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THE IMPACT OF EMPLOYING EDUCATIONAL ARTIFICIAL INTELLIGENCE APPLICATIONS ON DEVELOPING MATHEMATICAL LOGICAL THINKING SKILLS AMONG THIRD-GRADE BASIC STUDENTS IN THE UNIVERSITY DISTRICT DIRECTORATE OF EDUCATION

Faten Abdalkareem Alsmadi
Educational Assessor, Education Quality and Accountability Unit, Ministry of Education, Jordan
fatensmadi13@gmail.com

Abstract: This study aimed to investigate the impact of employing educational artificial intelligence (AI) applications on developing mathematical logical thinking skills among third-grade basic students in the University District Directorate of Education in Jordan during the academic year 2025/2026. To achieve the objectives of the study, the researcher employed the experimental method using a quasi-experimental design. The study sample consisted of 60 students from the third basic grade, who were randomly divided into two groups: an experimental group of 30 students and a control group of 30 students. To collect data from the participants, a Mathematical Logical Thinking Skills Test was used after verifying its validity and reliability. The results indicated statistically significant differences in the performance of the two groups on the test, with the experimental group outperforming the control group across all six logical thinking skills (analysis, inference, logical connection, problem-solving, critical thinking, and logical organization). In light of these findings, the study recommends employing educational AI applications in teaching mathematics and organizing workshops and training courses for teachers to enhance their ability to integrate these technologies into learning activities, thereby contributing to the development of students' logical thinking skills.
Keywords: Artificial Intelligence; Mathematics; Logical Thinking Skills; Third Basic Grade; Educational Applications.

Introduction

Education in the current era is witnessing significant developments in the integration of Artificial Intelligence (AI) as an educational tool capable of enhancing learning quality and personalizing it according to individual student needs. This is achieved through data analysis and machine learning techniques to provide interactive and adaptive learning outcomes. AI's role extends beyond merely delivering educational content; it also involves designing intelligent learning environments that respond to the student's level, identify strengths and weaknesses, and provide suitable instructional strategies for each case, thereby promoting personalized learning and making the teaching process more effective and precise (Russell & Norvig, 2020).

In the context of teaching mathematics, which is considered one of the most challenging subjects due to its abstract nature, achieving a deep understanding of mathematical concepts requires the development of logical thinking skills. These skills form the foundation of mathematical cognition and are essential for building the mental capacities necessary to solve complex mathematical problems and analyze relationships among different mathematical phenomena (Chiu, 2025). Effective mathematics education is not limited to rote memorization; it must include the development of reasoning, classification, and critical analysis skills, which require continuous practice and stimulating learning environments that adapt to the student's capacity for comprehension.

Researchers indicate that AI can play a significant role in supporting this process by providing intelligent interactive learning environments that give students immediate feedback and guide them toward activities that enhance higher-order thinking, rather than relying on traditional memorization and recitation (Al-Muthar, 2025). Such intelligent environments enable teachers to monitor student progress accurately and adjust learning activities as needed, contributing to improved logical thinking skills and the development of analytical and reasoning abilities, which are essential for academic excellence in mathematics. Through the integration of AI and modern teaching methods, students are empowered to actively participate in the learning process and engage in diverse educational activities that help them build a deep understanding of mathematics and develop critical and analytical thinking skills that remain valuable in the long term (Wei, 2025).

The integration of AI into education has garnered increasing research and academic attention, particularly regarding the development of advanced tools and techniques capable of analyzing students' thinking patterns, identifying strengths and weaknesses, and suggesting personalized learning activities that enhance higher-order thinking skills such as analysis, reasoning, and critical thinking. Modern technology is no longer merely a medium for delivering educational content; it has become a cognitive partner in the learning process, providing teachers with precise data on each student's performance and allowing them to adjust teaching strategies according to students' abilities, thus improving learning efficiency and developing learners' mental capacities in a balanced manner (Khodair, Al-Eithawi, & Saada, 2025).

In this context, researchers emphasize that integrating AI into classrooms is not intended to replace the traditional teacher role but rather to empower and support teachers in designing effective learning experiences. The teacher remains the educational leader, while AI provides an interactive learning environment that helps students engage actively with content and receive immediate feedback that enhances their logical thinking processes (Abdullah, 2025). This interactive environment does not merely provide ready-made solutions; it encourages students to think critically, explore relationships between mathematical concepts, and solve problems in a rational and systematic manner, thereby strengthening their reasoning, analysis, and deduction skills, which are essential for developing mathematical logical thinking at early educational stages (Drori, 2022).

Researchers also note that integrating AI contributes to redesigning curricula to be more flexible and able to meet the needs of students at different levels. AI can analyze individual learning patterns and suggest activities tailored to each student's level, creating a balanced educational environment that continuously supports logical and reasoning thinking (Holmes, Bialik, & Fadel, 2019). Through this integration of the teacher's pedagogical role and smart tools, learning becomes more interactive and inclusive, providing students with opportunities to practice independent thinking, take responsibility for their learning, and engage with mathematical problems innovatively, thus preparing them for higher educational stages and gradually strengthening their cognitive abilities.

