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How to Support The Algebraic Thinking Skills of Elementary School Students Using The Generative Multi-Representation Learning Model Modification Schema-Based Instruction?

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ABSTRACT
Elementary school teachers still do not fully utilize effective learning models, especially in teaching algebraic concepts. Lack of understanding of algebraic concepts has caused students to have difficulty mastering algebra, including calculation, representation, and mathematical modeling, as well as recognizing algebraic symbols and variables. This study aims to investigate the impact of the Generative Multi-Representation Learning Model Modified Schema-Based Instruction (MGMRM-SBI) on the algebraic thinking skills of elementary school students. An experimental method with a posttest-only control group design was employed, using Cluster Random Sampling to select a sample of 128 students. The research instrument was an algebraic thinking ability test, analyzed using a t-test with SPSS software. The t-test results indicated a significant difference in algebraic thinking skills between the experimental and control groups. The findings suggest that the MGMRM-SBI significantly enhances the algebraic thinking skills of elementary school students, proving to be more effective than the expository model.
Keywords*: Generative; Representasi; Instruksi Berbasis Schema; Algebraic Thinking*

ABSTRAK
Guru sekolah dasar masih belum sepenuhnya memanfaatkan model pembelajaran yang efektif khususnya dalam pembelajaran konsep aljabar. Kurangnya pemahaman konsep aljabar menyebabkan siswa kesulitan menguasai aljabar, meliputi perhitungan, representasi, dan pemodelan matematika, serta mengenal simbol dan variabel aljabar. Penelitian ini bertujuan untuk mengetahui pengaruh Model Pembelajaran Multi Representasi Generatif Modifikasi Skema Berbasis Instruksi (MGMRM-SBI) terhadap keterampilan berpikir aljabar siswa sekolah dasar. Metode yang digunakan adalah metode eksperimen dengan desain kelompok kontrol posttest-only, menggunakan Cluster Random Sampling untuk memilih sampel sebanyak 128 siswa. Instrumen penelitian berupa tes kemampuan berpikir aljabar, dianalisis menggunakan uji t dengan software SPSS. Hasil uji-t menunjukkan adanya perbedaan keterampilan beriki aljabar yang signifikan antara kelompok

eksperimen dan kelompok kontrol. Temuan menunjukkan bahwa MGMRM-SBI secara signifikan meningkatkan keterampilan berpikir aljabar siswa sekolah dasar, terbukti lebih efektif dibandingkan model ekspositori.
Kata Kunci: Generative; Representasi; Instruksi Berbasis Schema; Berpikir Aljabar

INTRODUCTION

The advancement of technology increasingly underscores the importance of mathematics in everyday life and professional careers. This necessity can be addressed through enhanced learning in schools, as the educational process significantly contributes to the improvement of students' competence and creativity (Mrizkidirmansyah & Febriandi, 2023). Despite this, many individuals encounter difficulties in comprehending mathematics due to its structural complexity, the teaching methods employed, and comprehension challenges, especially at the primary school level (Firda Halawati & Rahmi Hidayati, 2023; Mutlu, 2019). Engaging students actively in mathematics learning is crucial for enhancing their understanding of mathematical concepts and procedures. This approach should be supported by a dynamic learning environment and assignments that stimulate critical thinking and problem-solving skills (Litster et al., 2020).

Blanton et al. (2017) indicates that elementary school students have the ability to develop an understanding of variable notation and the concept of functional relationships if using the right approach. Algebraic thinking has an important role in solving mathematical problems, and it is recommended that it be developed from an early age (Lenz, 2022; Sibgatullin et al., 2022; Wettergren, 2022). Somasundram (2021) supports the idea, his opinion that the development of algebraic thinking at the elementary school level can help reduce students' difficulties when they formally learn algebra at a higher level. Switzer (2018) finds challenges in understanding abstract symbols and variables in students' mathematical contexts. In addition, Wahyuni et al. (2023) highlights that the use of algebra symbols, especially related to algebraic expressions, operations, and equations, is also an obstacle for students.

