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DEVELOPING PRIMARY SCHOOL STUDENTS' LOGICAL AND SYSTEMATIC THINKING THROUGH STEAM-BASED DIAGRAMMATIC PROBLEMS

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Abstract: This paper examines an innovative STEAM-oriented approach to developing logical and systematic thinking skills in primary school students through the application of diagrammatic problem-solving tasks. In contemporary education, there is an increasing demand for teaching methods that encourage active thinking, reasoning, and structured analysis from an early age. The proposed methodology combines interdisciplinary STEAM elements with visual representations to support learners in understanding complex relationships and organizing information effectively. Diagrammatic problems are utilized as a central instructional tool to enhance students' ability to interpret data, establish connections, and make reasoned conclusions. The study also discusses practical teaching strategies, classroom implementation techniques, and the role of guided learning in fostering independent and critical thinking. The results indicate that integrating diagram-based tasks within a STEAM framework positively influences students' cognitive engagement, logical reasoning, and overall academic development.

Keywords: cognitive skills, diagram-based learning, interdisciplinary approach, logical reasoning, primary school education, problem-solving skills, STEAM approach, systematic thinking.

Introduction

In the context of rapid global transformations and the growing demand for innovative and critical thinking, modern education systems increasingly emphasize the development of higher-order cognitive skills from the early stages of learning. Primary education, in particular, plays a fundamental role in shaping students' logical and systematic thinking abilities, which serve as the basis for their future intellectual growth. Traditional teaching methods, primarily focused on memorization and reproduction, are no longer sufficient to address contemporary educational challenges. Therefore, the implementation of interdisciplinary and student-centered approaches has become essential. One of the most effective approaches in this regard is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) framework, which integrates multiple disciplines and promotes both analytical and creative thinking. The inclusion of the arts component enhances students' imagination and supports innovative problem-solving skills, distinguishing STEAM from traditional STEM approaches [1]. This integration enables learners to develop a holistic understanding of knowledge and apply it in various contexts [2]. The theoretical foundations of logical thinking development are deeply rooted in cognitive development theories. Jean Piaget emphasized that children acquire logical reasoning skills through active engagement and interaction with their environment [3]. At the same time, Polya highlighted the importance of structured problem-solving processes in mathematics, suggesting that visual tools such as diagrams can significantly enhance students' reasoning and understanding [4]. In recent years, diagrammatic problem-solving has been recognized as an effective instructional strategy, particularly in primary education. Visual representations help students organize information, identify relationships, and reduce cognitive complexity during problem-solving tasks [5]. Moreover, the integration of diagram-based learning within the STEAM framework has been shown to improve students' engagement, creativity, and analytical thinking skills [6]. Furthermore, interdisciplinary approaches characteristic of STEAM education contribute to the development of systematic thinking by encouraging learners to apply knowledge from various domains to solve real-world problems [7]. The integration of artistic elements into scientific and mathematical learning also fosters flexible thinking and enhances students' ability to generate innovative solutions [8]. Despite the growing interest in STEAM-based education, there remains a need for effective methodologies aimed specifically at developing logical and systematic thinking in primary school students. Therefore, the use of diagrammatic problems within a STEAM framework represents a promising direction for both theoretical research and practical application in modern pedagogy.

Methods

This study employed a quasi-experimental research design to investigate the effectiveness of a STEAM-based methodology in developing primary school students' logical and systematic thinking through diagrammatic problem-solving tasks. The research was conducted in a natural classroom setting, ensuring the authenticity of the teaching and learning process. The participants of the study consisted of 60 primary school students (grades 3–4), divided into two groups: an experimental group (30 students) and a control group (30 students). The groups were selected based on similar academic performance levels to ensure comparability at the initial stage. The experimental group was taught using a STEAM-based approach integrated with diagrammatic problems, while the control group followed traditional instructional methods without the systematic use of visual problem-solving techniques. The research was carried out over a period of 8 weeks. During this time, the experimental group participated in specially designed lessons that incorporated interdisciplinary elements of science, technology, engineering, arts, and mathematics. Diagrammatic tasks such as схемalar (schemes), grafik tasvirlar (graphs), jadval-based problems, and logical visual puzzles were systematically included in classroom activities. These tasks were structured to encourage students to analyze relationships, organize information visually, and develop step-by-step reasoning skills. In contrast, the control group received instruction based on conventional teaching practices, primarily focused on verbal explanation, textbook exercises, and individual problem-solving without the use of diagrams as a central learning tool. This allowed for a clear comparison of the effectiveness of the proposed methodology. To assess the development of students' logical and systematic thinking, a set of diagnostic tools was employed, including pre-test and post-test assessments, observation protocols, and task-based performance evaluations. The tests were designed to measure students' abilities in logical reasoning, pattern recognition, sequencing, and problem-solving. Additionally, qualitative data were collected through classroom observations to analyze students' engagement, participation, and use of reasoning strategies. The collected data were analyzed using both quantitative and qualitative methods. Quantitative analysis involved comparing pre-test and post-test results between the experimental and control groups to identify changes in performance levels. Percentage analysis and comparative evaluation were used to determine the effectiveness of the intervention. Qualitative analysis focused on interpreting observational data to provide deeper insights into students' cognitive development and learning behaviors. The reliability and validity of the research were ensured through the use of consistent assessment criteria, controlled teaching conditions, and repeated measurements. Overall, the methodological approach allowed for a comprehensive evaluation of the impact of STEAM-based diagrammatic problem-solving on the development of primary school students' logical and systematic thinking skills.

