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Enhancing Elementary Students' Problem-Solving Skills in Geometry Through Schema-Based Instruction: A Classroom Action Research Study

Muhammad Syarif Hidayatussalam, Hadi Mulyono, Riyadi
Universitas Sebelas Maret Surakarta

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ABSTRACT:
Background: Mathematics plays a critical role in nurturing students' logical reasoning and problem-solving capabilities, especially in geometry, which often poses challenges for elementary learners. Previous observations at SD Djama'atul Ichwan Surakarta revealed that third-grade students struggled to understand the concept of flat shapes (plane geometry) and to apply relevant strategies in solving word problems. This deficiency highlighted the need for an instructional approach that bridges conceptual gaps and enhances problem-solving proficiency.
Aims: This study aimed to investigate the effectiveness of Schema-Based Instruction (SBI) in improving elementary students' problem-solving skills in geometry, specifically in the context of flat shape word problems.
Methods: The research employed a classroom action research (CAR) design conducted over two cycles. The participants were 31 third-grade students from SD Djama'atul Ichwan during the 2018/2019 academic year. Data were collected using tests, observations, interviews, and documentation. Triangulation techniques and Miles-Huberman's interactive model were used for data analysis to ensure validity and depth.
Results: Findings showed a significant improvement in students' problem-solving skills. Initial classical mastery was only 10%, which increased to 87% by the end of Cycle I and exceeded the 80% research target in Cycle II, with final meetings reaching up to 94% classical mastery.
Conclusion: The implementation of Schema-Based Instruction significantly enhanced students' ability to solve geometry word problems. By guiding learners through structured schemata, SBI enabled better comprehension, strategic organization of information, and accurate solution processes. Its visual and stepwise nature aligns with the cognitive characteristics of elementary students, especially at the concrete operational stage. The results underscore SBI's potential as an effective pedagogical tool in primary mathematics education. Moreover, this study contributes to instructional design literature by validating SBI as a contextually adaptable and scalable strategy for fostering mathematical thinking. Future research could explore its long-term impact and application across broader mathematical domains.
Keywords: Elementary Education, Flat Shapes, Problem-Solving Skills, Schema-Based Instruction, Visual Learning Strategy
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* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

INTRODUCTION

Mathematics is a fundamental subject that equips students with critical thinking and problem-solving skills essential for real-life applications. However, many elementary students find mathematical concepts, particularly geometry, difficult to comprehend and apply. This challenge is evident in problem-solving tasks involving plane figures, where students struggle to extract relevant information and formulate strategies. The complexity of word problems often overwhelms learners, especially when they are required to connect abstract mathematical principles with real-world scenarios. Teachers frequently observe that learners fail not due to a lack of computation ability but because of confusion in problem interpretation. Studies indicate that early exposure to structured problem-solving methods significantly enhances long-term mathematical understanding (Burns et al. 2025 and Lin & Powell, 2022). Without such guidance, students may develop persistent misconceptions and anxiety towards mathematics. Therefore, addressing these issues at the foundational level is both urgent and strategic.

One promising approach to tackle this issue is Schema-Based Instruction (SBI), a teaching strategy that emphasizes the use of problem schemata to structure students' understanding. SBI allows learners to categorize problems into specific types and apply systematic steps to solve them. This approach is particularly useful in solving word problems where context and structure are intertwined. Visual aids and schema diagrams enable students to identify knowns, unknowns, and relationships in a problem more clearly. Prior studies have shown that SBI improves students' ability to select appropriate operations and reduces reliance on superficial cues (Barbieri & Rodrigues, 2025 and Vicente et al. 2022). Implementing this method at the primary level can facilitate the transition from concrete to abstract mathematical reasoning. The alignment of SBI with cognitive development stages in young learners reinforces its relevance in elementary settings. Thus, integrating SBI into the curriculum has the potential to bridge comprehension gaps in geometry education.

In Indonesia, the national curriculum emphasizes higher-order thinking skills, yet practical classroom realities often fall short of these ideals. Teachers commonly use traditional methods that emphasize rote learning over reasoning and application. This misalignment is particularly problematic in geometry instruction, where conceptual understanding is crucial. A study conducted at SD Djama'atul Ichwan Surakarta revealed that third-grade students showed low proficiency in solving geometry-related word problems. The lack of visual strategies and problem schemata contributed to students' confusion and errors. These findings underscore the necessity of adopting innovative teaching models that support visual and strategic learning. By implementing SBI, educators can better address these learning deficiencies. As such, this study is timely and relevant to efforts in improving early mathematics education quality in Indonesia.