Kieran (2004) thinks mathematics initially involves developing a mindset in which letter-symbolic algebra is included as one of the means, although it does not rely entirely on algebra itself. According to Swafford and Langrall (2000) explain that the ability to think algebraically involves the ability to perform operations on numbers that are not yet known or represented by variables, while arithmetic is related to operations on numbers that are already known. Swafford and Langrall emphasize the nature of algebraic thinking, while Kieran explains that letter-symbolic algebra plays an important role but should not be the center of attention. Kieran's thinking provides more flexibility to explore and understand mathematical concepts through a variety of activities, which can enrich students' understanding of mathematics at the initial level. Another opinion, Chimoni et al. (2018) the concept of algebraic thinking can be described in the following four dimensions: a) deepen the understanding of structures and relationships in the three core algebraic content, namely general arithmetic, functional thinking, and modeling; b) understand basic concepts in algebra, such as equal signs, equivalence, equations, number properties, nature of operations, variables, unknown quantities, symbols, shared variations, and correspondence; c) engage in the process of searching for similarities and differences and validating structures and relationships, including observation, forecasting, representation, generalization, justification, and validation; d) use forms of reasoning such as abductive, inductive, and deductive to guide the extraction of conclusions.

The level of mathematics ability of fifth grade students in elementary schools in Indonesia can be assessed by analyzing data from the results of the National Assessment (AN), which reflects the extent to which they master competence in the field of algebra. Data from the 2022 National Assessment, which is a program from the Ministry of Education, Culture, Research, and Technology Kemendikbud (2023) shows that at the elementary school education level, the numeracy ability of grade V students nationally is at a moderate level, with a percentage of 46.67%. There was a significant increase of 16.1% from the previous year, which recorded a percentage of 30.66%. In addition, the results of observations made on students of SD Negeri in Region II East Jakarta, consisting of five public elementary schools, showed that numeracy ability data was divided into two categories, namely good and medium. Elementary schools that fall into the good category reach a percentage of 86.67%, which indicates that students have exceeded the minimum competencies set and the competency score in the algebra domain for this category reaches 53.94%.

Meanwhile, elementary schools whose numeracy ability falls into the medium category reached a percentage of 63.33%, which shows that students have achieved the minimum competencies set and the competency score in the algebra domain for this category reached 50.86%. Overall, the data presented showed an improvement in students' numeracy skills nationally compared to the previous year. Despite the increase nationally and based on the observations revealed, the results of the National Assessment have not been comprehensive representative of students' abilities because each school represents only a small sample randomly selected by the Education Office, with a total of 15 test participants. Improvements are still needed in various aspects of numeracy ability, especially in competency indicators in the algebraic domain.

Furthermore, the study involved interviews with elementary school teachers to gain a deeper understanding of the algebraic thinking skills of Grade V students. From the interview, teachers conveyed several difficulties faced by students, including: a) Elementary school teachers have not fully utilized effective learning models, especially in teaching algebra concepts; b) lack of understanding of algebraic concepts causes students difficulty in mastering algebra, including calculations, representations, and mathematical modeling; c) In addition, some students also have difficulty recognizing algebraic symbols and variables, which can hinder their ability to use algebra as a problem-solving tool. In overcoming these problems, teachers need to implement learning models that can improve students' algebraic thinking skills.

The generative learning model, first proposed by Osborne and Wittrock in 1983, consists of five main stages: orientation, idea stage, challenge and restructuring, application, and review (Breitwieser and Brod, 2021). According to Wong et al. (2011) multi-representation is a useful tool for motivating learners to understand special situations better. It involves validating representations used and evaluating the clarity of the answers produced. In addition, this approach also includes evaluation by students of the clarity of the answers produced (Flores et al., 2015). This approach includes various modes such as analogies, verbal statements, written texts, diagrams, graphs, and simulations (Tang et al., 2014).