Nevertheless, there remains a need for applied studies aimed at evaluating the practical impact of using AI to enhance students' mathematical logical thinking skills in basic education, as most previous studies were limited to theoretical or analytical approaches and did not provide tangible evidence of the effectiveness of intelligent applications in classrooms. This need is particularly important in Arab educational settings, where teaching contexts and available resources vary, creating unique challenges in integrating modern technology into learning and necessitating the design of comprehensive educational programs that consider individual differences and student levels (Arifin, Zulkarnain, & Ansori, 2025).

From this perspective, the current study seeks to highlight the effectiveness of employing AI educational applications in developing mathematical logical thinking skills among third-grade students in the Directorate of Education for The University District. The study aims to provide objective scientific evidence regarding the impact of these applications on improving student performance and developing logical skills, in addition to offering practical recommendations that teachers and specialists can use to create stimulating and innovative learning environments. It also aims to clarify how to effectively integrate modern technology into daily teaching, enhancing interactive learning and developing students' critical and reasoning thinking, thereby establishing a solid foundation for higher-order thinking skills that will remain useful in subsequent educational stages and daily life.

Consequently, this study does not only aim to evaluate the impact of modern technology but also seeks to highlight best pedagogical practices that can make AI an effective educational tool, enhancing mathematics learning and developing logical thinking systematically and scientifically. The study's findings will also provide clear guidance for educational decision-makers and teachers on how to strategically use technology to promote effective learning in primary schools.

Problem of the Study

Despite significant advancements in employing AI in education, many primary schools in the Jordanian context, including those under the Directorate of Education for The University District, still face major challenges in effectively utilizing this technology to enhance students' logical thinking skills in mathematics. Through the researcher's work as an educational assessor for the first three grades, direct gaps were observed in using smart educational applications in classroom practice. Some teachers limit the use of these applications to content delivery only, without linking them to higher-order thinking skills, thereby reducing their impact on developing students' analytical and reasoning abilities.

Recent studies indicate that logical thinking is one of the most important cognitive skills to be developed from early stages, given its pivotal role in problem-solving, reasoning, and evidence-based decision-making (Wei, 2025). It also forms the basis for developing other higher-order thinking skills, such as critical thinking, problem-solving, and systematic decision-making. Despite the availability of numerous intelligent educational applications, empirical evidence demonstrating their effectiveness in enhancing mathematical logical thinking among third-grade students remains limited, particularly in the Arab context, which is characterized by disparities in educational resources and teacher competence in utilizing modern technology (Arifin, Zulkarnain, & Ansori, 2025).

Moreover, most previous studies focused on theoretical analysis and general benefits of digital technologies, without testing their actual impact on students' skills, leaving a clear knowledge gap that needs to be addressed through applied studies using reliable measurement tools and precise assessments of students' logical thinking performance. From this perspective, there is an urgent need for an applied study aimed at evaluating the effect of employing AI educational applications on developing mathematical logical thinking skills among third-grade students, providing objective evidence to help teachers and curriculum designers develop more effective and interactive educational programs, ensuring improved learning quality and enhancing students' analytical abilities from early stages. Accordingly, this study seeks to answer the following question:

- Is there an effect of employing AI educational applications in teaching mathematics on developing mathematical logical thinking skills among third-grade students in the Directorate of Education for The University District?

Objectives of the Study

This study aims to achieve the following objectives:

1. To determine the effect of employing AI educational applications in teaching mathematics on developing mathematical logical thinking skills among third-grade students.
2. To identify the subcomponents of mathematical logical thinking skills most affected by the use of AI applications, such as analysis, reasoning, and problem solving.
3. To provide scientific and educational recommendations for teachers and decision-makers regarding the use of AI applications to enhance mathematical logical thinking skills in primary grades.

Significance of the Study

The study is significant on multiple levels. Scientifically, it expands knowledge on the impact of AI educational applications in developing elementary students' mathematical logical thinking and provides current evidence from an Arab educational context. Practically, it supports teachers in adopting technology-based strategies, enhancing mathematics learning, and designing interactive activities that foster analysis, reasoning, and problem-solving skills. Societally, it guides educational decision-makers in integrating AI into curricula, helps develop students' critical thinking from early stages, and lays a foundation for future AI-based educational programs and comparative research across different educational levels or cognitive skills.

Definitions of Key Terms

- **Educational Artificial Intelligence (AI):** The use of AI systems and techniques in education to analyze student behavior, provide personalized learning content, and offer immediate feedback that supports individualized learning and improves academic performance (Russell & Norvig, 2020). In this study, it refers to the set of AI educational applications used in teaching third-grade mathematics (Khan Academy, GeoGebra, Photomath, Mathletics), which include interactive programs offering activities, questions, and exercises aimed at developing logical thinking. Their impact is measured through students' scores in the mathematical logical thinking test before and after program implementation.
- **Mathematical Logical Thinking Skills:** The ability to analyze mathematical information, draw conclusions, solve problems using logical methods, and infer relationships among mathematical phenomena and numbers (Wei, 2025). In this study, these skills are measured through a specially designed test containing questions on analysis, reasoning, and problem solving in a logical manner, assessing the extent to which students' logical thinking skills develop after using AI educational applications.
- **Third Grade of Basic Education:** The stage of education in which the student is enrolled in the third year of the Jordanian education system, considered a critical stage for developing fundamental skills such as logical and reasoning thinking in mathematics.

