Journal of General Education and Humanities
Vol. 4, No. 2, May 2025, pp. 513 – 522, https://doi.org/10.58421/gehu.v4i2.435
ISSN 2963-7147

Enhancing Elementary Students' Mathematical Representation Skills Through Higher Order Thinking Skills (HOTS) Practice Questions

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Article Info

Article history:

Received 2025-04-08
Revised 2025-05-12
Accepted 2025-05-13

Keywords:

Elementary mathematics education
Higher Order Thinking Skills (HOTS)
Mathematical representation

ABSTRACT

This study aims to 1) evaluate students' mathematical representation skills before participating in HOTS practice questions, 2) evaluate students' mathematical representation skills after participating in HOTS practice questions, and 3) determine the improvement in students' mathematical representation skills through HOTS practice questions. This research uses a quantitative method with a one-group pretest-posttest design. The research population included 60 fifth-grade students from SD Negeri 1 Pelandakan, Cirebon, with a sample of 30 students selected using purposive sampling. The instrument used was a mathematical representation skills test. Data were analyzed using the N-Gain test and paired sample t-test to compare pretest and posttest results. The study results show that: 1) the average mathematical representation skills of students before participating in HOTS practice questions was 67.83, classified as weak category; 2) the average mathematical representation skills of students after participating in HOTS practice questions was 85.38, clasified as strong category; and 3) there was a significant improvement in students' mathematical representation skills, with an average N-Gain score of 0.5551 and $p < 0.000$. This improvement falls under the moderate category and is statistically significant. These findings suggest that HOTS-based practice questions effectively enhance mathematical understanding and should inform curriculum and instructional planning.

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1. INTRODUCTION

Mathematics is a fundamental discipline that plays an important role in the advancement of science and technology [1]. As a compulsory subject at various levels of education, mathematics serves to develop students' logical, analytical, critical, and creative

thinking skills [2]. According to the Indonesian Dictionary (KBBI), mathematics is a branch of science that studies numbers, the relationships between numbers, and the operational steps in solving problems related to numbers [3]. Through mathematics learning, students are expected to be able to solve problems, make appropriate decisions, and apply mathematical principles and concepts in everyday life [4]. However, in reality, many students perceive mathematics as a difficult subject due to its abstract and procedural nature [5].

One of the key competencies in mathematics is the skills of mathematical representation, which refers to students' capacity to express ideas or concepts in various forms, such as visual (diagrams, graphs), symbolic (formulas, equations), and verbal (explanations or arguments) [6]. Villegas as cited in Mulyaningsih et al. [7], classified this representation skills into three main types: 1) verbal representation, which refers to conveying answers through written descriptions or explanations; 2) visual representation, which involves the use of images, graphs, or illustrations to solve problems; and 3) symbolic representation, which involves using mathematical symbols or models to find solutions. These three forms of representation serve as a basis for assessing and improving students' ability to effectively communicate mathematical concepts. Research by Fathonah [8] also shows that this ability not only helps students understand mathematical concepts but also enhances their problem-solving skills and their ability to present solutions mathematically. Furthermore, representation skills act as an important bridge that connects abstract mathematical ideas to concrete forms, thus strengthening both understanding and problem-solving skills [9].

Despite its crucial role, Indonesian students' mathematical representation skills remain relatively low. The 2018 PISA results indicated that the average mathematics score of Indonesian students was only 379, far below the OECD average of 490 and the ASEAN average of 431 [10]. Even in 2022, the score dropped to 366, a decrease of 13 points from 2018, and still below the global average of 472 [11]. Juniarti [12] revealed that while mathematical representation skills contribute to learning outcomes, their contribution of only 9.42% indicates that many students have not yet mastered this skill optimally. On the other hand, a different result was found in a study by Izzati [13], who reported that students' average mathematical representation skilss falls into the strong category.

This discrepancy in students' mathematical representation skills may be influenced by various factors, including monotonous teaching methods and the lack of challenging practice problems [14]. To address this issue, innovative learning strategies specifically designed to improve students' mathematical representation skills are needed [15]. One promising approach is the use of HOTS practice questions, rooted in Bloom's Taxonomy, which emphasize the development of critical, analytical, and creative thinking. HOTS practice questions are known to deepen conceptual understanding and improve students' ability to represent mathematical concepts in various forms [16]. According to Khalid et al. [17], HOTS practice questions encourage students to analyze, evaluate, and create, thus strengthening their conceptual understanding and mathematical representation skills.

Several previous studies have shown that HOTS practice questions can enhance various mathematical abilities, including representation skills [18]. Saputri and Faiziyah

[19] found that students who regularly practiced HOTS practice questions demonstrated better mathematical representation abilities compared to those who only worked on routine problems. Additionally, a study by Utomo et al. [20] revealed that high-achieving students were more flexible in converting representations into various formats, including visual forms. These findings confirm that HOTS practice questions not only support conceptual understanding but also improve students' flexibility in mathematical representation.

