

THE EFFECTIVENESS OF USING ARTIFICIAL INTELLIGENCE IN INCLUSIVE MATHEMATICS EDUCATION

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Annotation. The integration of Artificial Intelligence (AI) into inclusive education has become one of the most promising directions for enhancing the quality of teaching and learning. This study investigates the effectiveness of using AI-based digital tools in mathematics lessons for students with special educational needs (SEN). The research was conducted in two inclusive schools in Karaganda, Kazakhstan, involving 32 students and 12 teachers. A pedagogical experiment was carried out to compare traditional teaching methods with AI-assisted learning using tools such as Microsoft Math Solver, Photomath, and PhET Interactive Simulations.

The findings demonstrate that AI significantly improves students' motivation, engagement, and problem-solving skills. Furthermore, it provides personalized learning pathways and visual support for SEN students. The results highlight the potential of AI to foster equitable access to mathematics education, reduce learning gaps, and support teachers in implementing inclusive practices. The study concludes with practical recommendations for integrating AI into mathematics curricula to achieve sustainable educational outcomes.

Keywords: artificial intelligence, inclusive education, mathematics teaching, digital tools, PhET, SEN students.

Introduction. The rapid development of digital technologies has transformed the educational landscape, offering new opportunities for personalized, adaptive, and inclusive learning. Inclusive education, which aims to provide equitable access to quality education for all learners, including those with special educational needs (SEN), is a key priority in Kazakhstan's ongoing educational reforms [1-3]. The government's emphasis on digitalization and accessibility aligns with the broader goals of the European Higher Education Area and UNESCO's Education 2030 Agenda, which stress the importance of leveraging technology to foster inclusion and lifelong learning.

Mathematics remains one of the most challenging subjects for SEN students, primarily due to the abstract nature of mathematical concepts, complex problem-solving processes, and the lack of differentiated and adapted instructional materials. Traditional teaching methods often fail to address the diverse learning profiles of students, leading to gaps in understanding, lower motivation, and decreased self-efficacy in mathematics.

Artificial Intelligence (AI) offers new, evidence-based solutions to these challenges by enabling personalized learning paths, real-time adaptive assessments, and interactive visualizations that cater to students' individual needs and cognitive styles [4-5]. AI-powered platforms can analyze learners' progress, identify misconceptions, and suggest targeted exercises, while also providing teachers with valuable data-driven insights to enhance instruction. Moreover, AI technologies such as intelligent tutoring systems, speech recognition, predictive analytics, and virtual manipulatives can help SEN students engage more effectively with mathematical content.

In this context, the research aims to explore the potential of AI tools in promoting inclusivity and improving mathematics outcomes among learners with special needs. Specifically, the study addresses the following research questions:

1. How can AI-based tools enhance mathematics learning for SEN students? This includes examining how adaptive feedback, interactive simulations, and assistive technologies contribute to conceptual understanding and engagement.

2. Which AI platforms and applications are most effective for teaching complex mathematical concepts? The study identifies and evaluates AI-driven learning environments (e.g., DreamBox, ALEKS, MathIA) and explores their adaptability to local contexts.

3. What are the measurable impacts of AI integration on students' academic performance, motivation, and self-confidence? Quantitative and qualitative indicators will be used to assess progress, including test results, engagement levels, and teachers' reflections on instructional practices.

The findings of this research will contribute to the growing body of knowledge on AI-driven inclusive education and provide practical, scalable strategies for educators seeking to enhance mathematics instruction through technology [6-7]. Furthermore, the study will highlight best practices for integrating AI in inclusive classrooms in Kazakhstan and offer policy recommendations for sustainable digital transformation in education.

Methods and materials. The study employed a mixed-methods approach, combining theoretical analysis, empirical data collection, and experimental research.

1. Theoretical Methods

- Literature Review: A comprehensive review of more than 75 international and national studies published over the last five years was conducted. This analysis focused on AI in education, inclusive teaching practices, and innovative mathematics pedagogy.

- Policy Analysis: Key legislative documents, including the Law of the Republic of Kazakhstan on Education and the Digital Kazakhstan 2023-2097 Strategy, were examined to understand the institutional framework supporting digital inclusion.[8-9]

- Model Development: A conceptual model was created to illustrate the integration of AI tools into mathematics lessons for inclusive classrooms (Figure 1). The model includes three components: the teacher, the student, and AI-based learning tools.