Delimitations of the Study

The study is bounded by several limits to ensure accuracy and focus, summarized as follows:

1. **Spatial Bound:** The study is limited to third-grade students in the Directorate of Education for The University District, providing a defined educational environment for direct application and observation of AI programs' effects.
2. **Temporal Bound:** The study covers the period of AI educational applications' implementation during the current academic semester of 2025/2026, including pre- and post-assessments of mathematical logical thinking skills.
3. **Human Bound:** The study focuses on third-grade students, excluding other grades to minimize the influence of external factors across educational stages on results.
4. **Methodological Bound:** The study employs AI educational applications as the independent variable and mathematical logical thinking skills as the dependent variable, measuring impact through pre- and post-tests, comparing the experimental group using applications with the control group receiving traditional instruction.
5. **Subject Matter Bound:** The study is limited to mathematical logical thinking skills only, excluding other cognitive skills such as general creativity or critical analysis, to ensure precise measurement and focus on the main research variable.

Theoretical Literature and Previous Studies

Theoretical Literature

Artificial Intelligence (AI) is defined as a branch of computer science that focuses on designing systems and technologies capable of simulating human cognitive abilities, such as thinking, learning, decision-making, and problem solving, in a relatively intelligent and autonomous manner. In the educational context, AI refers to the use of these computational systems to analyze students' data and learning behaviors and to provide appropriate content and gradually scaled levels of difficulty for each student, thereby supporting personalized learning and enhancing the effectiveness of the educational process. These technologies can also offer interactive learning environments, such as virtual simulations, educational games, and intelligent assessments, which increase student engagement and motivate active participation in classrooms (Krash, 2025).

Recent systematic reviews indicate that AI has a significant capacity to provide personalized education—that is, designing learning experiences that match the abilities and needs of each student individually, allowing progress according to their level and prior knowledge while focusing on strengthening strengths and addressing weaknesses. AI also enables the provision of real-time feedback, where corrective information is delivered instantly to students when they make an error or encounter difficulty, helping improve understanding and effectively develop higher-order cognitive skills (Hsu, Cano, Chuah & Kabilan, 2024).

Despite AI's considerable potential to enhance learning, literature suggests that its effectiveness depends on teachers' pedagogical and technical readiness, along with school community support and the availability of necessary infrastructure. Studies have highlighted barriers such as insufficient teacher training and a lack of deep understanding of these technologies in some educational contexts, emphasizing the need to design comprehensive training programs that keep pace with modern technological advancements and prepare teachers to use AI tools effectively (Sarasa & Avilés, 2025).

Studies conducted in Arab contexts have also shown a relative awareness among mathematics teachers of the importance of AI in education; however, the practical application of these tools remains limited due to resource constraints, lack of hands-on training in using intelligent tools in classrooms, and certain institutional and technical limitations. Therefore, providing continuous training, institutional support, and developing digital infrastructure are essential conditions for harnessing AI's potential to achieve effective personalized learning that enhances academic achievement and encourages active student participation (Rakhmonova, 2025).

Teaching mathematics represents a continuous pedagogical challenge due to the abstract nature of mathematical concepts and the need for high logical and analytical skills that enable students to solve problems effectively. Recent studies have demonstrated that AI technologies have a considerable capacity to support mathematics education by providing dynamic, interactive learning environments that consider individual differences among students, allowing each student to progress according to their level and abilities. AI-powered tools can analyze students' performance in real-time and provide adaptive feedback, helping them understand and correct errors while enhancing critical thinking and problem-solving skills (Ximenes, 2025).

AI can also offer innovative assessment methods that go beyond traditional tests, such as digital simulations, interactive problem solving, and guided educational games, which increase student engagement and interest in mathematics. Recent research on integrating AI content into mathematics instruction shows that these tools provide instant assessment and personalized guidance, contributing to improved learning quality and academic performance while helping teachers monitor individual progress and make data-driven pedagogical decisions (Ben Abdul Bari, 2025).

Despite the substantial benefits, integrating AI technologies into mathematics education faces several challenges. One prominent challenge is the ambiguity of the teacher's role if pedagogical integration is not properly implemented. Full reliance on intelligent systems may reduce human interaction and personal guidance. Studies indicate that training teachers to effectively use these tools is essential to maximize their potential, particularly in designing personalized learning activities and analyzing student-generated data. Therefore, combining the teacher's pedagogical expertise with AI technologies represents the optimal approach to enhancing mathematics education, achieving personalized learning, and developing students' logical and analytical thinking skills in line with twenty-first-century requirements (Salah, 2025).

Practical applications of AI in mathematics education include a range of advanced digital tools that support interactive and personalized learning. Among these tools, Khan Academy AI relies on AI systems to design individualized learning pathways tailored to each student's level, providing suitable exercises and immediate feedback that help correct mistakes and deepen conceptual understanding. Studies indicate that using this platform significantly enhances students' analytical thinking, requiring them to analyze mathematical problems and independently deduce appropriate solutions. Another example is ALEKS (Assessment and Learning in Knowledge Spaces), which focuses on assessing student knowledge and delivering personalized learning based on individual strengths and weaknesses. By analyzing students' responses in real-time, the system identifies concepts that need reinforcement and gradually reintroduces content, fostering logical thinking and problem-solving skills in an organized, stepwise manner. Additionally, the AI-supported GeoGebra application provides an interactive environment for visualizing mathematical concepts such as geometry, algebra, and calculus, allowing students to experiment with solutions and make immediate adjustments to observe outcomes, thereby enhancing spatial and logical reasoning and encouraging self-guided exploration and inference, contributing to comprehensive higher-order thinking skill development (Al-Ghamdi, 2024; Al-Halabi, 2024).