Nevertheless, there is still limited research that specifically examines the impact of HOTS practice questions on students' mathematical representation abilities. Most existing studies tend to focus more on critical and creative thinking skills without exploring the aspect of representation in depth. Therefore, this study aims to fill that gap by investigating the use of HOTS practice questions as a strategy to improve students' mathematical representation skills. The objectives of this study are: 1) evaluate the students' mathematical representation skilss before participating in HOTS practice questions, 2) evaluate the students' mathematical representation skilss after participating in HOTS practice questions, and 3) determine the improvement in students' mathematical representation skilss through Higher Order Thinking Skills (HOTS) practice questions.

The importance of this study lies in its contribution to educational practice and policy. By exploring how HOTS practice questions influence mathematical representation, this study offers insights into improving instructional design and curriculum. It supports the shift toward active learning strategies aligned with modern educational demands, enhancing both conceptual understanding and academic performance. The central hypothesis of this study suggests that consistent and structured implementation of HOTS practice questions can significantly improve students' ability to represent mathematical ideas in various forms. This highlights the importance of incorporating HOTS questions into mathematics instruction as a strategic approach to enhance students' conceptual understanding and boost their overall academic performance.

2. METHOD

This study employed a quantitative approach with a one-group pretest-posttest design [21]. This design was used to assess the impact of Higher Order Thinking Skills (HOTS) practice questions on the improvement of students' mathematical representation abilities. In this design, data were collected through pretests and posttests to evaluate students' mathematical representation abilities before and after the application of HOTS practice questions. The focus of the study was to observe changes in students' mathematical representation abilities after receiving the treatment.

The study was conducted in November 2024 at SD Negeri 1 Pelandakan, Cirebon. This school was purposively selected due to its curriculum and facilities that support mathematics learning. Furthermore, the school regularly provides HOTS practice questions every week and has adequate resources to facilitate the smooth running of the research.

The population of the study consisted of all fifth-grade students at SD Negeri 1 Pelandakan, Cirebon, who participated in mathematics lessons. The sample was determined using purposive sampling, selecting one class that exhibited a diverse range of mathematical abilities but had a sufficient foundational understanding to participate in the

treatment [22]. The sample consisted of 30 students, who were designated as the experimental group and given both pretests and posttests to measure changes in their mathematical representation abilities after the treatment [23].

The research procedure began with the implementation of a pretest to assess students' initial mathematical representation abilities. The test included several questions designed to assess students' abilities to describe and solve mathematical problems. The pretest instrument was developed based on three main indicators of mathematical representation: 1) verbal representation, 2) visual representation, and 3) symbolic representation. After the pretest, students underwent the treatment, which consisted of HOTS practice questions across two sessions. In each session, students worked on questions designed to develop higher-order thinking skills such as analyzing, evaluating, and creating mathematical solutions.

Following the treatment, students completed the posttest, which had the same structure and level of difficulty as the pretest, with the aim of measuring improvements in their mathematical representation abilities. Data from the pretest and posttest were analyzed to identify significant differences before and after the treatment. The main instruments in this study were the pretest and posttest questions, which were pretested beforehand. Prior to their use, the mathematical representation test instruments were piloted to assess their validity, reliability, discriminative power, and difficulty level.

The data analysis in this study employed inferential analysis involved the use of the N-Gain test and the paired sample t-test to assess whether there was a statistically significant difference in students' mathematical representation abilities before and after the implementation of HOTS practice questions [24]. The paired sample t-test was used because the data came from the same group of students measured before and after the intervention. Descriptive statistics were also applied to summarize the mean scores, standard deviations, and score changes from pretest to posttest. This combined analysis provided a clearer and more accurate interpretation of the impact of HOTS practice questions on students' mathematical representation skills.

3. RESULTS

3.1. Description of Students' Mathematical Representation Skills Pretest Results

The pretest data on students' mathematical representation abilities were obtained by administering a test to 30 students before the treatment. Based on the pretest results, the descriptive statistics are as follows:

Table 1. Pretest Statistical Description of Students' Mathematical Representation Skills

Pretest of Students' Mathematical Representation Skills	
N	30
Min	25
Max	96
Sum	2035
Mean	67.83
Std. Deviation	18.960

3.2. Description of Students' Mathematical Representation Skills Posttest Results

The posttest data on students' mathematical representation skills were collected by administering an assessment to 30 students following the treatment. The results of this posttest were then analyzed, and the descriptive statistical findings are presented as follows:

Table 2. Posttest Statistical Description of Students' Mathematical Representation Skills

