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The Influence of Manipulative Media on Enhancing Mathematical Representation Skills of Fourth Grade Elementary School Students

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Keywords

Manipulative Media, Mathematical Representation, Mathematics Learning, Constructivism, Elementary School

Abstract

This study aims to analyze the influence of using manipulative media on enhancing the mathematical representation skills of fourth-grade elementary school students. A quasi-experimental method with a pretest-posttest control group design was used. The research was conducted at SDN Sumberwuluh 1 Mojokerto, with a sample of fourth-grade students divided into experimental and control groups. Data were collected through mathematical representation ability tests, teacher and student activity observation sheets, and documentation. The results showed that manipulative media had a significantly positive effect on students' mathematical representation skills. The experimental group exhibited higher improvement than the control group, with an average N-Gain Score of 0.71 (high category). Aspects of students' visual, symbolic, and verbal representation experienced significant improvement. In conclusion, manipulative media helps students connect abstract concepts with concrete representations, facilitating a deeper understanding of mathematics.

Introduction

Mathematics education in elementary school serves as a crucial foundation in building students' mathematical conceptual understanding for subsequent educational levels. At the elementary level, mathematics education aims to equip students with logical, analytical, systematic, critical, and creative thinking abilities, as well as collaborative skills (Jamil et al., 2024; Sitopu et al., 2024). These capabilities are essential for students to acquire, manage, and utilize information to survive in an ever-changing, uncertain, and competitive environment.

At the elementary school level, students' cognitive development characteristics remain at the concrete operational stage. During this stage, students are not yet capable of formal and abstract thinking (Darmayanti et al., 2022; Pakpahan & Saragih, 2022; Rabillas et al., 2023). Their logical thinking is closely tied to real objects or direct experiences. Therefore, elementary school mathematics instruction needs to be designed with consideration for these characteristics to ensure that abstract mathematical concepts can be well understood by students (Solihin & Habibie, 2024).

Mathematical representation ability is one of the crucial skills that must be developed from elementary school onward. Mathematical representation is a form of students' interpretative thinking toward a problem, used as a tool to find solutions to that problem (Mainali, 2021). This ability encompasses students' capacity to communicate their mathematical ideas in various forms, such as visual (pictures, diagrams, graphs), symbolic (mathematical notation, numerics), and verbal (words or written text) (Matabane & Machaba, 2023; Sari & Yuberta, 2022). Elementary school students need to develop mathematical representation skills for several reasons (Kaitera & Harmoinen, 2022). *First*, representation helps students organize their thoughts about mathematical concepts. *Second*, representation facilitates a deeper understanding of relationships between mathematical concepts. *Third*, representation enables students to communicate their mathematical thinking to others. Fourth, representation helps students recognize connections between related mathematical concepts.

The use of manipulative media in mathematics learning becomes one solution to help students develop mathematical representation skills. Manipulative media are concrete objects specifically designed that can be manipulated by students to understand mathematical concepts (Anggraini et al., 2023). These media can include buttons, beads, Cuisenaire rods, logic blocks, tangrams, or other objects that can be used to model mathematical concepts. Manipulative media play an important role in elementary school mathematics learning for several reasons (Supriadi et al., 2022). *First*, manipulative media bridge the gap between abstract mathematical concepts and students' concrete thinking. *Second*, the use of manipulative media provides hands-on experiences that enable students to actively discover and construct their own understanding. *Third*, manipulative media help students visualize mathematical concepts and make connections between concrete and abstract representations.

Based on observations conducted in Grade IV at SDN Sumberwuluh 1 Mojokerto, several problems were identified regarding mathematics learning and students' mathematical representation abilities. Students tend to struggle with understanding abstract mathematical concepts, such as fractions and measurement, due to the lack of concrete learning media usage. Teachers rarely use manipulative media such as fraction blocks, buttons, or other teaching aids, resulting in instruction that often relies solely on lectures and textbooks. This condition impacts students' low mathematical representation abilities. Students experience difficulties in depicting mathematical concepts in visual forms, such as creating diagrams or pictures, as well as symbolic forms, such as equations or arithmetic operations. Less varied learning methods also cause students to appear passive and less enthusiastic in participating in mathematics learning (Lugosi & Uribe, 2022). Additionally, there is a significant gap between high-achieving and low-achieving students in representing mathematical ideas, especially in problem-solving tasks.