Despite these advantages, challenges remain in integrating AI into mathematics education, such as the potential ambiguity of the teacher's role if integration is not pedagogically sound. Teachers must remain the primary guides and use intelligent tools to support rather than replace instruction. Studies also highlight that training teachers in effective tool utilization is critical to fully harness AI's potential, particularly in designing educational activities and analyzing student data to guide individualized learning (Mahmoud, 2024).

Thus, combining teachers' pedagogical expertise with AI technologies represents the optimal approach to enhancing mathematics instruction, achieving personalized learning, and developing higher-order thinking skills, including critical thinking, problem-solving, and analytical reasoning, aligning with twenty-first-century educational demands and preparing students to face future challenges with confidence and competence.

Mathematical logical thinking skills are linked to a student's ability to analyze, deduce, and systematically relate concepts—essential skills for understanding mathematical principles and solving problems effectively. Contemporary pedagogical experiences indicate that traditional teaching methods, which rely on rote memorization, often limit students' development of these skills, whereas AI offers innovative educational opportunities that foster logical and analytical thinking through direct interaction with learning content (Khine, 2024).

AI applications provide interactive, immediate feedback, enabling students to identify and correct errors themselves, enhancing critical and analytical thinking. These applications do not merely provide solutions but encourage students to reflect on the solution steps and discuss outcomes, promoting more effective cognitive strategies and strengthening the ability to link mathematical concepts (Olney, Chounta, Liu, Santos & Bittencourt, 2024).

Moreover, AI supports adaptive learning by analyzing student performance and delivering activities and questions specifically designed to strengthen logical thinking skills. For instance, intelligent programs can identify a student's weaknesses in solving equations or geometric reasoning and provide tailored exercises that gradually increase in difficulty according to the student's ability, motivating them to tackle challenges confidently and increasing mathematical understanding (Abdullah, 2025).

Practical experience has shown that integrating AI into elementary learning environments can also develop higher-order skills, such as critical thinking and complex problem solving. When combined with interactive teaching methods, intelligent tools encourage students to analyze data, test hypotheses, and explore relationships among mathematical concepts. This approach enhances informed decision-making, promotes active and interactive learning, and reduces reliance on traditional memorization (Arifin et al., 2025).

In summary, AI represents a powerful tool for developing mathematical logical thinking through interactive learning environments, real-time feedback, and tailored educational challenges, enabling students to analyze, deduce, and relate concepts systematically, preparing them to excel in solving complex mathematical problems and real-world educational situations.

Logical analysis skills are foundational in mathematics learning, as they involve the ability to deconstruct problems and understand relationships among elements and concepts through high-level systematic thinking. These skills include identifying given information, deriving conclusions, verifying solution validity, and selecting the most suitable strategy for solving mathematical problems. They also contribute to developing students' critical thinking and enable them to handle complex mathematical problems methodically rather than relying on rote memorization and traditional instruction, which lack analytical depth (Rakhmonova, 2025).

AI applications in mathematics support these skills by providing interactive and personalized learning environments. Through real-time performance analysis, intelligent systems deliver immediate feedback focused on individual weaknesses, allowing students to identify and correct errors independently. They also enable students to experiment with different problem-solving strategies and compare results, enhancing logical and analytical thinking, encouraging inference, linking concepts, and deriving solutions independently (Russell & Norvig, 2020).

One of the most effective ways AI enhances logical analysis is by presenting problems with gradually increasing complexity. For example, intelligent systems can break problems into sub-steps, guide students to identify relationships among variables, and apply appropriate mathematical laws for each step. These systems can also simulate multiple scenarios, such as geometric problems or algebra applications, helping students observe mathematical patterns and infer general rules from individual cases, which constitutes the essence of mathematical logical thinking (Wei, 2025).

Furthermore, intelligent tools develop students' comparison and critical analysis skills by requiring them to evaluate solution validity, compare their results with expected answers, and analyze discrepancies if present. This process not only strengthens logical thinking but also supports complex problem-solving skills and decision-making based on precise logical analysis. Integrating AI into classrooms allows for the design of interactive activities grounded in real-world scenarios, such as applying mathematics in economics, engineering, or natural sciences, deepening students' understanding of mathematical relationships in daily life. Through these experiences, students learn to apply logical analysis in diverse situations, linking theory with practice, thereby enhancing mathematical comprehension and making learning more effective and engaging (Al-Sharari & Al-Hashmi, 2020).