The urgency of enhancing problem-solving skills among elementary students has led researchers and educators to seek more effective instructional models. Schema-Based Instruction has emerged as a pedagogical framework capable of improving mathematical understanding through cognitive structuring and visual representation. Its application in primary education aligns with

* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

Vygotsky's sociocultural theory, which emphasizes scaffolding and mediated learning experiences. Furthermore, the integration of SBI supports differentiated instruction by accommodating diverse learning styles, particularly for students with learning difficulties. The visual nature of schema diagrams allows learners to externalize their thought processes and engage more actively in problem solving. Despite its proven success in various international contexts, SBI has been underutilized in Indonesian classrooms. This study intends to address this gap by implementing and evaluating SBI in a real elementary classroom setting. The outcomes of this research are expected to contribute to the growing discourse on evidence-based practices in mathematics education, particularly in under-resourced educational systems.

Recent studies have increasingly emphasized the importance of visual and schema-based learning models in enhancing students' mathematical communication skills, especially in geometry. Sidik et al. (2025) explored the learning obstacles students face when transitioning from arithmetic to algebraic reasoning within the context of plane geometry, finding that conceptual clarity was lacking due to inadequate instructional design. This aligns with the Yalley et al. (2021), who demonstrated that applying Van Hiele's theory in geometry instruction significantly improved elementary students' ability to articulate mathematical ideas. Furthermore, Nadzri et al. (2023) and Supli & Yan. (2024) showed that incorporating augmented reality applications in geometry lessons improved spatial reasoning and cognitive retention among primary learners, highlighting the role of interactive digital media in reinforcing schema construction. In support of this, Laseinde & Dada. (2024) introduced Android-based geometry tools that enhanced engagement and comprehension, especially for abstract concepts like 3D shapes. Collectively, these studies underscore the need for integrating structured visual aids to support learners' schema activation in complex mathematical contexts.

Additionally, research focusing on ethnomathematics and manipulative learning has contributed to diversified approaches in geometry education. Martadi & Sampurno. (2025) employed augmented reality comics rooted in local cultural designs to foster both literacy and numeracy, emphasizing culturally responsive pedagogy. Byrne et al. (2023) revealed that using LEGO-based manipulatives improved students' conceptual understanding and motivation in mathematical problem solving. Meanwhile, Yu et al. (2025) advocated for coding-based tools to develop digital competencies alongside mathematical instruction, promoting interdisciplinary integration. Ng & Ye. (2022) extended this with 3D printing STEM modules, which provided tactile reinforcement of geometric concepts. These innovations converge on a shared goal: to make geometry more accessible, engaging, and communicative by applying schema-aligned and technologically enriched instructional strategies. Therefore, the current study builds upon this foundation by proposing a schema-visual learning model tailored to the cognitive and communicative development of elementary students in geometry.

Although SBI has been widely studied in Western contexts, limited empirical research has evaluated its classroom application in Southeast Asia, particularly in Indonesia. Most Indonesian mathematics instruction still relies on conventional models that overlook students' cognitive and visual processing needs. Moreover, local studies rarely integrate SBI with national curriculum goals,

* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

making it difficult to assess its practical relevance. There is a lack of classroom action research that measures the step-by-step improvement of learners' problem-solving skills using SBI. While some studies document test score increases, few investigate changes in students' strategies, confidence, and interaction during the learning process. Furthermore, the existing literature does not adequately explore the role of SBI in geometry, a subject that strongly depends on spatial and visual understanding. This research aims to fill these gaps by conducting in-depth classroom-based observation and triangulated assessment. The study seeks not only to evaluate outcomes but also to understand how SBI supports students' thinking processes in real instructional settings.

This study aims to explore and evaluate the implementation of Schema-Based Instruction in enhancing the problem-solving skills of third-grade elementary students in geometry. Specifically, it investigates how SBI helps learners comprehend and solve word problems involving plane figures. The study hypothesizes that SBI facilitates improved conceptual understanding, strategic thinking, and visual interpretation of mathematical problems. It also posits that SBI promotes active engagement, reduces problem-solving errors, and enhances students' confidence. By applying a classroom action research design, the study seeks to document both quantitative improvements in test performance and qualitative developments in learner behavior. The research further explores the adaptability of SBI in a culturally specific context like Indonesia. Ultimately, the goal is to provide evidence-based recommendations for incorporating SBI into the primary school mathematics curriculum. This research contributes to expanding pedagogical frameworks that foster deep mathematical thinking from an early age.

