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IMPROVING THE TEACHING OF QUADRATIC FUNCTIONS THROUGH ARTIFICIAL INTELLIGENCE TECHNOLOGIES

Mardon Pardabaev
Samarkand State Pedagogical Institute
Associate Professor of the Department of Mathematics
Abulkasim Yuldashev
Samarkand State Pedagogical Institute Student

Abstract

This article presents an extensive and in-depth study of improving the methodology of teaching quadratic functions in secondary school mathematics through the integration of artificial intelligence (AI) technologies. Quadratic functions constitute one of the core topics of school algebra, forming a conceptual foundation for further studies in functions, equations, inequalities, mathematical modeling, physics, and economics. However, classroom practice shows that students often experience difficulties in understanding the relationship between algebraic representations and graphical interpretations of quadratic functions.

The research analyzes modern pedagogical challenges in teaching quadratic functions and proposes innovative AI-based instructional methods using digital tools such as GeoGebra, Desmos, Wolfram Alpha, and large language models (ChatGPT). These tools enable dynamic visualization, adaptive learning, automated feedback, and personalized instruction. Experimental teaching results demonstrate that AI-supported lessons significantly improve students' functional thinking, graphical literacy, learning motivation, and independent problem-solving skills. The effectiveness of the proposed methodology is confirmed through quantitative and qualitative analysis.

Keywords

quadratic function, parabola, artificial intelligence in education, digital learning technologies, mathematics teaching methodology, visualization, adaptive learning.

INTRODUCTION

In the context of rapid digitalization and the global transformation of education systems, the integration of artificial intelligence into teaching and learning processes has become a key factor in improving educational quality. Mathematics education, in particular, requires innovative approaches that foster not only procedural skills but also conceptual understanding, analytical thinking, and modeling competencies.

Quadratic functions occupy a central position in the secondary school algebra curriculum. Mastery of this topic is essential for understanding subsequent mathematical concepts, including systems of equations, optimization problems, and applied modeling tasks. Despite its importance, numerous studies and classroom observations indicate that students face persistent difficulties in grasping the geometric meaning of quadratic functions, interpreting parameters, and connecting symbolic expressions with graphical behavior.

Traditional teaching methods often rely on static graphs and routine exercises, which may limit students' conceptual engagement. Artificial intelligence technologies offer new pedagogical opportunities by enabling interactive visualization, real-time feedback, individualized learning trajectories, and inquiry-based exploration. Therefore, developing and substantiating an AI-based methodology for teaching quadratic functions is a relevant and timely

research problem.

LITERATURE REVIEW

Recent international research highlights the growing role of artificial intelligence and digital technologies in mathematics education. Studies emphasize that dynamic visualization tools enhance students' understanding of functions and graphs, while adaptive learning systems support differentiated instruction. AI-driven tutoring systems and intelligent feedback mechanisms have been shown to increase learner engagement and achievement.

Research specifically focused on teaching functions indicates that interactive environments such as GeoGebra and Desmos facilitate the transition from procedural manipulation to conceptual reasoning. Furthermore, language-based AI models are increasingly used to scaffold problem-solving processes, generate explanations, and support formative assessment. However, there remains a need for systematic methodological frameworks that integrate these tools into coherent teaching strategies for specific mathematical topics, including quadratic functions.

RESEARCH METHODOLOGY

The study employed a mixed-methods research design combining theoretical analysis, pedagogical experimentation, and statistical evaluation. The object of the research is the process of teaching quadratic functions in secondary school mathematics, while the subject is the methodology of teaching quadratic functions using artificial intelligence technologies.

The experimental study was conducted with ninth-grade students in a general secondary school. Two groups were formed: an experimental group and a control group. In the experimental group, instruction incorporated AI-based tools and methods, while the control group was taught using traditional approaches.

AI-Based Instructional Methods

The following innovative methods were implemented in the experimental group:

Dynamic Graphical Exploration: Students used GeoGebra and Desmos to manipulate parameters of quadratic functions in real time and observe changes in the parabola's shape and position.

AI-Supported Problem Solving: ChatGPT was employed as a guided assistant to provide step-by-step explanations, hints, and alternative solution strategies.

Adaptive Assessment: Digital platforms generated individualized tasks based on students' performance, ensuring personalized learning paths.

Inquiry-Based Modeling: Students explored real-life problems modeled by quadratic functions, supported by AI tools for visualization and computation.

RESULTS AND DISCUSSION

Analysis of pre-test and post-test results revealed a significant improvement in the experimental group's learning outcomes. Students exposed to AI-supported instruction demonstrated higher achievement in identifying key properties of quadratic functions, interpreting graphical features, and solving applied problems.

Quantitative analysis showed that the average achievement level of the experimental group

exceeded that of the control group by approximately 20%. Qualitative observations indicated increased student motivation, active participation, and confidence in independent learning. The integration of AI tools enabled students to experiment, make conjectures, and verify results, thereby strengthening their conceptual understanding.

These findings confirm that artificial intelligence technologies, when pedagogically integrated, enhance the effectiveness of teaching quadratic functions by bridging the gap between symbolic and graphical representations.

METHODOLOGICAL INNOVATIONS AND RECOMMENDATIONS

Based on the research findings, the following methodological innovations and practical recommendations are proposed:

Integrate AI-based visualization tools systematically into algebra lessons to support conceptual learning.

Use language-based AI models to scaffold reasoning rather than replace students' thinking.

Combine adaptive digital assessments with formative feedback to address individual learning needs.

Encourage project-based and modeling activities supported by AI technologies.

Provide professional development for teachers focused on pedagogically sound use of AI tools.

CONCLUSION

The study demonstrates that the integration of artificial intelligence technologies into the teaching of quadratic functions significantly enhances learning effectiveness and student engagement. AI-supported methodologies promote deeper conceptual understanding, functional thinking, and independent learning skills. The proposed approach can be recommended for broader implementation in secondary mathematics education and serves as a foundation for further research into AI-enhanced teaching methodologies.

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