The use of manipulative media can positively influence the improvement of students' mathematical representation abilities. When students use manipulative media, they actively engage in constructing mathematical understanding through exploration and discovery (Byrne et al., 2023). Manipulative media help students understand abstract concepts in concrete and meaningful ways. Students can see, touch, and manipulate physical objects to understand mathematical relationships and develop strong mental representations. Through the use of manipulative media, students can develop various forms of mathematical representation. Visual representation can be developed when students use manipulative media to create models or pictures of mathematical situations (Garderen et al., 2021). Symbolic representation can be developed when students translate their manipulative experiences into mathematical notation. Verbal representation can be developed when students discuss and explain their thinking using manipulative media as references (Solihin et al., 2024).

Several previous studies have demonstrated the effectiveness of using manipulative media in mathematics learning. Research conducted by Gündüz et al. (2022) showed that the use of manipulative media can improve mathematical concept understanding and representation abilities of elementary school students. Another study by Sulistyawati et al. (2021) found that mathematics learning with manipulative media can significantly increase students' learning motivation and achievement.

The use of manipulative media also aligns with mathematics learning principles that emphasize providing direct experiences to students. Through the use of manipulative media, mathematics learning becomes more meaningful because students can construct their own understanding based on concrete experiences (Ahmad, 2024; Siller & Ahmad, 2024). This aligns with constructivist learning theory, which emphasizes that knowledge cannot be directly transferred from teacher to student but must be actively built by students through experience.

Based on the urgency of developing mathematical representation abilities and problems found in the field, research on the influence of manipulative media use on improving

mathematical representation abilities of fourth-grade elementary school students is necessary. This research is important to provide empirical evidence about the effectiveness of using manipulative media in improving students' mathematical representation abilities, as well as to provide alternative solutions for mathematics learning problems in elementary schools.

This research is expected to provide theoretical and practical contributions to elementary school mathematics education. Theoretically, this research can enrich studies about the use of manipulative media and the development of elementary school students' mathematical representation abilities. Practically, the results of this research can serve as a reference for teachers in designing effective mathematics learning using manipulative media to improve students' mathematical representation abilities.

Method

Research design

This study adopts a quantitative approach using a quasi-experimental design. The specific design applied is a nonequivalent control group design, where two non-randomly selected groups are utilized: an experimental group receiving manipulative media treatment and a control group using conventional learning methods. The research was conducted at SDN Sumberwuluh 1 Mojokerto during the even semester of the 2024/2025 academic year. The implementation lasted 8 weeks, with each group having 2 learning sessions per week.

Research sample

The study population consisted of all fourth-grade students at SDN Sumberwuluh 1 Mojokerto, comprising two parallel classes with a total of 56 students. A saturated sampling technique was used, meaning all members of the population were included as the sample. Class IVA (28 students) served as the experimental group, while Class IVB (28 students) acted as the control group.

Research procedure

The research was carried out in three main stages. In the preparation stage, research instruments were developed, including test items, observation sheets, and validation forms. Instruments were validated by experts to ensure their alignment with research objectives. A pilot test was conducted with students outside the sample to assess the validity and reliability of the instruments. Based on the results, necessary revisions were made.

In the implementation stage, a pretest was administered to both groups to assess their initial mathematical representation abilities. The experimental group underwent learning sessions using manipulative media, while the control group followed conventional methods. Observations were conducted during each session to monitor teacher and student activities. At the end of the instructional sessions, a posttest was given to both groups to measure their final mathematical representation abilities.

Data analysis

In the data analysis stage, descriptive statistics (mean, standard deviation, maximum, and minimum values) were calculated to summarize the data. Assumptions for data analysis were tested, including normality (Shapiro-Wilk test), homogeneity (Levene's test), and linearity. Hypotheses were tested using statistical methods: Independent Sample t-test to compare the mathematical representation abilities of the experimental and control groups, Paired Sample t-test to analyze improvements within each group, and N-Gain Score was calculated to determine the extent of improvement in both groups.

Data were collected using the following techniques: Pretest and posttest instruments were used to measure students' mathematical representation abilities before and after the intervention. Teacher and student activities were observed to assess the implementation of manipulative media in learning. Supporting data, such as photos of learning activities and students' work, were collected.