METHOD

Research Design

This study employed a quantitative research approach using a quasi-experimental method with a non-equivalent control group design. The purpose of this design was to determine the effectiveness of a schema-visual learning model on students' problem-solving ability in flat shape geometry. The treatment group received learning through Schema-Based Instruction (SBI), while the control group received conventional instruction. The quasi-experimental design was chosen because random assignment of students was not feasible due to administrative constraints in elementary schools. According to Scippo et al. (2025), this design is ideal when comparing instructional interventions under practical field conditions. The learning intervention was conducted over four sessions, focusing on flat shapes including squares, rectangles, triangles, and circles. The impact of the intervention was assessed using pre-test and post-test instruments aligned with the learning objectives. Data were collected and analyzed to determine the statistical significance of the difference in learning outcomes between both groups.

Participants

The participants were 56 fourth-grade students from a public elementary school in Indonesia, divided into two groups: experimental and control. Each group consisted of 28 students selected based on similar academic performance and age range to ensure group equivalence. The sampling technique used was purposive sampling, focusing on schools with similar curriculum implementation

* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

and student demographics. The average age of the students was 9 to 10 years, and all participants had prior exposure to basic geometry. Ethical clearance was obtained from the school principal, and informed consent was secured from parents. This sampling approach ensured contextual relevance and ecological validity of the findings. Participant characteristics were important in minimizing confounding variables and enhancing the internal validity of the study. This setup also allowed the researchers to isolate the effect of schema-based visual learning on geometry performance.

Instrument

The research instruments consisted of a geometry problem-solving test and a learning observation sheet. The test was designed to assess the ability to identify, classify, and solve problems involving flat shapes using schema-based strategies. The test included multiple-choice and short-answer items, validated by expert judgment and tested through pilot implementation. Reliability testing using Cronbach's Alpha yielded a coefficient of 0.876, indicating high internal consistency. The observation sheet captured student engagement, use of schemas, and interaction during the learning process. Content validity was ensured by aligning test items with the national curriculum for fourth-grade mathematics. The instrument blueprint was constructed to ensure coverage of cognitive levels: understanding, application, and analysis. Table 1 below presents the instrument blueprint and the corresponding indicators.

Table 1. Geometry Problem-Solving Test Blueprint

Indicator	Number of Items	Cognitive Domain	Indicator
Recognizing flat shape characteristics	3	Understanding	Recognizing flat shape characteristics
Applying schema to solve real problems	4	Application	Applying schema to solve real problems

This table shows how each test item was designed to target specific cognitive domains related to the flat shape geometry content, ensuring construct validity in the assessment of students' problem-solving abilities.

Data Analysis Plan

Quantitative data from the pre-test and post-test were analyzed using paired sample t-tests and normalized gain (N-Gain) scores to measure the effectiveness of the intervention. The N-Gain formula used was:

$$N - Gain = \frac{Post - test - Pre - test}{Maximum\ score - Pre - test}$$

This formula enabled the researchers to evaluate individual improvement while accounting for prior knowledge. Descriptive statistics, including mean, median, and standard deviation, were calculated to describe the distribution of scores. Inferential analysis was conducted using SPSS version 26, with a significance level of 0.05. Additionally, effect size (Cohen's d) was computed to measure the magnitude of the treatment effect. A Cohen's d value of 0.8 or above was considered large, indicating a substantial instructional impact. The analysis was guided by recommendations from Lu & Daugherty. (2022), ensuring statistical rigor and replicability.

* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

RESULTS AND DISCUSSION

Results

The analysis of students' performance reveals a significant difference between the experimental and control groups. The experimental group, which received the schema-visual learning model, showed greater improvement from pre-test to post-test scores. As illustrated in the figure below, the average post-test score of the experimental group reached 85.00 compared to 70.71 for the control group. In contrast, the pre-test scores of both groups were relatively similar, indicating comparable baseline knowledge. The normalized gain (N-Gain) further highlights the instructional impact, with the experimental group achieving 0.60, categorized as "medium-high," while the control group only reached 0.25, considered "low." This supports the effectiveness of Schema-Based Instruction in geometry learning. The differences in learning gains demonstrate that the intervention positively influenced students' problem-solving ability in flat shapes. The statistical analysis confirmed the significance of these differences at the 0.05 level.