Posttest of Students' Mathematical Representation Skills	
N	30
Min	62.5
Max	100
Sum	2561.5
Mean	85.38
Std. Deviation	10.477

3.3. Improvement in Students' Mathematical Representation Skills after the Implementation of HOTS practice questions

In order to evaluate the enhancement of students' mathematical representation skills after the implementation of HOTS practice questions, both the N-Gain test and paired sample t-test were utilized. The N-Gain test was used to measure the level of improvement by comparing students' pretest and posttest results. The findings from the N-Gain analysis on students' mathematical representation abilities are presented below:

Table 3. Results of the N-Gain Test on Students' Mathematical Representation Skills

RN	N-Gain Score	Criteria	RN	N-Gain Score	Criteria
R-1	0.49	Medium	R-16	0.79	High
R-2	0.38	Medium	R-17	0.26	Low
R-3	0.16	Low	R-18	0.36	Medium
R-4	0.50	Medium	R-19	0.68	Medium
R-5	0.54	Medium	R-20	0.31	Medium
R-6	0.16	Low	R-21	0.31	Medium
R-7	0.67	Medium	R-22	0.62	Medium
R-8	0.60	Medium	R-23	0.69	Medium
R-9	0.67	Medium	R-24	0.60	Medium
R-10	0.69	Medium	R-25	0.50	Medium
R-11	0.76	High	R-26	0.50	Medium
R-12	0.77	High	R-27	0.62	Medium
R-13	0.26	Low	R-28	1.00	High
R-14	0.19	Low	R-29	1.00	High
R-15	0.60	Medium	R-30	1.00	High

Referring to Table 3, the N-Gain analysis reveals that 6 students demonstrated a high level of improvement, 19 students showed a medium level of improvement, and 5 students had a low level of improvement. This distribution suggests that most students experienced a moderate enhancement in their ability to represent mathematical concepts following the use of HOTS practice questions. The specific results from the N-Gain analysis are detailed in the section below:

Table 4. N-Gain Test Statistics on Students' Mathematical Representation Skills

	N	Minimum	Maximum	Mean
N-Gain Score	30	0.16	1.00	0.5551
N-Gain Percentage	Medium	16.00	100.00	55.51

According to Table 4, the mean N-Gain score indicating the improvement in students' mathematical representation skills following the application of HOTS practice questions is 0.5551, which falls into the medium category. This finding suggests that the treatment had a moderate level of effectiveness in enhancing students' ability to represent mathematical concepts.

Before advancing to more detailed inferential analysis, it is crucial to verify that the data meet the normality assumption. Normality testing is a fundamental step in determining whether parametric statistical methods can be applied to the data. To ensure the validity of subsequent analyses, the Shapiro-Wilk test was conducted on the N-Gain scores, with a significance level set at 0.05. The hypotheses for this test are outlined as follows:

H_0 : The data are drawn from a normally distributed population

H_1 : The data are not drawn from a normally distributed population

The decision rules are:

H_0 is accepted if the significance ≥ 0.05

H_0 is rejected if the significance is ≤ 0.05.

Table 5. Normality Test

Group	Pretest	Posttest	N-Gain Score
N	30	30	30
Kolmogorov-Smirnov Z	0.062	0.118	0.200
Shapiro-Wilk	0.88	0.056	0.237
Conclusion	Normal	Normal	Normal

The normality test for the N-Gain scores, as shown in Table 5, was conducted using the Shapiro-Wilk method, which resulted in a significance value of 0.237. Since this value exceeds the 0.05 threshold (> 0.05), it indicates that the N-Gain scores are normally distributed. Therefore, the assumption of normality is satisfied, allowing the use of parametric statistical methods, such as the paired sample t-test.

After confirming normality, a paired sample t-test was performed to assess whether the improvement in students' mathematical representation skills from pretest to posttest was statistically significant. The hypothesis testing was conducted following these criteria:

H_0 : There is no significant difference in students' mathematical representation skills before and after the implementation of HOTS practice questions

H_1 : There is a significant difference in students' mathematical representation skills before and after the implementation of HOTS practice questions

The testing criteria are:

Reject H_0 if the significance value ≤ 0.05

Accept H_0 if the significance value > 0.05

Table 6. Results of the Paired Sample t-test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest Posttest	-17.550	12.238	2.9234	-22.120	-12.980	-7.855	29	0.000

The paired sample t-test results presented in Table 6 show a significance value of 0.000, which is lower than the 0.05 threshold ($p < 0.05$). This indicates a significant difference between students' pretest and posttest scores regarding their mathematical representation skills. The average difference in scores was -17.550, with the negative value indicating that the posttest scores were considerably higher than the pretest scores. The negative t-value of -7.855 further supports this conclusion, confirming that the observed improvement after the intervention was significant. These results suggest that HOTS (Higher Order Thinking Skills) practice questions had a substantial and positive effect on students' ability to represent mathematical ideas. The statistically significant improvement highlights the effectiveness of integrating HOTS-based activities into mathematics teaching, as they promote deeper cognitive processes such as analysis, evaluation, and solution creation, which contribute to better representation and comprehension of mathematical concepts.