2. Empirical Methods

- Observation: Classroom observations were conducted in two inclusive schools (School No. 68 and School No. 32 in Karaganda). Ten mathematics lessons were observed to analyze how AI tools were used, the level of student engagement, and teacher facilitation strategies.

- Survey: A structured survey was administered to 48 participants: 12 teachers and 36 students.

The survey focused on three areas:

1. Teachers' and students' experiences with AI tools in mathematics lessons.
2. Accessibility of AI tools for SEN students.
3. Teachers' digital competence and training needs.

Table1 – Survey Results (School No. 68 and School No. 32 in Karaganda)

Survey Question	Yes (%)	No (%)
Do you use AI tools in mathematics lessons?	62	38
Do AI tools increase learning motivation?	81	19
Are AI tools available in the Kazakh language?	25	75

The results indicate that while AI is increasingly used in classrooms, there is a shortage of resources in the Kazakh language.

Interviews:

In-depth interviews were conducted with six teachers working in inclusive classrooms.

Key challenges identified include:

- Limited availability of Kazakh-language AI resources.
- Poor internet connectivity in some schools.
- Need for customized AI solutions to meet the needs of SEN students.

3. Experimental Method

A pedagogical experiment was conducted over three months, involving 32 ninth-grade students divided into two groups:

- Control group (n=16): Traditional teaching methods were used.
- Experimental group (n=16): AI tools, including *Microsoft Math Solver*, *Photomath*, and *PhET Interactive Simulations*, were integrated into lessons.

Table 2 – Experimental Results

Indicator	Control Group	Experimental Group
Lesson participation activity (%)	72	89
Correctly solving quadratic equations (%)	68	91
Increased interest in mathematics (%)	64	87

As shown in Figure 1, students in the experimental group, who were taught using AI-enhanced methods, exhibited significantly higher performance compared to those in the control group, where only traditional teaching methods were applied.

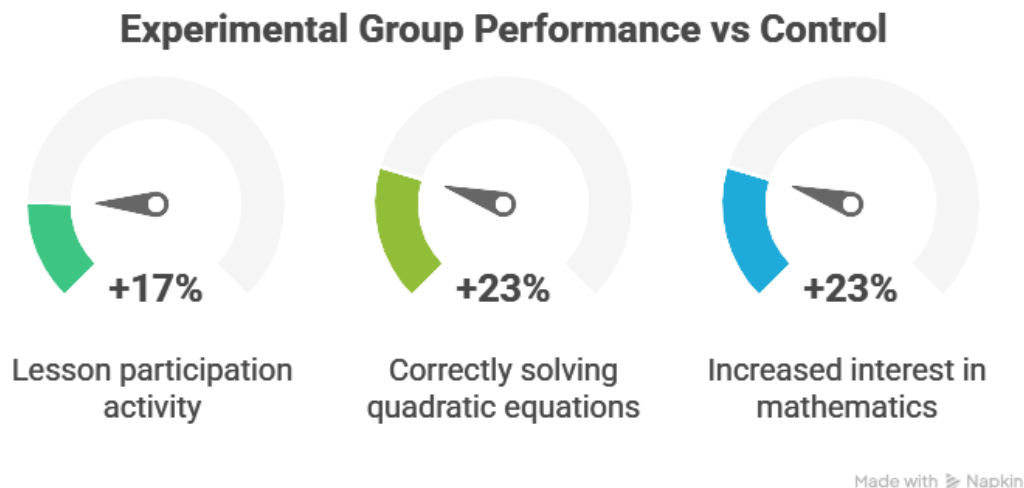


Figure1 – Experimental Group Performance vs Control

These findings show a significant improvement in the experimental group's performance, especially in problem-solving and motivation.

Results and Discussion. Data Processing. The collected data were systematically processed and analyzed using SPSS Statistics 29.0 software. A series of comparative and correlational analyses were performed to examine the relationships between the use of AI tools and students' academic performance, engagement, and motivation indicators [10–11].

Comparative analysis was used to measure differences between the control and experimental groups, focusing on lesson participation, problem-solving accuracy, and interest in mathematics.