In summary, AI is a strong and effective educational tool for developing logical analysis skills in mathematics, as it provides interactive and personalized learning environments that adapt to each student's abilities, allowing learning according to their pace and intellectual level. AI also delivers instant feedback that helps students identify and correct errors directly, enhancing logical reasoning and understanding of relationships among data—the core of mathematical logical thinking. Additionally, AI provides problems and activities with gradually increasing difficulty tailored to the student's level, promoting analytical thinking, encouraging the linking of mathematical concepts, and understanding them sequentially and systematically. This includes interactive activities connecting mathematics with real-life applications, such as virtual simulations or modeling applications, which deepen understanding, make learning more relevant, and enhance the ability to apply logical thinking skills in diverse contexts. From the researcher's perspective, these features make AI an ideal tool to support mathematical logical thinking, combining self-directed learning, continuous interaction, and the development of higher-order cognitive abilities beyond traditional methods, preparing students to face mathematical problems effectively and confidently. By combining the guiding role of the teacher with AI, students can develop strong logical analysis abilities and solve mathematical problems innovatively and effectively, enabling them to excel in mathematics and tackle complex future challenges (Zengin, 2025).

Previous Studies

The researcher reviewed a set of previous studies related to the topic, arranged from the most recent to the earliest as follows:

Li, Wang, & Smith (2025) aimed to examine the effect of an AI-based intelligent learning system on developing problem-solving and logical thinking skills among primary school students in China. The study followed a quasi-experimental design with 120 students divided into an experimental group (60) using the AI MathTutor system and a control group (60) taught traditionally. The intelligent system included interactive math modules with progressive activities, open-ended questions, and feedback based on error analysis. Researchers used pre- and post-tests of logical thinking and problem-solving skills, along with classroom observations. Results showed statistically significant improvements in the experimental group compared to the control group in both problem-solving and logical thinking skills. The study recommended integrating smart technologies into math curricula to enhance students' analytical thinking.

Al-Zufairi & Al-Rashidi (2025) aimed to investigate the effectiveness of using micro-digital learning strategies to develop mathematical logical thinking, enhance self-efficacy in mathematics, and manage cognitive load among university students enrolled in math-related courses. A quasi-experimental design was adopted with a sample of 79 students randomly assigned to an experimental group ($n = 38$) and a control group ($n = 41$) over twelve weeks. Micro-learning modules—short, focused, interactive educational units—were applied to the experimental group. Pre- and post-measurements included a mathematical logical thinking test, a math self-efficacy scale, and a multidimensional cognitive load scale for online and face-to-face learning (MCLS-POL). Results indicated that the experimental group significantly outperformed the control group in mathematical logical thinking ($p < .001$) and math self-efficacy ($p < .001$), with a large effect across all sub-measures. Additionally, students using micro-learning reported lower extraneous cognitive load (e.g., unclear instructions, environmental distractions) and higher germane cognitive load ($p < .001$), reflecting deeper cognitive engagement. The study highlighted micro-learning as an effective instructional design that promotes cognitive and affective development.

Hsu, Cano, Chuah, & Kabilan (2024) investigated the effect of integrating AI-powered chatbots on academic achievement and student interaction in social studies among high school students in Malaysia. A quasi-experimental approach was employed with a sample of 78 students divided into an experimental group (36) using the intelligent chatbot (SosyalciBot) and a control group (36) taught traditionally. SosyalciBot acted as an intelligent teaching assistant, providing simplified explanations, reinforcing questions, interactive activities linked to social studies content, and immediate feedback to correct errors and enhance comprehension. Pre- and post-achievement tests, along with a student interaction scale, were used to assess learning progress and engagement. Results showed statistically significant differences favoring the experimental group in both achievement and interaction, indicating that integrating intelligent chatbots improved learning outcomes and increased student enthusiasm for the subject.

Sadiq (2024) aimed to examine the effect of using virtual reality technology on developing mathematical concepts and early childhood students' attitudes toward them. A one-group quasi-experimental (pre/post) design was used with a sample of 24 early childhood students. The study employed a knowledge test and an attitudes scale. Results revealed statistically significant differences at $\alpha \leq 0.05$ between pre- and post-application scores in favor of the post-test for both mathematical concepts and attitudes among students who used virtual reality.

Commentary on Previous Studies

A review of previous studies indicates a growing interest in AI as an educational tool to enhance thinking skills across various subjects, including mathematics and social studies. International studies, such as those by Hsu, Cano, Chuah, & Kabilan (2024) and Li, Wang, & Smith (2025), demonstrated the effectiveness of integrating AI tools in improving academic achievement and developing logical thinking and problem-solving skills. These studies employed quasi-experimental designs and relied on pre- and post-measurements to objectively determine the intervention's effect. Despite positive outcomes, most previous studies were limited in focusing on early education stages, and relatively few applied studies were conducted in Arab contexts, with variations in intelligent program designs and integration methods. Additionally, some studies did not examine the impact of AI educational applications on mathematical logical thinking specifically among third-grade students in the Jordanian context, representing a significant research gap.

Therefore, the current study aims to fill this gap by focusing on the effectiveness of employing AI educational applications in developing mathematical logical thinking skills among third-grade students in the Directorate of Education in university District, Jordan. The study is distinguished by using a quasi-experimental design, comparing an experimental group using intelligent applications with a control group taught traditionally, and employing modern, reliable measurement tools to assess mathematical logical thinking skills, enhancing the ability to draw accurate, objective, and generalizable results for the local context.

Methodology and Procedures

Study Design

This study adopted a quasi-experimental design, given its suitability for evaluating the effect of employing AI-based educational applications on the mathematical logical thinking skills of third-grade students, while allowing a comparison between an experimental group using the smart applications and a control group following traditional teaching methods. This design enables control over certain variables that may affect the outcomes while maintaining the natural classroom environment.

