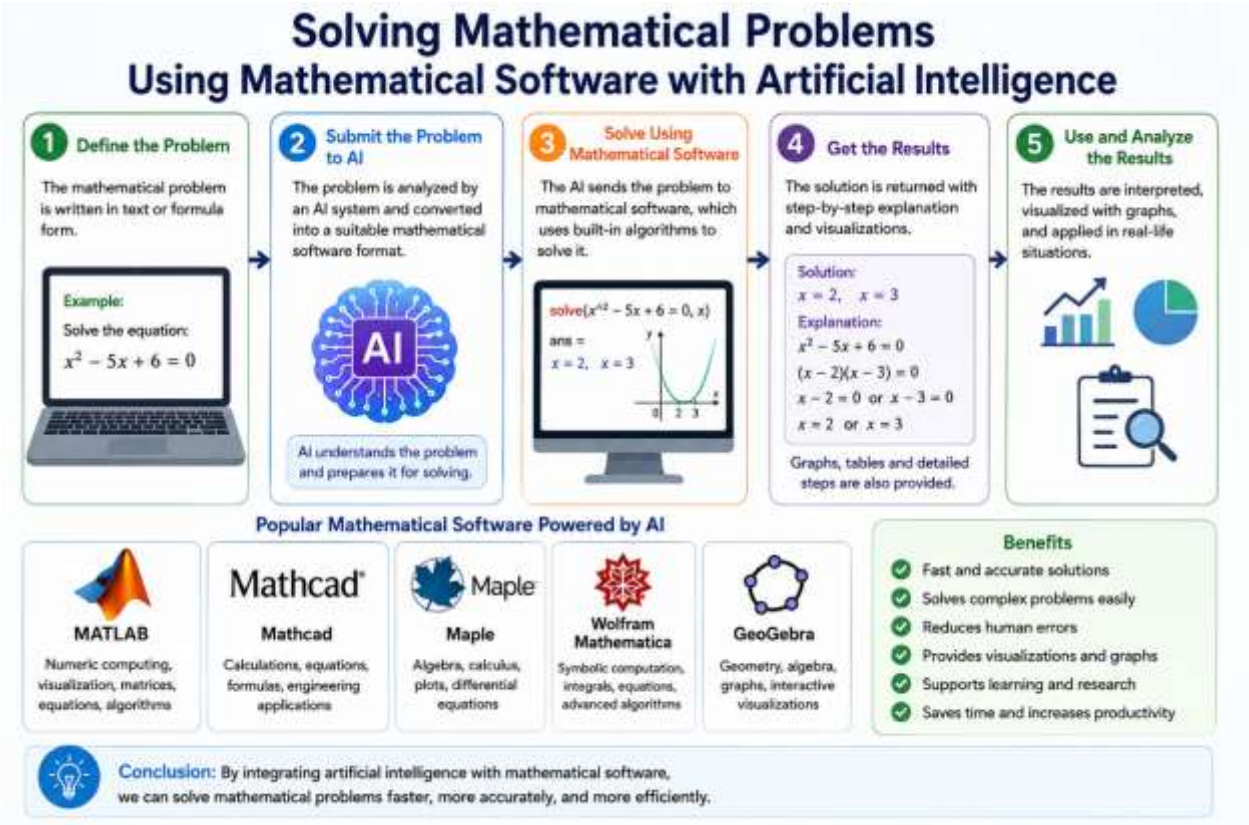
Theoretical Foundations

At present, the combined use of generative artificial intelligence and mathematical software packages is considered one of the most effective approaches for solving mathematical problems, analyzing spatial figures, and developing three-dimensional (3D) models. In the fields of education and scientific research, digital technologies—particularly mathematical software packages and Generative Artificial Intelligence (AI)—are increasingly being integrated, creating a fundamentally new and innovative technological ecosystem. These tools not only perform complex calculations within seconds but also enable the visualization of abstract mathematical concepts in a manner that enhances comprehension and practical understanding.

Mathematical software packages, such as MATLAB, Mathematica, and Maple, provide highly accurate computational capabilities, generate graphical representations, and offer powerful environments for scientific modeling and simulation. However, effective utilization of these software systems generally requires users to possess programming knowledge and an understanding of coding algorithms. This requirement may present challenges and barriers for many learners and practitioners.