Schema-Based Instruction (SBI) emphasizes problem structure analysis and the use of schemas or diagrams to represent key information in problems (Jitendra et al., 2009). It involves explicit instruction, problem type identification, multiple examples, and visual representation models (Kingsdorf and Krawec, 2014; Powell, 2011). Although there are several approaches involving the use of schemas, the most common in the literature is schema-based instruction (SBI) according to (Peltier & Vannest, 2017) SBI explicitly teaches students to: 1) Identify schemas (problem types), 2) Use schematic diagrams to represent the number of problems, 3) Identify plans to solve problems, and 4) Implement plans and check for fairness. Research has shown that generative learning models positively impact mathematical problem-solving and creative thinking skills (Kusairi et al., 2020). Studies by Wardono et al. (2020) and Mahama and Kyeremeh (2022) found that the use of multiple representations enhances students' understanding and algebraic thinking skills. Kusumaningsih and Herman (2018) also found that the application of multiple representation strategies has a positive impact on algebraic thinking skills, especially in the context of a realistic approach to mathematics. Students who used multiple representation strategies showed better algebraic thinking skills than those who used scientific approaches, with more than 75% of students achieving a level of learning completion. According to Peltier and Vannest (2018) and Skinner and Cuevas (2023) demonstrated that SBI improves problem-solving accuracy and performance in procedural and computational fluency. Another study conducted by (Karayil and Praveen (2020) concluded that the application of Schema-Based Instruction (SBI) significantly improves problem-solving abilities compared to direct translational strategies, demonstrating the effectiveness of SBI in the context of problem-solving in the physical sciences.

This research uniquely applies a modified generative multi-representation model integrated with schema-based instruction, providing a holistic and interactive approach to teaching algebra concepts to students. The study aims to determine the effect of the Generative Multi-Representation Learning Model Modified Schema-Based Instruction (MGMRM-SBI) on the algebraic thinking skills of elementary school students.

METHODS

Type and Design

This research uses an experimental method. Experimental research identifies independent, dependent, and nuisance variables and shows the way in which the randomization and statistical aspects of experiments should be carried out. The main goal of experimental design is to establish a causal relationship between independent and dependent variables (Miller et al., 2020; Roger E. Krik, 2009). The experimental design used was a posttest-only control group design, a sample of research was randomly selected after which a test after a teratment pretest was likely not needed when randomization was used and a large number of students and/or teachers were involved (Gribbons Joan Herman, 1996; Shadish et al., 2002). This design structure involves the formation of two groups: an experimental group (receiving treatment) and a control group (without prior treatment). The structure of this design can be described through the following table:

Table 1. Design Experiment

Group	Treatment	Posttest
R	X	O1
R	-	O2

The sample was selected using purposive sampling from elementary schools in Region II, East Jakarta. The population comprised fifth-grade students at SDN Cibubur 04 Pagi. The purposive sampling method was used to select specific classes (A, B, C, and D) that were representative of the student population in terms of academic performance and demographics. This method ensures that the sample accurately reflects the population characteristics and allows for a targeted assessment of the intervention's effectiveness. Implementation of the Generative Multi Representation Learning Model Modified Schema Based Learning (MGMRM-SBI) in this study uses five stages of learning described in Table 2 below.

Table 2. Syntax of Generative Multi Representation Learning Model Modification Schema Based Learning (MGMRM-SBI)

Steps	Description of Activities
Orientation (Identification schema and Muti representation)	Students reflect on previous knowledge and experience related to the material to be studied. They made schema mappings and various mathematical representations introduced by the teacher. They try to relate these representations to their understanding of the concepts being taught.
Focusing on Ideas (Used to the Type of problems and analyze representation ideas)	Students conduct an in-depth analysis of the types of problems introduced by the teacher using various representations of ideas including the selection of representations that best suit the type of problem given.
Challenge and restructuring (Familiarize with similar and different problems situationally and structurally, and manipulate the transformation of idea representation)	Students engage in group discussions to share ideas, strategies, and problem-solving outcomes. Explore and manipulate representations of ideas, try to reimagine a problem or combine multiple representations to produce a more complete solution.
Application (Practice problem solving using representation to a specific situation different types of problem schemes Multi Representation)	Students are given problems that represent real and diverse situations. Students apply mathematical concepts that have been learned using various representations of ideas. such as verbal representations, diagrams, graphs, or mathematical equations to present their solutions. This selection is based on the type of problem and modeling skills required.
Evaluation	Students complete worksheets that have been provided, and students actively participate in class evaluation sessions, providing feedback to classmates and responding to feedback from teachers.