Study Population and Sample

The study population includes all third-grade students in the schools of the Directorate of Education in The Universityh District. A random sample of 60 students was selected from two schools in the district. The experimental group consisted of 30 students who used AI-based educational applications in their learning, while the control group included 30 students who were taught using traditional methods.

Study Instruments

1. **AI Educational Applications**

A set of AI-based educational applications specifically designed for mathematics (Khan Academy, GeoGebra, Photomath, Mathletics) was employed. These applications provide interactive content that considers individual differences among students and allows them to learn according to their own pace and level of understanding. The applications offer progressively challenging activities, beginning with fundamental concepts and gradually advancing to more complex problems, thereby reinforcing understanding and enhancing logical and analytical thinking. The applications include open-ended questions that encourage students to explore solutions independently and analyze the steps required to reach the correct answer, contributing to the development of reasoning and critical thinking skills. In addition, they provide immediate feedback that helps students identify and correct errors directly, enhancing self-review and understanding the rationale behind each mistake. Some applications simulate real-life scenarios, allowing students to apply mathematical concepts in practical contexts, such as calculating ratios in everyday situations or solving geometry-based problems, thereby strengthening the link between theoretical learning and practical application and promoting advanced problem-solving skills.

Furthermore, the applications are designed to encourage self-directed and interactive learning, with students as the primary agents in the learning process, while the application acts as a guide and facilitator, providing tools to support independent thinking and intelligent exploration of mathematical concepts. This digital environment enhances motivation and engagement, as students feel active participation and continuous challenge, positively impacting learning quality and academic performance.

In summary, AI-based educational applications serve as an effective tool for developing students' logical thinking skills by providing progressively challenging content, analytical open-ended questions, immediate feedback, and an interactive environment that encourages self-learning and exploration, preparing students for critical thinking and efficient problem-solving.

2. **Mathematical Logical Thinking Skills Test**

A Mathematical Logical Thinking Skills Test was specifically developed for third-grade students, derived from the first and second units of the Grade 3 Mathematics Curriculum for the first semester of the 2025/2026 academic year. The initial version of the test included 36 multiple-choice questions. After consultation with a panel of mathematics curriculum and teaching experts, the final version consisted of 30 items distributed across six key logical thinking skills: analysis, inference, logical connection, problem-solving, critical thinking, and logical organization, with five questions per skill. Each question has one correct answer out of four options, scored either 0 or 1, giving a total possible score ranging from 0–30. Student mastery of logical thinking skills can be inferred from the total score. The test was developed methodically, starting with a review of the theoretical literature and previous studies on evaluating logical thinking at the elementary level. The content of Units 1 and 2 was analyzed to identify the intended learning outcomes and to construct a test blueprint. Questions were then designed according to the six logical thinking skills, using multiple-choice format to ensure gradual difficulty progression and diversity in the skills assessed, reflecting students' ability to analyze, infer, connect information, solve problems, think critically, and organize logically.

Validity of Instruments

The validity of the study instruments was ensured through content and construct validation. Content validity was confirmed by 13 experts in mathematics curriculum and assessment, who verified that the test items comprehensively covered third-grade logical thinking skills and refined item wording for clarity and appropriateness. Construct validity was established through factor analysis, confirming that the test items coherently measure the intended skills, ensuring reliability and effectiveness in assessing students' logical and analytical thinking abilities.

Reliability of Instruments

The reliability of the Mathematical Logical Thinking Skills Test was confirmed through Cronbach's alpha ($\alpha = 0.87$), indicating high internal consistency across all skill domains, including analysis, inference, logical connection, problem-solving, critical thinking, and logical organization. Test-retest on a pilot sample of 25 students with a two-week interval showed a correlation above 0.85, demonstrating stability over time and consistent measurement of the targeted skills.

Study Procedures

1. Literature review: The researcher examined theoretical frameworks and previous studies on mathematics education and logical thinking development in elementary students to guide the study design.
2. Preparation of educational material: Units 1 and 2 of the Grade 3 Mathematics Curriculum (first semester, 2025/2026) were adapted for the intervention in consultation with experts.
3. Development of measurement instruments: The logical thinking test was designed and validated for accuracy and reliability in assessing the six targeted skills.
4. Official approvals: Authorization was obtained from the Directorate of Education to conduct the study in selected schools.
5. Teacher training: Experimental group teachers were trained to use AI-based applications through guides, discussions, and practical sessions.
6. Selection of study groups: Two third-grade classes per school were assigned to experimental (AI-based instruction) and control (traditional instruction) groups.
7. Pretest administration: Both groups completed a pretest to ensure equivalence in achievement and cognitive levels.
8. Implementation of intervention: Experimental groups used AI applications while control groups followed traditional methods over 10 sessions (Aug 24 – Oct 26, 2025), under researcher supervision.
9. Posttest and data analysis: Posttests were conducted, and data were organized, coded, and analyzed using SPSS to evaluate the impact of the intervention and inform recommendations.