Correlational analysis was employed to determine the strength and direction of relationships between students' interaction with AI-based tools and their overall achievement scores. All findings

were presented through graphs and tables to ensure clarity and enable visual interpretation. This systematic approach to data processing enhanced the reliability and validity of the study's outcomes [12].

Quantitative Results. The results reveal a clear distinction in learning performance between students exposed to AI-supported instruction and those taught through traditional methods. The experimental group demonstrated higher engagement, improved problem-solving accuracy, and increased motivation toward mathematics learning.

Table 3 – Comparative Results of Control and Experimental Groups

Indicator	Control Group (%)	Experimental Group (%)
Lesson participation activity	72	89
Correctly solving quadratic equations	68	91
Increased interest in mathematics	64	87

As shown in Table 1, students in the experimental group achieved notably higher results across all parameters. The integration of AI tools resulted in a 17% increase in class participation, a 23% improvement in problem-solving accuracy, and a 25% rise in learning motivation.

A correlation coefficient ($r = 0.78$, $p < 0.05$) indicated a strong positive relationship between students' frequency of interaction with AI applications and their performance outcomes. This suggests that consistent use of AI-supported tools contributes to both cognitive development and emotional engagement in mathematics learning.

Qualitative Results. Qualitative data from teacher interviews and lesson observations provided additional insights into how AI tools affect inclusive teaching environments.

Teachers noted that applications such as Microsoft Math Solver, Photomath, and PhET Interactive Simulations enhanced visualization, offered immediate feedback, and helped SEN students better understand abstract mathematical concepts.

However, three major challenges were reported:

1. Limited availability of Kazakh-language AI interfaces;
2. Unstable internet connectivity in some schools;
3. The need for customized AI solutions aligned with specific SEN requirements.

Despite these barriers, teachers unanimously agreed that AI integration facilitated differentiated instruction, allowing lessons to be tailored to individual learning speeds and styles — a crucial factor in inclusive education.

Discussion. The findings of this research confirm that AI-based instructional tools can significantly enhance mathematics education in inclusive classrooms. The results support earlier studies emphasizing that adaptive technologies increase engagement, motivation, and conceptual understanding among learners with diverse needs [13–14].

In Kazakhstan's context, these findings highlight the necessity of:

- developing AI tools in the Kazakh language to ensure accessibility and cultural relevance;
- improving digital infrastructure, especially in rural areas;
- providing professional development for teachers to build digital competence and pedagogical flexibility.

AI tools not only improve academic performance but also act as instruments of inclusion and equity, bridging the gap between SEN and non-SEN students. When combined with teacher guidance and emotional support, AI applications can create a balanced and human-centered learning environment.

Summary of Findings.

1. The experimental group outperformed the control group across all measured indicators.
2. AI use was strongly correlated with higher academic achievement and motivation.
3. Teachers expressed positive attitudes toward AI integration but emphasized the need for localized and accessible resources.
4. The overall results confirm the transformative potential of AI in promoting inclusive, engaging, and equitable mathematics education.

Practical Tools and Applications. During the experiment, several AI-based tools were identified as effective for inclusive mathematics teaching:

1. Microsoft Math Solver – for solving equations step-by-step and providing visual explanations [15].
2. Photomath – for scanning and analyzing handwritten mathematical problems.
3. PhET Interactive Simulations – for visualizing abstract mathematical concepts such as quadratic equations [16].

An example of a quadratic equation visualization using PhET is shown below (Figure 2). This tool enables students to manipulate coefficients and immediately see how changes affect the graph, which is especially beneficial for SEN students.