Results

The results of the experimental study demonstrate a significant positive impact of the STEAM-based methodology incorporating diagrammatic problem-solving on the development of primary school students' logical and systematic thinking skills. At the initial stage of the

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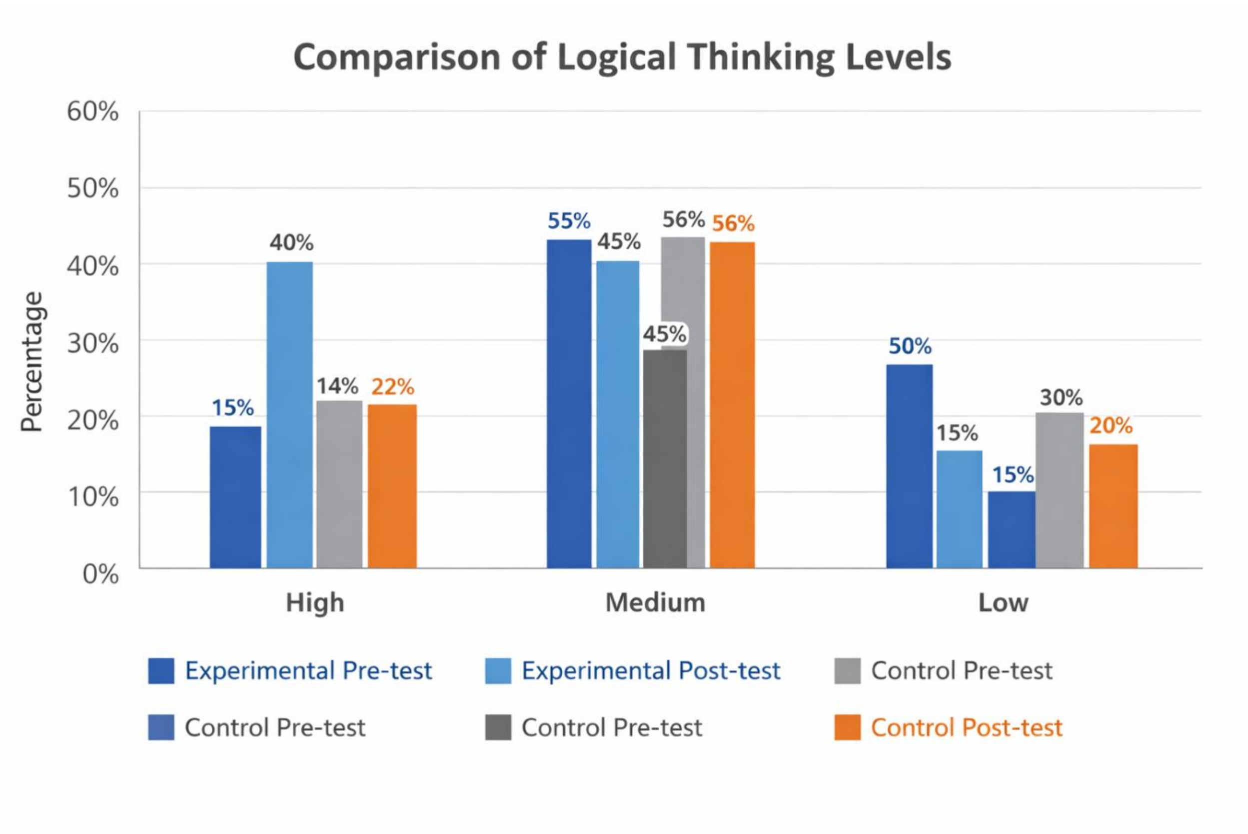
research, pre-test results indicated that both the experimental and control groups had nearly identical levels of logical thinking development. In the experimental group, 15% of students demonstrated a high level of logical thinking, 55% showed a medium level, and 30% were at a low level. Similarly, in the control group, 14% of students were at a high level, 56% at a medium level, and 30% at a low level. These results confirmed that both groups were comparable before the implementation of the intervention. After the 8-week experimental period, the post-test results revealed notable differences between the two groups. In the experimental group, the proportion of students with a high level of logical thinking increased significantly from 15% to 40%. At the same time, the percentage of students at the medium level slightly decreased from 55% to 45%, indicating a transition of learners from medium to higher levels of performance. Importantly, the proportion of students at the low level decreased from 30% to 15%, reflecting a substantial improvement in overall cognitive development. In contrast, the control group showed only moderate changes. The percentage of students at the high level increased from 14% to 22%, while the medium level slightly increased from 56% to 58%. The proportion of students at the low level decreased from 30% to 20%, indicating some progress; however, the improvements were not as pronounced as those observed in the experimental group. Comparative analysis of the results highlights that the experimental group outperformed the control group across all indicators. The increase in high-level performance in the experimental group (25%) was significantly greater than in the control group (8%). Additionally, the reduction in low-level performance was more substantial in the experimental group (15%) compared to the control group (10%). These findings confirm the effectiveness of integrating diagrammatic problems within a STEAM framework in enhancing students' logical reasoning and structured thinking. Qualitative observations further support these findings. Students in the experimental group demonstrated higher engagement during lessons, actively participated in discussions, and showed improved abilities to analyze, interpret, and represent information visually. They were more likely to approach problems systematically, using step-by-step reasoning and diagrammatic representations. In contrast, students in the control group tended to rely more on memorization and trial-and-error strategies. Overall, the results indicate that the use of diagrammatic problem-solving within a STEAM-based instructional approach significantly contributes to the development of logical and systematic thinking in primary school students. The observed improvements suggest that this methodology not only enhances academic performance but also fosters essential cognitive skills necessary for effective learning.