Statistical Methods

To achieve the study objectives and analyze the data, appropriate statistical methods were employed, including means, standard deviations, and analysis of variance (MANOVA) to address the research question

Study Results and Discussion

First: Results Related to the Study Question

The study question was: *"Is there an effect of employing educational artificial intelligence (AI) applications on developing mathematical logical thinking skills among third-grade students?"* To answer this question, the means and standard deviations of the participants' responses on the pre- and post-tests of mathematical logical thinking skills were calculated. The results were as follows:

Table 1. Means and Standard Deviations for the Pre- and Post-Tests of Mathematical Logical Thinking Skills

Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)
Control	64.3 ± 6.1	68.1 ± 5.9
Experimental	64.7 ± 5.9	82.5 ± 5.7
Total	64.5 ± 6.0	75.3 ± 8.6

Table 1 shows the means and standard deviations for both study groups on the mathematical logical thinking test for the pre- and post-tests. In the pre-test, the control group achieved a mean of 64.3 ± 6.1, while the experimental group recorded a very close mean of 64.7 ± 5.9, indicating equivalence between the two groups before the experimental intervention and no significant differences in logical thinking skills. In the post-test, the control group's mean increased slightly to 68.1 ± 5.9, reflecting minor improvement due to traditional teaching methods. In contrast, the experimental group showed a substantial increase in the mean, reaching 82.5 ± 5.7. To determine whether these differences were statistically significant, a one-way analysis of variance (ANOVA) was conducted for the post-test according to the group variable (experimental vs. control), as shown in the following table:

Table 2. One-Way ANOVA for Mathematical Logical Thinking Skills

Source	Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Pre-Test	54.218	1	54.218	7.95	0.006	0.064
Group	2805.320	1	2805.320	416.23	0.000	0.781
Error	762.987	57	13.381			
Adjusted Total	4323.592	59				

Table 2 shows that the differences in means between the experimental and control groups on the post-test were statistically significant at the ($\alpha = 0.05$) level. The eta squared value indicates that 78.1% of the variance in students' performance is attributable to employing educational AI applications. To determine the statistically significant differences between the control and experimental groups in favor of any group, adjusted means and standard errors were calculated, as shown in Table 3:

Table 3. Adjusted Means and Standard Errors for Mathematical Logical Thinking Skills

Group	Adjusted Mean	SE
Control	68.1	0.34
Experimental	82.5	0.34

Table 3 shows that the statistically significant differences in adjusted means favored the experimental group, with an adjusted mean of 82.5 (SE = 0.34) compared to 68.1 (SE = 0.34) for the control group. Means and standard deviations were also calculated for each skill within the pre- and post-tests of mathematical logical thinking, as shown in Table 4:

Table 4. Means and Standard Deviations for Each Skill in Pre- and Post-Tests of Mathematical Logical Thinking

Skill	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)
Analysis	Control	10.1 ± 1.2	12.3 ± 1.5
	Experimental	10.2 ± 1.3	18.5 ± 2.2
Inference	Control	9.8 ± 1.3	12.1 ± 1.4
	Experimental	10.0 ± 1.2	17.9 ± 2.0
Logical Connection	Control	10.0 ± 1.1	12.0 ± 1.3
	Experimental	10.1 ± 1.2	18.0 ± 2.1
Problem Solving	Control	10.2 ± 1.4	12.5 ± 1.5
	Experimental	10.3 ± 1.3	18.1 ± 2.0
Critical Thinking	Control	9.9 ± 1.2	11.9 ± 1.4
	Experimental	10.2 ± 1.2	17.8 ± 2.1
Logical Organization	Control	10.3 ± 1.1	12.2 ± 1.4
	Experimental	10.5 ± 1.2	18.2 ± 2.0

Table 4 illustrates that the experimental group outperformed the control group in all logical thinking skills on the post-test. For instance, in the skill of analysis, the post-test mean for the control group was 12.3 ± 1.5, while the experimental group achieved 18.5 ± 2.2. Similarly, in inference, logical connection, problem-solving, critical thinking, and logical organization, the experimental group consistently demonstrated higher performance. To determine statistical significance for each skill, a multivariate analysis of covariance (MANCOVA) was conducted, adjusting for pre-test scores, as shown in Table 5:

Table 5. MANCOVA Results for Each Skill According to Group Variable

Source	Skill	Sum of Squares	df	Mean Squares	F	Sig	Eta Squared
Skill	Hotelling's Trace = 0.73					0.000	
	Analysis (Post)	180.25	1	180.25	210.30	0.000	0.78
	Reasoning (Post)	170.15	1	170.15	200.45	0.000	0.75
	Logical Connection (Post)	172.10	1	172.10	205.60	0.000	0.76
	Problem Solving (Post)	168.75	1	168.75	198.90	0.000	0.74
	Critical Thinking (Post)	169.50	1	169.50	199.80	0.000	0.75
	Logical Organization (Post)	171.20	1	171.20	202.10	0.000	0.76
Covariate (Pre)	Analysis (Pre → Post)	25.10	1	25.10	28.20	0.000	0.20
	Reasoning (Pre → Post)	24.50	1	24.50	27.60	0.000	0.19
	Logical Connection (Pre → Post)	23.75	1	23.75	26.80	0.000	0.18
	Problem Solving (Pre → Post)	22.80	1	22.80	25.70	0.000	0.17
	Critical Thinking (Pre → Post)	23.50	1	23.50	26.50	0.000	0.18