Data and Data Sources

The research instrument used is an algebraic thinking ability test in the form of description test questions. There are six items of description questions that cover the concepts of flat area, comparison, and proportion. This test is designed to evaluate algebraic thinking skills. This test was given after treatment to both groups, both experimental and control groups, without difference, and the preparation of the test was based on indicators of algebraic thinking ability which included: a) using symbols in mathematical modeling; b) generalize the arithmetic pattern of a problem; c) make informed predictions; d) make evidence in solving problems. Before the test questions are given, validity and reliability are tested to experts in the field of mathematics.

Data collection technique

The results of the validity test show that algebraic thinking problems are declared feasible and can be used in research, then trials were carried out on grade VI students who had studied flat area material to determine the difficulty index. After the test of the questions, there are two questions declared too difficult and in the category of low validity, then the questions used in the study are six questions that have been declared valid and reliable as an important requirement in experimental research. The quality of experimental research is considered in terms of its reliability and validity. Reliability refers to the extent to which measurements or experimental procedures give rise to consistent interpretations of the construction they set out to measure (Miller et al., 2020).

Data analysis

Data analysis was performed using a t-test with SPSS statistical software to compare the mean scores between the two groups, ensuring the normality and homogeneity of the data before conducting the independent t-test (Flannelly et al., 2015; Mcdonald, 2009).

RESULTS AND DISCUSSION

The results in this study were obtained from tests of algebraic thinking skills conducted on two groups: the experimental group (using the Generative Multi Representation Learning Model Modified Schema Based Instruction) and the control group (using the expository model). The following is a description of the analysis of the test results.

Table 3. Descriptif Statistics Data

Statistics	Experimental Class	Control Class
Mean	72, 89	66, 38
Minimum	48,00	52,00
Maximum	95,00	86,00
Std. Deviation	10, 51	8, 40
N	64	64

Table 3 above, shows the post-test score of the experimental class was higher compared to the control class, with an average algebraic thinking ability of 72.89. Before conducting a hypothesis test, a data normality test and a homogeneity test were carried out. If the data is normally distributed, parametric statistical techniques can be used; Conversely, if it is not normally distributed, nonparametric statistical techniques can be used. The initial step is to analyze the normality of the data using the Kolmogorov-Smirnov test, the results of which are listed in Table 4 below.

Table 4. Normality Test Results

Variabel	Experimental Class	Control Class	Conclusion
Algebraic Thinking	0,092	0,062	Normal Distribution

From Table 4, it is found that the normality test produces significance values. This suggests that the data for both groups came from normally distributed populations. The next step is to check if both groups have homogeneous variance. The homogeneity test is performed using the Levene test. The homogeneity test results are in Table 5.

Table 5. HomogeneityTest Results

Variabel	Sig.	Conclusion
Algebraic Thinking	0,067	Homogeneous

Based on the predetermined research design, hypothesis analysis was carried out using t-tests. The t-test is performed after ensuring that the requirements of population normality and homogeneity of population variance are met. From the calculation results, it was found that both groups had normally distributed data and homogeneous variance. With the data having met both conditions, the next step is to perform a T-test on the data. The following are the results of the T-test using SPSS 26:

Table 6. T-Test Results

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Algebraic Thinking	Equal variances assumed	3.873	126	.000	6.51563	1.68231	3.18638	9.84487

The results of the t-test above showed a significant difference between the algebraic thinking skills of students in the experimental and control classes. This is evidenced by the significance value (2 sides) = 0.000 < sig. = 0.05 (coefficient). Specifically, based on data analysis, two findings were obtained: first, the ability to think algebraically in the experimental class was higher than in the control class. Second, the learning model of the Generative Multi Representation Learning Model Modified Schema Based Instruction has a significant influence on improving algebraic thinking skills.