The main research instrument was a test to measure students' mathematical representation skills in visual, symbolic, and verbal forms. Other instruments included observation sheets for teacher and student activities, validation forms for ensuring the quality of instruments, and documentation sheets for recording learning activities.

The research was considered successful based on the following criteria: A significant difference in mathematical representation abilities between the experimental and control groups, higher improvement in the experimental group compared to the control group, and at least 75% of students in the experimental group achieving the minimum competency criteria (KKM).

Various manipulative media were used during the study to facilitate concrete understanding of mathematical concepts, including fraction blocks for understanding fractions, geoboards for teaching plane geometry, unit cubes for volume measurement, fraction cards for fraction operations, and clock models for time measurement.

Ethical aspects of the research included obtaining permission from the school, maintaining confidentiality of participants' identities, ensuring no harm to participants, presenting data objectively, and treating all participants equitably in accordance with the research plan.

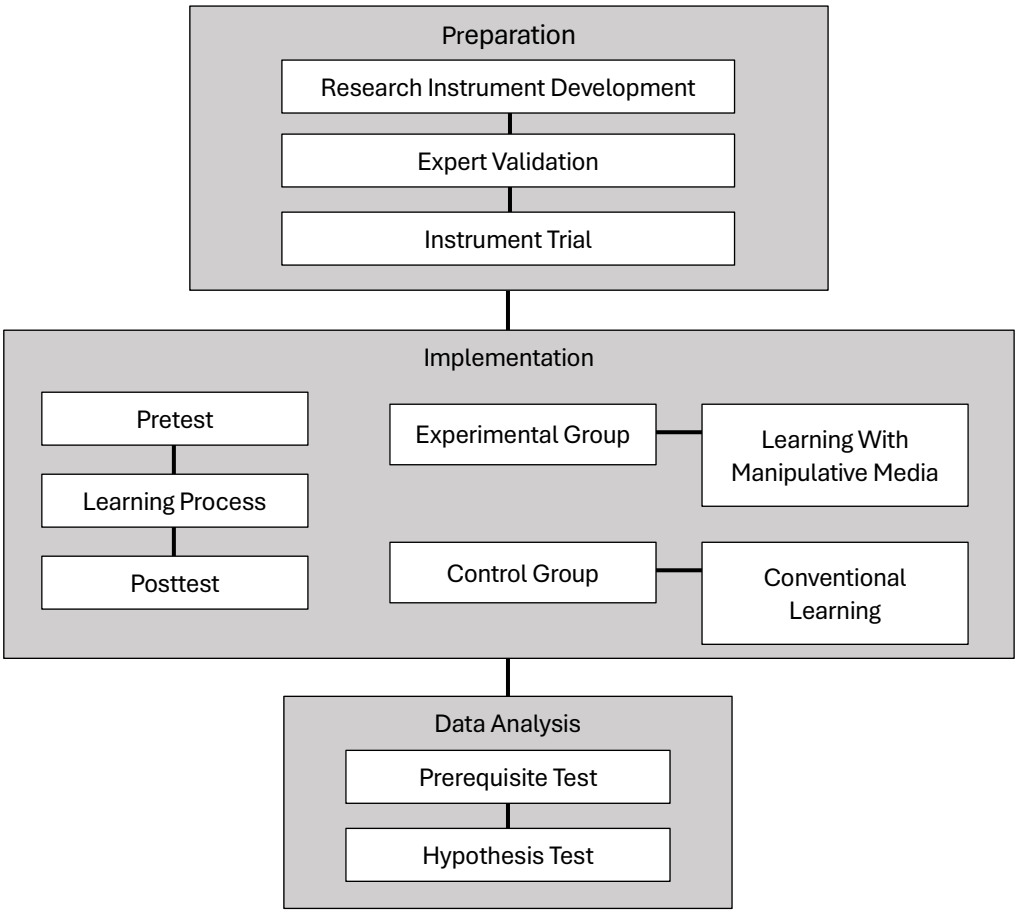

Figure 1. Research Framework Diagram

Results and Discussion

Results

Mathematical Representation Ability Test Results

Measurement of students' mathematical representation skills was conducted through pretests and posttests in both groups. The pretest aimed to determine the students' initial abilities before the treatment, while the posttest measured their final abilities after the treatment. Descriptive statistical analysis revealed an interesting pattern in the students' progress.