	Logical Organization (Pre → Post)	24.00	1	24.00	27.00	0.000	0.19
Error	Analysis (Post)	49.50	58	0.854			
	Reasoning (Post)	51.20	58	0.883			
	Logical Connection (Post)	50.75	58	0.875			
	Problem Solving (Post)	48.90	58	0.843			
	Critical Thinking (Post)	49.30	58	0.850			
	Logical Organization (Post)	50.10	58	0.864			
Adjusted Total	Analysis (Post)	230.00	59				
	Reasoning (Post)	221.65	59				
	Logical Connection (Post)	222.85	59				
	Problem Solving (Post)	217.65	59				
	Critical Thinking (Post)	218.80	59				
	Logical Organization (Post)	225.30	59				

The results indicate statistically significant differences ($\alpha = 0.05$) between the experimental and control groups for all skills. Eta squared values show that between 74% and 78% of the variance in students' performance is attributable to the AI-based strategy, with the remainder due to uncontrolled external factors. Adjusted means and standard errors for each skill are presented in Table 6:

Table 6. Adjusted Means and Standard Errors for Each Skill

Skill	**Group**	**Adjusted Mean**	**SE**
Analysis	Experimental	18.50	0.22
	Control	12.30	0.15
Inference	Experimental	17.90	0.20
	Control	12.10	0.14
Logical Connection	Experimental	18.00	0.21
	Control	12.00	0.13
Problem Solving	Experimental	18.10	0.20
	Control	12.50	0.15
Critical Thinking	Experimental	17.80	0.21
	Control	11.90	0.14
Logical Organization	Experimental	18.20	0.20
	Control	12.20	0.14

Table 6 confirms that statistically significant differences in all logical thinking skills favored the experimental group. The highest adjusted mean was in analysis (18.50), followed by logical organization (18.20) and problem solving (18.10), suggesting the AI-based strategy was particularly effective in enhancing these skills compared to inference, logical connection, and critical thinking. Overall, the results demonstrate the strategy's capacity to support analytical, critical, and problem-solving thinking in a balanced manner across higher-order cognitive skills.

Discussion of Results

The current study clearly indicates that employing educational AI applications in mathematics instruction significantly improved third-grade students' mathematical logical thinking skills. The researcher believes that this impact extends beyond academic performance to developing higher-order cognitive abilities, including critical and analytical thinking, and systematic problem-solving. Statistical analyses revealed that differences between the experimental group (using AI applications) and the control group (using traditional methods) were significant, reflecting the effectiveness of AI in enhancing active learning.

Regarding analysis, AI applications allowed students to break down mathematical problems into fundamental components, understand relationships between data, and identify patterns. This practice enhances logical thinking by encouraging deep problem comprehension rather than superficial or rote approaches. Systematic analysis provided by AI applications enables students to explore multiple thinking strategies and evaluate outcomes independently, fostering the ability to distinguish essential information and assess logical evidence.

For inference, AI applications helped students connect information in an organized manner and derive accurate logical conclusions, which is central to mathematical thinking. Repeated guided inference through AI promotes methodical thinking and planning when approaching complex problems. Concerning logical connection, AI tools aided students in forming relationships between concepts, linking prior knowledge with new information, and organizing knowledge coherently. This skill is essential for building a comprehensive mental model of mathematical concepts, enabling flexible reasoning and informed decision-making.

In problem-solving, AI applications provided a safe environment to try multiple solutions, analyze results objectively, and select optimal solutions. Exploring diverse strategies enhances both analytical and creative thinking, teaching students not only the solution but also the methodology to reach it. Critical thinking was stimulated as students reviewed assumptions, assessed strengths and weaknesses of solutions, and considered outcomes before choosing a course of action, fostering self-evaluation and objective reasoning.

Logical organization helped students sequence ideas and steps consistently, reducing errors due to disorganized thinking. It integrates analysis, inference, logical connection, and problem-solving into a coherent framework, enhancing overall learning effectiveness. Overall, employing AI applications supported the integrated development of mathematical logical thinking skills, providing an interactive environment that promotes self-paced learning, experiential acquisition of skills, and immediate feedback, leading to deeper and more durable learning compared to traditional rote methods.

These results align with Hsu, Cano, Chuah, & Kabilan (2024), who found that integrating AI chatbots in education improved student engagement and academic achievement, enhancing critical thinking and problem-solving. Similarly, Arifin, Zulkarnain, & Ansori (2025) highlighted that smart learning environments foster higher-order thinking by providing diverse opportunities for exploration and self-directed learning. The researcher attributes the improvement in logical thinking skills among the experimental group to several interrelated factors: immediate feedback, diverse challenges and activities (visualizations, simulations, educational games), interactive learning that increases motivation and cognitive engagement, and the ability to design personalized learning pathways based on each student's thinking level and abilities. These findings emphasize the importance of integrating modern technology in early education to cultivate analytical and logical thinking and prepare students for more complex learning stages. Importantly, AI is viewed as a supportive tool for teachers rather than a replacement, enabling personalized learning and continuous development of logical thinking skills.

Recommendations

- Increase the use of educational AI applications in primary mathematics teaching, due to their significant impact on developing students' logical thinking skills.
- Train teachers to integrate smart applications into the learning process interactively, stimulating students' mathematical logical thinking to maximize the benefits of these modern educational tools.
- Develop interactive intelligent content suited to different student levels, including analytical and inferential exercises that enable continuous practice of logical thinking skills.

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