The Effect of the Generative Multi Representation Learning Model Modified Schema Based Instruction (MGMRM-SBI) on Algebraic Thinking Ability (RQ)

In the Orientation stage (Identification schema and Muti representation) students try to understand the schema and various mathematical representations taught by the teacher during the learning process, using analogies and metaphors. They also reflect on previous knowledge and experience related to the material to be studied. This finding fits with the theory that states the use of analogies supports students' understanding of abstract concepts by referring to concepts that are easier to understand, and this can help in the development of students' ability to develop problem-solving strategies (Tang et al., 2014). During this stage, students attempted to understand various mathematical representations introduced by the teacher using analogies and metaphors. This approach supported students in comprehending abstract concepts and developing problem-solving strategies. The use of metaphors provided concrete images, helping students overcome difficulties in understanding complex concepts. This aligns with previous research indicating that generative learning enhances critical reading and writing skills, fostering a positive attitude during the learning process (Buchner, 2022).

Students analyzed the types of problems and selected appropriate representations. The multi-representation approach, involving symbols and equations, aided students in understanding mathematical relationships. Previous studies have shown that using multiple representations improves problem-solving and algebraic thinking skills at the elementary level (Wong et al., 2011; Kusumaningsih & Herman, 2018; Mahama & Kyeremeh, 2022).

In the Challenge and restructuring stage (Familiarize with similar and different problems situationally and structurally, and manipulate the transformation of idea representation) Teachers use various visual representations in the learning process. Students can observe relationships between variables and formulate generalizations based on the graphs presented, helping them develop abilities in generalization and pattern understanding. Students are given a problem using a representation as in Figure 1 below.

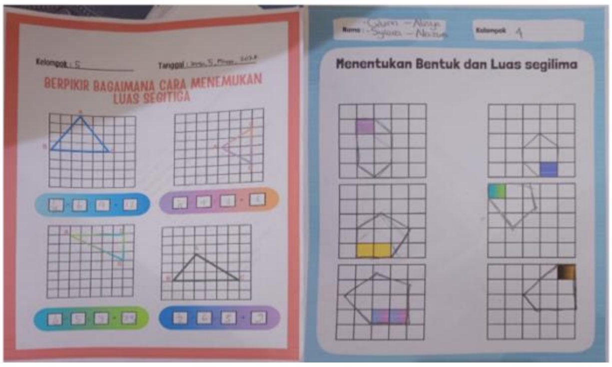

Figure **1**. Multi Representation

The findings of this study are in accordance with the theory which argues students can see how the symbols represent relationships and operations, which ultimately helps them understand the symbols. The use of mathematical representations allows students to model real situations and tackle problems by detailing mathematical steps. Typically, there are four modes of representation in the mathematical domain: (1) verbal, (2) graphing, (3) algebra, and (4) numeric (Tang et al., 2014). The results of this study are supported by other studies that find the use of variables can, potentially, improve students' understanding of variables and generalizations, provided that programming praxis is embedded in appropriate algebraic logos and on solving equations involving two unknown representations (Xie & Cai, 2022). At the Application Application Stage (Practice of problem solving using representations of specific situations, different types of Multi Representation problem schemes) Students are given problems that represent real and diverse situations. Students apply the mathematical concepts they have learned using various representations of ideas. such as verbal representations, diagrams, graphs, or mathematical equations to present their solutions. This selection is based on the type of problem and modeling skills required.