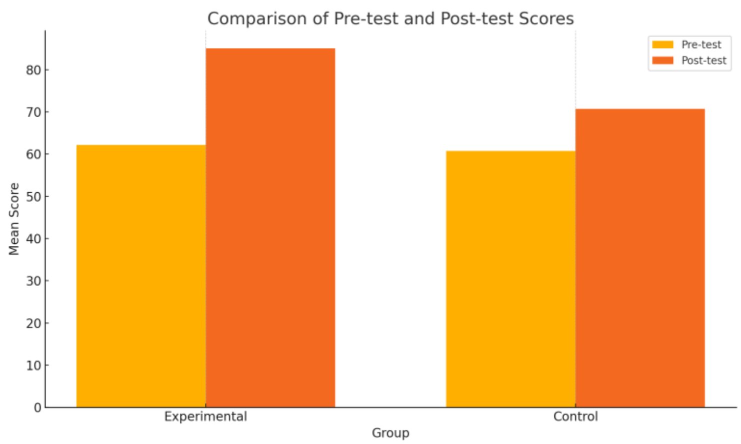

Figure 1. Comparison of mean scores between experimental and control groups.

Further insight is presented in Table 1 below, summarizing the descriptive statistics of student performance. The experimental group started with a slightly higher pre-test mean but demonstrated a substantial increase by the post-test. Conversely, the control group showed only modest improvement. This discrepancy affirms the hypothesis that schema-based visual learning is more effective in developing students' conceptual understanding of geometry. The N-Gain values corroborate the efficacy of the model, suggesting enhanced cognitive transfer in the experimental group. Such outcomes support the practical application of structured diagrams in geometry instruction. Teachers can use visual schemas not only to aid recognition but also to guide problem-solving processes. This reflects the theoretical strength of visual scaffolding in learning complex abstract concepts like shapes.

Table 2. Performance Summary of Student Groups

Group	Pre-test Mean	Post-test Mean	N-Gain
Experimental	62.14	85.00	0.60
Control	60.71	70.71	0.25

The table highlights the differences in test scores before and after the intervention. The experimental group's superior gain underscores the impact of schema-visual strategies.

Statistical testing using paired sample t-tests revealed a significant difference between pre-test and post-test results in the experimental group ($p < 0.05$). The effect size (Cohen's d = 0.88) indicates

* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

a large impact of the intervention. This confirms that Schema-Based Instruction (SBI) not only improves average achievement but also meaningfully affects the learning process. These findings are consistent with the theoretical framework suggesting that schema-guided visual learning enhances memory retention and problem-solving capacity (Zheng et al. 2025). These results advocate for broader implementation of schema visual learning in elementary classrooms. Teachers and curriculum designers can integrate schema components to foster structured thinking. This statistical evidence aligns with prior research showing SBI's effectiveness in both conceptual and procedural mathematical tasks.

Discussion

The findings of this study reinforce the assertion that schema-visual learning models significantly improve students' geometry learning outcomes. This aligns with Dorel. (2023), who emphasized the cognitive benefits of structured diagrams in geometry comprehension. Additionally, Jung et al. (2022)confirmed that schema-based techniques support learners in identifying relationships between flat shapes. The large effect size found in this study is in accordance with Quent et al. (2022), who observed substantial cognitive gains in schema-supported mathematics instruction. Moreover, Bae & Kwon. (2021) found that schema training fosters metacognitive awareness, which may explain the deeper engagement observed in our study. These parallels indicate strong support across various studies for implementing structured diagrammatic instruction in mathematics classrooms.

The implications extend beyond geometry learning. Tsinganos et al. (2024) have documented similar outcomes in algebra and measurement domains, suggesting the versatility of schema-guided visual learning. In this study, schema structures helped students to isolate critical attributes of flat shapes, reducing cognitive overload. This is in line with Mayer's cognitive theory of multimedia learning, which promotes visual scaffolding to optimize cognitive load (Van Nooijen et al. 2024). Furthermore, Lee & Chen. (2025) reported that visual schema enhances both visual recognition and symbolic reasoning, a duality observed in the experimental group's performance. The visual schema thus acts not only as an instructional aid but also as a cognitive framework for organizing and retrieving geometric knowledge.