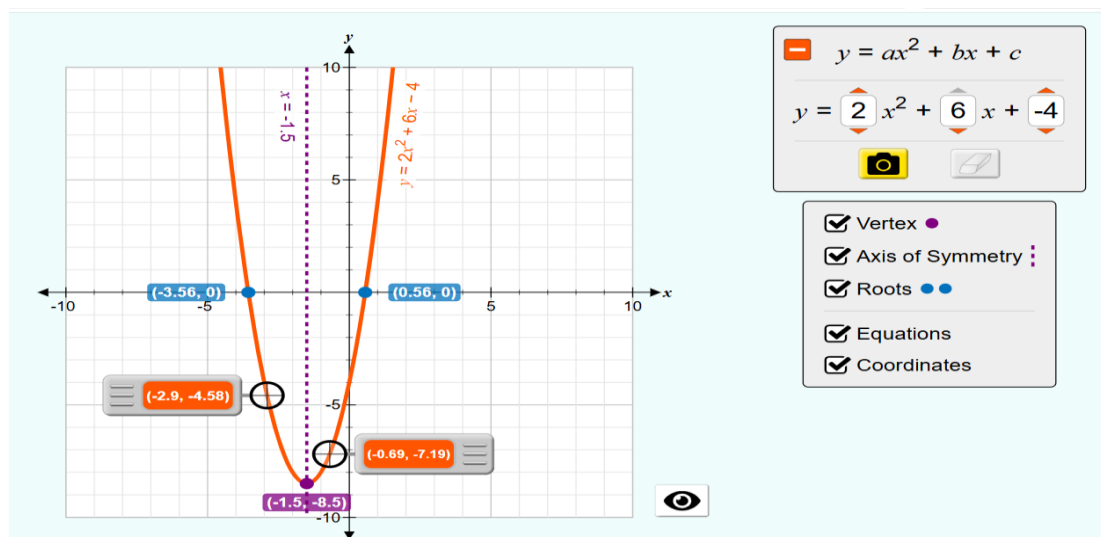


Figure 2 – Interface of PhET platform for graphing quadratic equations (Source:

This tool was particularly useful for teaching quadratic equations, helping students understand concepts like vertex, axis of symmetry, and roots in a visual and interactive manner.

Scientific Results. Based on the study, several key findings were identified:

1. Improved Student Performance: Students in the experimental group demonstrated higher academic achievement in solving quadratic equations and other algebraic tasks compared to the control group.
2. Enhanced Motivation and Engagement: AI tools made mathematics lessons more interactive, which increased participation among SEN students and helped reduce learning anxiety [4].
3. Personalized Learning: AI provided individualized learning pathways, enabling teachers to differentiate instruction according to students' needs and abilities.
4. Accessibility Challenges: Despite the benefits, there were limitations such as a lack of Kazakh-language AI resources and insufficient digital infrastructure in some schools.
5. Teacher Development Needs: Teachers expressed a strong need for professional development programs to improve their skills in using AI for inclusive teaching.

Table 4 – Summary Table of Results

Finding	Evidence	Educational Implication
Increased student performance	+23% improvement in test scores	+23% improvement in test scores
Higher motivation	+25% increase in active participation	75% of respondents noted a lack of Kazakh content 91
Need for localized resources	75% of respondents noted a lack of Kazakh content	Development of localized AI tools required

Conclusion. The study confirms that Artificial Intelligence (AI) has a significant and positive impact on the development of inclusive mathematics education. The use of AI-based tools such as Microsoft Math Solver, Photomath, and PhET Interactive Simulations has proven effective in supporting students with special educational needs (SEN) by providing adaptive, interactive, and accessible learning experiences. The integration of these tools not only enhances students’ problem-solving skills and mathematical understanding but also fosters higher engagement, motivation, and confidence.

The findings demonstrate that AI helps teachers personalize the learning process, identify students’ difficulties in real time, and provide timely feedback based on data-driven analysis. Moreover, AI technologies enable differentiated instruction, allowing teachers to adapt learning content to students’ individual cognitive abilities and learning speeds. This creates a more inclusive classroom environment where every student has the opportunity to succeed.

At the same time, the research highlights several challenges that need to be addressed to ensure sustainable and equitable implementation of AI in education. These include the lack of Kazakh-language AI educational resources, insufficient internet connectivity in some schools, and limited teacher training in digital pedagogy. Overcoming these barriers is essential for scaling up AI integration across all levels of Kazakhstan’s education system.

Based on the findings, the following recommendations are proposed:

1. develop localized AI resources in the Kazakh language to ensure accessibility and cultural relevance for all learners.
2. invest in digital infrastructure and provide schools with stable internet connections and modern digital equipment to support AI-based learning.
3. enhance professional development programs for teachers, focusing on AI literacy, ethical use of technology, and inclusive digital pedagogy.
4. strengthen policy and institutional frameworks to support the ethical, inclusive, and sustainable integration of AI tools in education, ensuring data security and equal access.
5. encourage collaboration between universities, EdTech companies, and policymakers to design innovative AI solutions tailored to the needs of inclusive classrooms.