The experimental group showed a 25% increase in high-level logical thinking after the intervention, while the control group showed only an 8% increase. The proportion of low-level students decreased more significantly in the experimental group (15%) compared to the control group (10%). Medium-level students in the experimental group decreased slightly, indicating a transition to higher-level performance.

Discussion

The results of this study provide compelling evidence that the integration of diagrammatic problem-solving within a STEAM-based instructional framework significantly enhances logical and systematic thinking among primary school students. The experimental group demonstrated a notable increase in high-level logical thinking (from 15% to 40%) and a substantial reduction in low-level performance (from 30% to 15%), whereas the control group, following traditional methods, showed only modest improvements. These findings suggest that conventional teaching approaches may not be sufficient to fully develop higher-order cognitive skills in early education. The effectiveness of diagrammatic problem-solving can be attributed to several interrelated factors. First, visual representation of information facilitates students' comprehension of abstract concepts by allowing them to identify patterns, relationships, and sequences more easily. This is consistent with Mayer's (2009) cognitive theory of multimedia learning, which emphasizes the role of visual elements in reducing cognitive load and enhancing understanding. Second, the inclusion of arts within the STEAM framework encourages creativity and flexible thinking, which complements logical reasoning and fosters a more holistic cognitive development (Bequette & Bequette, 2012; Land, 2013). Furthermore, the study underscores the importance of an active, student-centered learning environment. Observational data revealed that students in the experimental group engaged more fully in problem-solving activities, collaborated effectively with peers, and demonstrated a greater willingness to explore multiple solution strategies. These behaviors reflect the development of metacognitive skills, as students not only applied reasoning processes but also monitored and adjusted their approaches in real-time. This aligns with Piaget's (1972) assertion that active engagement is critical for the development of logical thinking in children. The results also highlight the role of systematic instruction within a STEAM-based approach. By structuring diagrammatic tasks to progress from simple to complex problems, students were gradually guided to develop step-by-step reasoning skills, improving both their analytical capacity and confidence in problem-solving. This finding supports Polya's (1957) perspective that structured problem-solving methods are essential for fostering independent and systematic thinking. In addition, the integration of interdisciplinary content in STEAM instruction allowed students to transfer knowledge across domains, reinforcing their cognitive flexibility and ability to approach problems from multiple perspectives. This suggests that educational strategies combining STEM content with arts and visual problem-solving techniques can produce more robust learning outcomes than conventional, single-discipline instruction. Overall, the discussion indicates that diagrammatic problem-solving within a STEAM framework is an effective methodology for enhancing logical and systematic thinking in primary education. It not only improves measurable cognitive outcomes but also promotes engagement, creativity, and independent reasoning, all of which are critical for preparing students for future academic and real-world challenges.