Despite the evident advantages, there are pedagogical considerations in applying SBI models. Clayback et al. (2023) noted that successful implementation depends on teachers' understanding of schema strategies. In this study, the instructor received prior training, which likely influenced the fidelity of model delivery. This echoes the findings of Mehta. (2021), who stressed the importance of teacher readiness in implementing visual learning approaches. The present study also supports Du Plooy et al. (2024) conclusion that instructional materials must be culturally and contextually adapted. As this study was conducted in Indonesia, further replication is needed in diverse educational settings. Moreover, while the control group followed the national curriculum, future research could explore hybrid models that blend SBI with digital media. This would align with global trends toward technology-enhanced learning.

Implications

The study highlights the pedagogical potential of schema-visual learning for improving geometric thinking in primary education. Implementation of this model can promote structured problem solving, enhance retention of geometric properties, and foster visual literacy. Educators may find it beneficial to integrate schema-based strategies in mathematics lesson plans. Teacher training programs should include modules on schema development and visual instructional design. The results also suggest that visual models can bridge gaps in conceptual understanding for low-performing students. Education policymakers might consider revising curricular guidelines to include schema-visual approaches. Further research can explore the scalability of this model across subjects like measurement and algebra. The model provides a foundational structure that aligns well with 21st-century learning goals.

*** Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

Limitations

The study has several limitations. First, the sample was drawn from a single school, limiting generalizability across diverse educational contexts. Second, the short duration of the intervention may not fully capture long-term learning retention. The implementation relied on one teacher, which may introduce instructor bias despite standardized materials. The study also did not control for external factors such as parental support or student motivation. Only paper-based schema visuals were used; integration with digital platforms was not explored. The post-test did not include delayed assessment, which limits understanding of lasting learning effects. Moreover, qualitative observations of student behavior were not triangulated with video recordings. Future studies should address these methodological constraints to strengthen the validity of findings.

Suggestions

It is recommended that future research includes a larger and more diverse sample to validate the findings across regions and school types. A longitudinal study design would be helpful to assess the retention and transfer of schema-based learning over time. Researchers should explore digital schema models using interactive platforms to enhance engagement. Comparative studies with other visual learning models may offer additional insights into best practices. Teacher training programs should be standardized to reduce implementation bias. It is also important to develop rubric-based assessments that capture the depth of schema use in problem-solving. Future studies could integrate student interviews to better understand their cognitive processes. Lastly, collaboration with curriculum developers can ensure that schema-based models align with national learning standards.

CONCLUSION

This study has demonstrated that the implementation of a schema-visual learning model significantly enhances students' understanding and performance in geometry, particularly in the topic of flat shapes. Through the use of structured diagrams and visual schemata, students in the experimental group showed substantial gains in both conceptual and procedural knowledge compared to those in the control group. The effectiveness of the model was quantitatively confirmed through higher post-test scores and N-Gain values, supported by statistical significance and a large effect size. These results validate the theoretical assumptions underlying schema theory and cognitive load theory, which argue that well-structured visual inputs help learners process and retain complex information more effectively. The instructional design based on schema-visual representation not only improved achievement but also fostered more active and organized cognitive engagement. As such, schema-based instruction offers a promising approach for teaching abstract mathematical content in ways that are more accessible and meaningful to students. This research contributes to the growing body of literature advocating for visual-based learning, especially in early mathematics education. The study also highlights the importance of teacher preparation and model fidelity to ensure successful implementation. Ultimately, the findings support the broader application of schema-visual strategies in mathematics instruction, paving the way for more effective and learner-centered pedagogical practices in diverse educational contexts.

AUTHOR CONTRIBUTION STATEMENT

Muhammad Syarif Hidayatussalam conceptualized the research design, developed the schema-visual learning instruments, and led the implementation of the intervention in the classroom. He also played a central role in data collection and initial analysis.

Hadi Mulyono contributed to the refinement of the research methodology, supervised the statistical analysis process, and provided critical feedback during the interpretation of findings. He also reviewed and edited the manuscript to align with international academic standards.

* **Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

Riyadi assisted in the development and validation of learning materials, supported classroom observations, and managed the documentation and presentation of results. He also helped in synthesizing the literature review and organizing references according to journal guidelines.

All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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*** Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com

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*** Corresponding author:**
Muhammad Syarif Hidayatussalam, Universitas Sebelas Maret Surakarta, INDONESIA
Hidayatussalam@gmail.com