Table 1. Descriptive Statistics of Pretest and Posttest

Statistic	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
N	28	28	28	28
Mean	58.21	82.64	57.89	71.43
Std. Dev	8.73	7.92	8.91	8.54
Min	45	70	44	60
Max	75	95	74	85

In the experimental group, the pretest scores showed an average of 58.21 with a standard deviation of 8.73. The lowest score obtained was 45 and the highest score reached 75. After being given learning with manipulative media, the posttest results showed a substantial increase with an average of 82.64 and a standard deviation of 7.92. The lowest score increased to 70 and the highest score reached 95. This average increase of 24.43 points indicates the positive impact of using manipulative media.

Meanwhile, the control group that used conventional learning showed different results. The pretest score of the control group had an average of 57.89 with a standard deviation of 8.91, the lowest score of 44 and the highest score of 74. In the posttest, there was an increase with an average of 71.43 and a standard deviation of 8.54, where the lowest score increased to 60 and the highest score reached 85. Although there was an increase of 13.54 points, this increase was not as large as that achieved by the experimental group.

Normality Test Analysis

Before testing the hypothesis, a normality test was conducted using the Shapiro-Wilk method to ensure data distribution.

Table 2. Shapiro-Wilk Normality Test Results

Group	Data	Statistic	df	Sig.
Experimental	Pretest	0.967	28	0.498
	Posttest	0.952	28	0.223
Control	Pretest	0.959	28	0.337
	Posttest	0.961	28	0.371

The normality test results in the experimental group showed a significance value of 0.498 for the pretest and 0.223 for the posttest. While in the control group, a significance value of 0.337 was obtained for the pretest and 0.371 for the posttest. All significance values were above > 0.05, which confirmed that the data in both groups were normally distributed. The normality of this data distribution is a valid basis for conducting further parametric analysis.

Homogeneity Test Analysis

The homogeneity test using the Levene method showed results that supported the assumption of equality of variance between the two groups.

Table 3. Levene's Test for Homogeneity of Variances

Data	Levene Statistic	df1	df2	Sig.
Pretest	0.042	1	54	0.839
Posttest	0.325	1	54	0.571

In the pretest data, the Levene statistical value was 0.042 with a significance of 0.839. For posttest data, the Levene statistical value was 0.325 with a significance of 0.571. Significance values greater than > 0.05 in both tests confirm that the data variances of the two groups are homogeneous, thus qualifying for comparative analysis.

Hypothesis Testing

a. Independent Sample t-test Analysis

Table 4. Independent Sample t-test Results

t-value	df	Sig. (2-tailed)	Mean Difference
5.247	54	0.000	11.21

The results of the independent sample t-test for posttest data yielded a value of t = 5.247 with 54 degrees of freedom and a significance of 0.000. The average difference between the two groups of 11.21 points indicates a significant advantage of the experimental group over the control group. These results prove the effectiveness of using manipulative media in improving students' mathematical representation skills.

b. Paired Sample t-test Analysis

Table 5. Paired Sample t-test Test Results

Group	t-value	df	Sig. (2-tailed)
Experimental	18.432	27	0.000
Control	12.754	27	0.000

The experimental group showed a result of t = 18.432 with a significance of 0.000, while the control group produced t = 12.754 with a significance of 0.000. Although both groups showed significant improvement, the larger t value in the experimental group indicated a more substantial improvement.

c. N-Gain Score Analysis

Table 6. N-Gain Score Calculation Results

Group	N-Gain Score	Category
Experimental	0.71	High
Control	0.43	Medium

The N-Gain Score calculation provides results that further strengthen the research findings. The experimental group achieved a score of 0.71 which is included in the high category, while the control group obtained a score of 0.43 which is included in the medium category. This

difference confirms that the use of manipulative media has a greater impact in improving students' mathematical representation skills.

Learning Observation Results

Observations of learning activities showed positive developments from meeting to meeting.