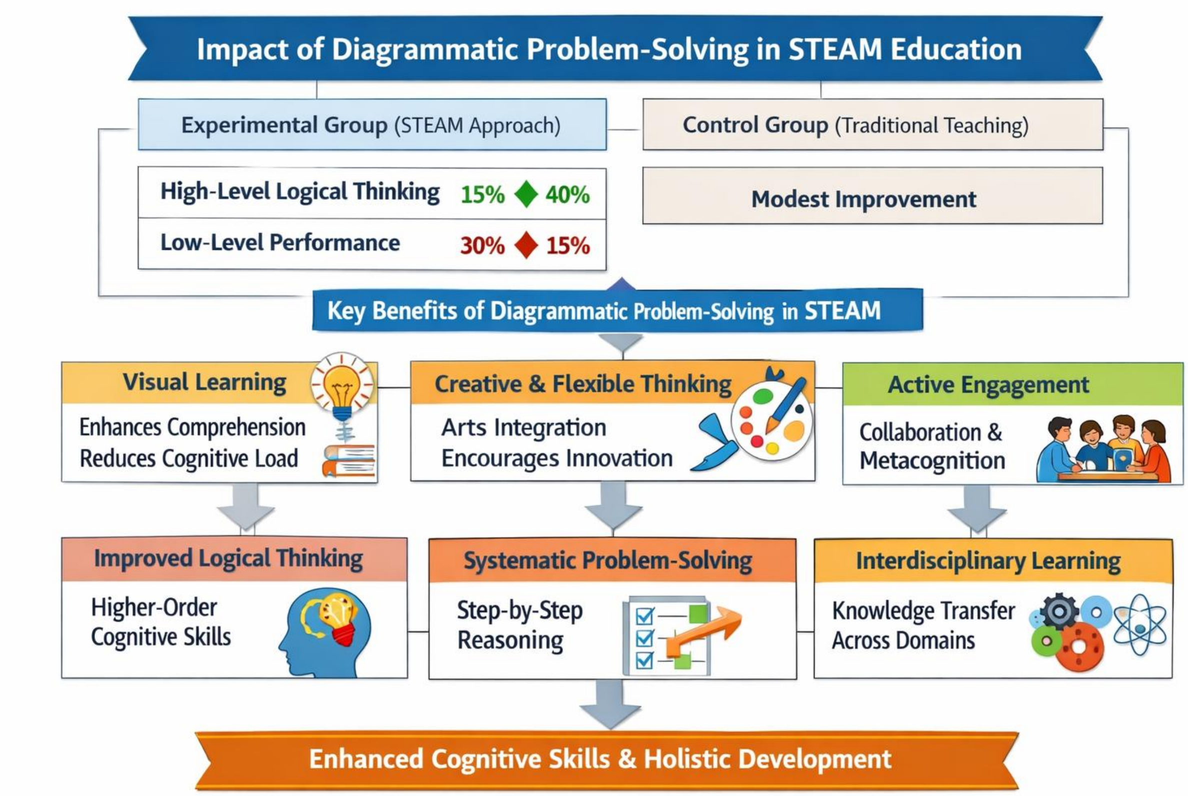


Diagram type: Conceptual flowchart diagram; the diagram illustrates the STEAM-based instructional method and its outcomes. It visually represents the connection between the learning process and cognitive development. Purpose; To explain the benefits and outcomes of the STEAM-based diagrammatic problem-solving method in education. To visually show its impact on students' logical and systematic thinking skills. Structure and elements: starting Point: "STEAM-based Instruction". Main Directions: diagrammatic problem solving- visual understanding step-by-step shinking. Art and interdisciplinary activities- reativity applying knowledge across subjects. Student behaviors: active participation, collaboration, metacognitive monitoring. Outcomes: increase in high-level logical thinking, reduction of low-level performance, problem-solving skills, and development of cognitive flexibility. Visual features:

color coding: blue: instruction learning. Green: active participation behaviors. Yellow, orange: cognitive processes outcomes. Flowchart structure- shows step-by-step interaction and results. Pictograms and frames make it clear and visually explanatory. Diagram function: to visually explain the teaching methodology. To compare experimental and control group results. To briefly show the practical and cognitive effects of the method.

Conclusion

1. The STEAM-based diagrammatic problem-solving method effectively enhances students' logical and systematic thinking skills.

2. Using diagrams and visual tools in the learning process improves students' step-by-step reasoning and problem-solving abilities.

3. Interdisciplinary and art-based activities help students develop creativity and apply knowledge across different subjects.

4. Active participation and collaboration strengthen students' metacognitive monitoring and independent learning skills.

5. This method reduces low-level performance while increasing high-level logical thinking and cognitive flexibility.

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