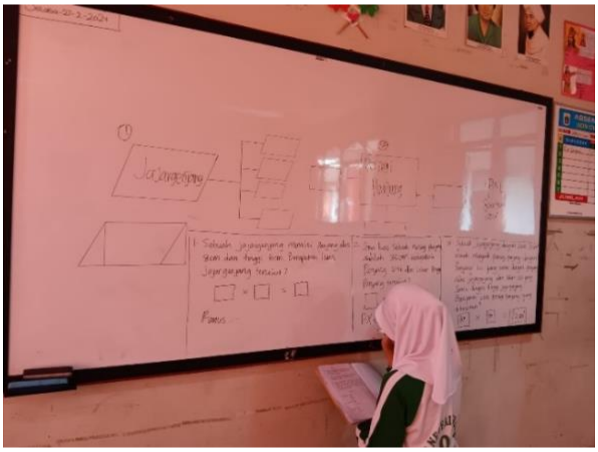

Figure 2. Types Of Problem Schemes

The MGMRM-SBI model includes explicit instruction that helps students identify different problem types and provides multiple examples and visual representation models (Jitendra et al., 2009; Kingsdorf & Krawec, 2014). This explicit instruction enables students to understand and solve problems more effectively by recognizing patterns and applying appropriate schemas. The use of Schema-Based Instruction (SBI) was shown to improve accuracy in problem-solving tasks. Students in the experimental group consistently performed better in procedural fluency and computational fluency, particularly in word problems involving the addition and subtraction of two-digit integers without regroupin (Peltier & Vannest, 2017; Skinner & Cuevas, 2023). This suggests that SBI provides a structured approach that enhances students' ability to tackle mathematical problems accurately. Other studies corroborate that SBI significantly improves students' problem-solving abilities compared to direct translational strategies. This improvement is observed in both virtual and concrete conditions, indicating the versatility and effectiveness of SBI across different learning environments (Karayil & Praveen, 2020). Students who received SBI were better at completing worksheets and actively participating in class evaluations, providing and responding to feedback, which further reinforced their learning.

Teachers should incorporate various visual aids such as diagrams, graphs, and charts to help students visualize algebraic concepts. For example, when teaching equations, teachers can use balance scales or number lines to represent equality visually. Utilize interactive tools such as digital whiteboards or educational software that allow students to manipulate variables and see the effects in real-time. Use everyday analogies and metaphors to explain abstract algebraic concepts. For instance, comparing algebraic variables to containers that can hold different quantities can make the concept more relatable. Integrate stories or scenarios where algebraic thinking is required, making the learning process engaging and relatable. Provide clear, step-by-step instructions on how to approach algebraic problems. This includes identifying the type of problem, choosing the appropriate representation, and applying the correct operations. Offer numerous examples of different types of algebraic problems and solve them using various methods to show different approaches to finding a solution. Encourage students to work in groups to discuss and solve algebraic problems. This collaborative approach allows students to share ideas and strategies, enhancing their understanding. Facilitate sessions where students can present their solutions and receive feedback from their peers, fostering a deeper understanding through discussion and critique. Use real-world problems that require algebraic thinking to solve. This could involve budgeting exercises, measuring areas and perimeters, or analyzing data from simple experiments. Implement project-based learning activities where students must apply algebraic concepts to complete a project, such as designing a simple game or creating a budget plan for a classroom event. Conduct regular assessments to evaluate students' understanding and mastery of algebraic concepts. This includes quizzes, tests, and practical assignments. Provide timely and constructive feedback on students' work, highlighting their strengths and areas for improvement. Participate in professional development workshops and training sessions focused on the MGMRM-SBI approach. This helps teachers stay updated with the latest instructional strategies and techniques. Engage in professional learning communities where teachers can share experiences, challenges, and successes related to implementing the MGMRM-SBI approach. By systematically integrating these strategies, elementary school teachers can create a dynamic and supportive learning environment that significantly enhances students' algebraic thinking skills. This approach not only helps students grasp complex algebraic concepts but also prepares them for more advanced mathematical challenges in the future.

CONCLUSION

Based on the analysis and discussion, it can be concluded that the Generative Multi-Representation Learning Model Modified Schema-Based Instruction (MGMRM-SBI) significantly improves elementary students' algebraic thinking skills. This model is more effective than the expository model in enhancing students' ability to use symbols in mathematical modeling, generalize arithmetic patterns, make informed predictions, and provide evidence in problem-solving. The findings suggest that the MGMRM-SBI model can be an effective instructional strategy for elementary school teachers to improve their students' algebraic thinking skills. Teachers are encouraged to incorporate visual representations, analogies, and metaphors in their teaching to help students grasp complex algebraic concepts. This study's generalizability is limited as it focused on a specific school in East Jakarta. Future research should include a more diverse sample to represent various educational contexts. Additionally, further studies could explore the long-term effects of the MGMRM-SBI model on students' overall mathematical performance. Educational practitioners can apply the MGMRM-SBI model to design lesson plans and activities that foster algebraic thinking from an early age. This approach not only aids in understanding algebra but also prepares students for more advanced mathematical concepts in the future. By implementing this model, educators can address the common challenges faced in teaching algebra and provide a robust foundation for students' mathematical development.

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