In contrast, generative artificial intelligence systems significantly simplify user interaction. To obtain assistance, users typically need only provide a problem statement, an image of the mathematical task, or, in the case of geometric problems, the name and properties of the geometric figure. Generative AI can explain mathematical solutions step by step, interpret formulas, generate algorithms, and support the personalization of the learning process. These capabilities provide substantial benefits for both students and researchers.

Furthermore, in the areas of spatial geometry and three-dimensional modeling, artificial intelligence facilitates the automatic construction, visualization, and rapid generation of geometric objects and 3D models. In engineering, architecture, design, and education, these technologies are increasingly contributing to the development of innovative solutions and enhancing the efficiency of problem-solving and modeling processes.



In the fields of pedagogy and psychology, creative thinking is commonly assessed through the following criteria:

- Originality and accuracy;
- Flexibility;
- Fluency;
- The ability to perceive and analyze a problem from multiple perspectives.

Mathematical creativity, in turn, is characterized by the ability to identify multiple solutions to a given problem, develop novel solution methods, and apply mathematical concepts and ideas to real-world situations.

Recent studies indicate that generative artificial intelligence tools provide students with opportunities to:

- Explore alternative solution approaches;
- Construct mathematical models;
- Formulate and test hypotheses;
- Analyze complex problems through a step-by-step reasoning process.

These capabilities contribute to the enhancement of students' creative and analytical thinking skills, thereby supporting deeper engagement in mathematical problem-solving activities.

Proposed Pedagogical Model

The use of generative artificial intelligence in mathematical problem-solving can be organized through the following stages:

Stage 1. Problem Comprehension

Students examine the problem statement and utilize artificial intelligence tools to analyze different interpretations and perspectives of the problem.

Stage 2. Idea Generation

With the assistance of ChatGPT or other generative AI tools, multiple potential solution strategies and approaches are generated.

Stage 3. Critical Analysis

Students critically evaluate the solutions proposed by artificial intelligence, identify possible errors or limitations, and suggest alternative approaches.

Stage 4. Creative Transformation

Based on the existing solutions, students develop new mathematical models, modify solution strategies, or construct alternative methods for solving the problem.

Stage 5. Reflection

Students evaluate their own learning activities and analyze the effectiveness of using artificial intelligence throughout the problem-solving process.

Research Hypothesis

It is hypothesized that if generative artificial intelligence tools are integrated into the mathematical problem-solving process in a purposeful and methodologically grounded manner, students will demonstrate higher levels of:

- Original thinking;
- Problem-solving ability;
- Mathematical creativity;
- Research and inquiry skills;

when compared with students engaged in traditional instructional approaches.

Consequently, the pedagogically sound integration of generative artificial intelligence into mathematics education is expected to enhance students' cognitive engagement, creative performance, and overall effectiveness in mathematical problem-solving.

Results and Discussion

Contemporary research indicates that generative artificial intelligence possesses significant potential to support creative activities within educational environments. However, its effectiveness is directly dependent on students' active engagement in the learning process and their ability to critically evaluate and analyze the generated outputs.

Therefore, in mathematics education, generative artificial intelligence should be employed not merely as a tool for providing ready-made answers, but rather as an intellectual partner that facilitates reasoning, exploration, and knowledge construction. Such an approach promotes the development of students' independent thinking, critical analysis, and creative problem-solving abilities.

The findings suggest that the pedagogically guided integration of generative AI into mathematical problem-solving can create a more interactive and intellectually stimulating learning environment. By encouraging learners to evaluate alternative solutions, formulate hypotheses, and reflect on their reasoning processes, generative AI contributes to the enhancement of higher-order cognitive skills and mathematical creativity.

Conclusion

Generative artificial intelligence technologies are creating new opportunities for personalizing mathematics education, analyzing complex problems, and fostering students' creative potential. Their integration into the mathematical problem-solving process contributes to the development of creative thinking, research competencies, and innovative skills among learners.

Future research should focus on conducting experimental studies in this field, refining criteria for assessing creative thinking, and developing evidence-based pedagogical models for the effective integration of generative artificial intelligence into mathematics education. These directions represent important scientific and educational priorities for advancing both theory and practice.

In addition, it can be emphasized that while mathematical software packages ensure computational accuracy and efficiency, generative artificial intelligence expands opportunities for analysis, explanation, reasoning, and creative modeling. The integration of these technologies is shaping a new stage in the development of digital education and scientific research, providing innovative pathways for teaching, learning, and knowledge generation.

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