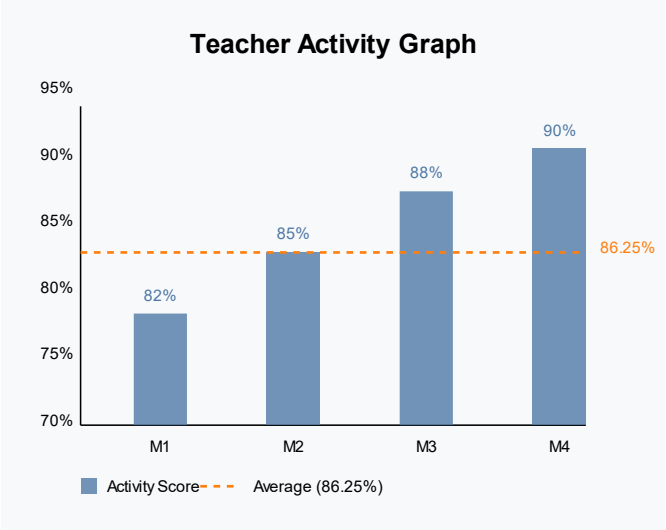

Figure 2. Teacher Activity Graph

Teacher activities showed a consistent increase from 82% in the first meeting to 90% in the fourth meeting, with an overall average of 86.25% which is included in the very good category. This increase reflects the teacher's better adaptation and mastery in implementing learning with manipulative media.

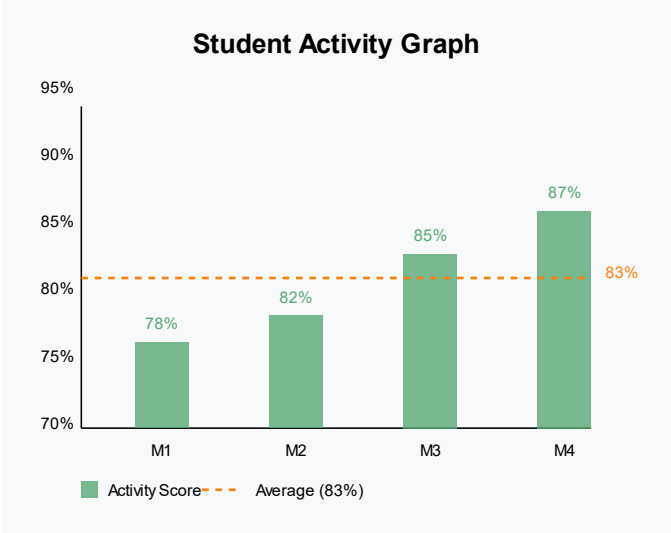

Figure 3. Student Activity Graph

Student activities also showed a positive trend, increasing from 78% in the first meeting to 87% in the fourth meeting, with an average of 83% which is included in the good category. This increase is characterized by students' active participation in using manipulative media, more intensive interaction in group discussions, and better ability to represent mathematical concepts using the media provided.

Qualitative observations during learning revealed some important findings:

1. Students showed high enthusiasm when using manipulative media, especially when exploring the concept of fractions with fraction blocks and flat shapes with geoboards.
2. There was an increase in students' ability to translate concrete representations using manipulative media into mathematical images and symbols.
3. Group discussions became more lively because students had concrete objects to refer to in explaining their thinking.
4. Learning time management is more effective as teachers and students' familiarity with the use of manipulative media increases.

Based on the overall results of the analysis, it can be concluded that the use of manipulative media has a significant positive effect on improving the mathematical representation skills of fourth grade elementary school students. This conclusion is supported by empirical evidence in the form of:

1. Significant differences between the posttest results of the experimental and control groups
2. Higher ability improvement in the experimental group compared to the control group
3. Achievement of research success indicators with 85.7% of experimental group students reaching KKM
4. Observation results that show effective learning implementation and increased student learning activities

Discussion

The use of manipulative media in mathematics instruction has shown a significantly positive impact on improving fourth-grade elementary school students' mathematical representation abilities. Analysis of the research findings reveals several key points supporting the effectiveness of manipulative media in mathematics learning. Based on data analysis, higher improvement in mathematical representation ability was observed in the experimental group compared to the control group. This aligns with Campilla & Castañaga (2021), who found that the use of manipulative media enhances elementary students' mathematical conceptual understanding, with an average improvement of 27.5%. Manipulative media aids students in

bridging the gap between abstract concepts and their concrete representations. The significant improvement in the experimental group (N-Gain Score 0.71) indicates the effectiveness of manipulative media in facilitating the development of mathematical representation skills. As stated by Solihin & Rahmawati (2024), the use of concrete media in mathematics learning helps students construct understanding through direct experience with physical objects.