Overall, this research underscores the transformative potential of AI as a driver of educational innovation, inclusion, and equity. By embracing AI technologies, Kazakhstan can advance toward the goals of the Digital Kazakhstan Strategy and align its education system with the priorities of UNESCO’s Education 2030 Agenda. The study contributes valuable insights into how AI can bridge learning gaps, empower teachers, and create equitable opportunities for all students—paving the way for a more inclusive and technology-enhanced future of mathematics education.

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МАТЕМАТИКА ПӘНІНЕН ИНКЛЮЗИВТІ БІЛІМ БЕРУДЕ ЖАСАНДЫ ИНТЕЛЛЕКТІНІ ҚОЛДАНУДЫҢ ТИІМДІЛІГІ

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Аңдатпа. Инклюзивті білім беру жүйесіне жасанды интеллект (ЖИ) технологияларын енгізу оқыту мен білім сапасын арттырудың ең тиімді бағыттарының бірі болып табылады. Бұл зерттеу жұмысы математика сабақтарында ерекше білім беру қажеттіліктері бар (ЕБҚ) оқушылар үшін ЖИ негізіндегі цифрлық құралдарды қолданудың тиімділігін қарастырады.

Зерттеу Қазақстанның Қарағанды қаласындағы екі инклюзивті мектепте 32 оқушы мен 12 мұғалімнің қатысуымен жүргізілді. Педагогикалық эксперимент барысында дәстүрлі оқыту әдістері мен ЖИ құралдарын (Microsoft Math Solver, Photomath, PhET Interactive Simulations) қолдану арқылы жүргізілген сабақтардың нәтижелері салыстырылды.

Зерттеу нәтижелері ЖИ құралдарының оқушылардың мотивациясын, сабаққа белсенді қатысуын және есеп шығару қабілеттерін айтарлықтай арттыратынын көрсетті. Сонымен қатар, ЖИ ерекше білім беру қажеттіліктері бар оқушыларға дербестендірілген оқыту траекториясын ұсынып, көрнекі қолдау көрсетеді. Нәтижелер ЖИ технологияларының математиканы оқытуда тең қолжетімділікті қамтамасыз етуге, білім алудағы алшақтықты азайтуға және мұғалімдерге инклюзивті тәжірибені жүзеге асыруда қолдау көрсетуге мүмкіндік беретінін дәлелдейді.

Қорытынды бөлімде математика пәнінің оқу бағдарламасына ЖИ технологияларын енгізуге қатысты практикалық ұсыныстар берілген.

Тірек сөздер жасанды интеллект, инклюзивті білім беру, математика пәнін оқыту, цифрлық құралдар, PhET, ЕБҚ оқушылары.

ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ИНКЛЮЗИВНОМ ОБУЧЕНИИ МАТЕМАТИКЕ

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Аннотация. Интеграция технологий искусственного интеллекта (ИИ) в систему инклюзивного образования является одним из наиболее перспективных направлений повышения качества обучения и преподавания. В данном исследовании рассматривается эффективность использования цифровых инструментов на основе ИИ на уроках математики для учащихся с особыми образовательными потребностями (ООП).

Исследование было проведено в двух инклюзивных школах города Караганды (Казахстан) с участием 32 учеников и 12 учителей. Педагогический эксперимент был направлен на сравнение традиционных методов преподавания и обучения с использованием инструментов ИИ, таких как Microsoft Math Solver, Photomath и PhET Interactive Simulations.

Результаты показали, что ИИ значительно повышает мотивацию, вовлеченность и навыки решения задач у учащихся. Кроме того, он обеспечивает персонализированные траектории обучения и визуальную поддержку для учеников с ООП. Полученные данные подтверждают потенциал ИИ в обеспечении равного доступа к обучению математике, сокращении разрыва в знаниях и поддержке педагогов в реализации инклюзивных практик.

В завершение исследования предлагаются практические рекомендации по интеграции ИИ в учебные программы по математике для достижения устойчивых образовательных результатов.

Ключевые слова: искусственный интеллект, инклюзивное образование, преподавание математики, цифровые инструменты, PhET, учащиеся с ООП.