4. DISCUSSION

The results of this study show a significant improvement in students' mathematical representation abilities after the implementation of HOTS (Higher Order Thinking Skills) practice questions. Initially, students' mathematical representation ability was weak, with an average score of 67.83, reflecting the challenges identified in the 2018 and 2022 Programme for International Student Assessment (PISA) reports, which indicated that Indonesian students' performance in mathematics remains below international standards [10], [11]. This low score suggests that difficulties in mathematical representation are not just individual issues but represent a broader systemic challenge in the national mathematics education framework.

Following the implementation of HOTS practice questions, students' mathematical representation skills improved significantly, reaching a high category with an average score of 85.38. This result is in line with the findings of Izzati [13], who reported that students' representation abilities can reach strong levels when supported by appropriate learning strategies. Similarly, Fathonah [8] underscores the crucial role of representation skills in enhancing problem-solving capabilities and effective mathematical communication.

Further analysis of the pretest and posttest scores reveals a statistically significant improvement, supported by both the N-Gain test and the paired sample t-test. These findings confirm the positive impact of HOTS practice questions on students' mathematical representation abilities. This result is in line with the research by Khalid et al. [17], who

emphasized that engaging students in HOTS activities promotes deeper thinking, including analysis, evaluation, and creation, which in turn improves their conceptual understanding and ability to represent mathematical ideas effectively. Supporting this, Saputri and Faiziyah [19] found that students regularly exposed to HOTS-type problems demonstrated superior mathematical representation skills compared to those who predominantly engaged with routine problems.

The success observed in this study may be attributed to the nature of HOTS questions, which push students beyond rote learning. Rather than merely recalling procedures, students are challenged to interpret problems critically, construct solutions creatively, and justify their reasoning. As noted by Wahyuni and Efuansyah [25], such cognitive engagement fosters a more meaningful and enduring understanding of mathematical concepts. This supports existing literature that advocates the integration of HOTS in mathematics education to better equip students for real-life challenges.

However, the study also acknowledges several limitations. Despite the overall improvement, the effectiveness of HOTS practice questions can be influenced by factors such as limited instructional time, varying levels of student readiness, and the degree of teacher support. This is consistent with observations by Sa'dijah and Agusta [26], who emphasize that the successful implementation of HOTS strategies heavily depends on thoughtful planning, adequate scaffolding, and effective classroom execution.

In terms of contribution, this study adds novelty to the field of mathematics education by specifically investigating the impact of HOTS practice questions on students' mathematical representation skills. The domain that has received relatively limited attention compared to other aspects of higher-order thinking, such as critical or creative thinking [27]. Thus, this research not only reinforces the value of HOTS in fostering broad cognitive skills but also highlights its specific role in enhancing students' abilities to represent and communicate mathematical ideas effectively.

Implications for teachers and curriculum designers are crucial in applying these findings. Teachers are encouraged to incorporate tasks that promote HOTS into their lesson plans systematically. This approach has the potential to significantly enhance students' cognitive engagement and critical thinking significantly, thereby improving their ability to represent mathematical ideas. Additionally, ongoing teacher support is essential throughout the learning process. Teachers should provide consistent guidance to help students navigate the complexities of HOTS tasks and maintain their motivation to tackle challenging problems. Furthermore, educators are advised to create practice questions that reflect real-world situations. This makes lessons more relevant and engaging for students while also helping them understand the practical applications of mathematical concepts in everyday life.

However, the study acknowledges some key limitations. The absence of a control group limits the ability to compare the results with a group that did not receive the HOTS treatment. Moreover, the small sample size means that the findings may not be generalizable to a broader population. Future research should aim to address these limitations by utilizing a larger sample size and incorporating a control group for comparison.

5. CONCLUSION

Based on the findings regarding the improvement students' mathematical representation skilss through Higher Order Thinking Skills (HOTS) practice questions, it can be concluded that: 1) the average mathematical representation skilss of students before participating in HOTS practice questions was 67.83, categorized as weak category; 2) the average mathematical representation skilss of students after participating in HOTS practice questions was 85.38, categorized as strong category; and 3) there was a significant improvement in students' mathematical representation skilss, with an average N-Gain score of 0.5551 and a p-value of 0.000. This improvement falls under the moderate category and is statistically significant. Future studies could use comparative designs with control groups and larger sample sizes to better validate and generalize these findings, providing a deeper understanding of the long-term impact of HOTS on mathematical representation skills.

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