The visual representation aspect was one of the components that showed significant improvement in this study. Using manipulative media such as fraction blocks and geoboards positively impacted students' visual representation abilities. The posttest results revealed a substantial improvement in students' ability to create mathematical diagrams and images. Rau & Herder (2021) found that manipulating physical objects helps students develop strong mental imagery of mathematical concepts, which they can then translate into visual representations. Gündüz et al. (2022) emphasized that manipulative media provides concrete experiences that help students visualize abstract mathematical concepts. When students can see and manipulate physical objects, they develop a deeper understanding of mathematical relationships.

Students' symbolic and verbal representation abilities also showed promising development. Students in the experimental group demonstrated greater ability to translate mathematical situations into symbols, equations, or mathematical expressions. This aligns with Donovan & Alibali (2021), who stated that manipulative experiences help students comprehend the meanings behind mathematical symbols. Siller & Ahmad (2024) further highlighted that manipulative media bridges the gap between concrete and abstract understanding, aiding students in understanding the relationships between physical and symbolic representations in mathematics. The improvement in verbal representation skills was evident in students' enhanced ability to articulate their mathematical thinking. Classroom observations revealed that students became more confident in communicating their mathematical ideas when they had manipulative media as a reference.

The teaching process with manipulative media showed positive development from one meeting to the next. Tkácová et al. (2023) stressed that the effectiveness of manipulative media depends on the quality of its implementation in teaching. The improvement in teacher activity from 82% to 90% reflected positive adaptation to the use of manipulative media. Schnepel & Aunio (2022) emphasized that the effective use of manipulative media requires careful planning and systematic implementation. Teachers need to understand how to use the media to facilitate meaningful learning. The increase in student activity from 78% to 87% indicated greater active engagement in learning. Tabuena & Pentang (2021) found that using manipulative media increases students' motivation and participation in mathematics learning.

The pedagogical implications of the successful use of manipulative media in enhancing mathematical representation abilities encompass several important aspects. Donovan & Fyfe (2022) highlighted that elementary mathematics instruction should begin with concrete experiences before transitioning to abstract concepts. Manipulative media allows differentiated

learning tailored to students' needs. Solihin et al. (2024) discovered that manipulative media accommodates various learning styles and skill levels. Byrne et al. (2023) stressed the importance of developing deep conceptual understanding through manipulative media, beyond mere procedural learning. However, some challenges in implementing learning with manipulative media warrant attention. Dewi & Verawati (2022) identified that using manipulative media requires more time than conventional teaching methods. Levitskaya & Fedorov (2021) emphasized that teacher proficiency in effectively using manipulative media is a key success factor.

The contributions of this study include significant theoretical and practical aspects. Theoretically, this study reinforces constructivist learning theories in the context of elementary mathematics instruction and provides empirical evidence of the effectiveness of manipulative media. Practically, it offers an effective learning model and practical guidance for teachers in implementing instruction with manipulative media. However, some research limitations, such as the study's duration and the generalization of findings, must be considered.

Based on the findings of this study, several recommendations for future research include conducting longitudinal studies to understand long-term impacts, exploring interactions between manipulative media use and variables such as learning styles and student motivation, and developing more innovative manipulative media. As stated by Sulistyaningsih (2022), the use of manipulative media is not just a learning aid but an integral component in building robust mathematical understanding among elementary students. In conclusion, this study provides valuable contributions to the development of mathematics teaching practices in elementary schools and opens avenues for further research to improve the quality of mathematics education.

Conclusion

Based on the research findings and discussion regarding the impact of manipulative media on improving fourth-grade elementary school students' mathematical representation abilities, it can be concluded that the use of manipulative media has a significantly positive effect on enhancing students' mathematical representation skills. The improvement in mathematical representation abilities in the experimental group that used manipulative media was higher than in the control group. The implementation of instruction with manipulative media was effective, as indicated by an average teacher activity score of 86.25% (very good) and a student activity score of 83% (good). There was a noticeable improvement in the quality of instruction from session to session. Manipulative media successfully facilitated the development of students' visual, symbolic, and verbal representation abilities. Students demonstrated increased ability in creating drawings, using mathematical symbols, and communicating mathematical ideas. The success criteria were achieved, with 85.7% of

students in the experimental group meeting the minimum passing criteria, demonstrating the effectiveness of manipulative media in mathematics instruction.

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