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Meta-analysis: Enhancing Mathematical Representation Ability Through the Discovery Learning

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ABSTRACT

To date, numerous studies have explored mathematical representation abilities delivered through the Discovery Learning. This study aims to identify and analyze published research on the effectiveness of the Discovery Learning in enhancing students' mathematical representation abilities using a meta-analysis. The data analyzed consists of 10 articles published in online journals. The Discovery Learning as the independent variable and mathematical representation ability as the dependent variable. Based on the calculation results, the average effect size was 3,08 categorized as very large, and the paired sample t-test showed a significant difference in students' mathematical representation abilities before and after being taught using the Discovery Learning. From these results, it can be concluded that the Discovery Learning significantly enhances mathematical representation abilities.

Keywords: *Meta-analysis, Mathematical Representation, Discovery Learning*

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INTRODUCTION

Mathematics education is essential in preparing students for the challenges of the modern era. In an increasingly digitized society, mathematics instruction is not only centered on conceptual understanding but also emphasizes mastering 21st-century skills, the effective use of technology. However, numerous studies indicate that mathematical representation abilities across various educational levels remain relatively low. This issue is often attributed to traditional teacher-centered teaching approaches, limited integration of relevant technology, and the lack of instructional strategies that foster active student exploration (Putri & Zulkardi, 2020).

According to (Mahendra, 2019), mathematical representation refers to the expression of mathematical ideas, such as problems, statements, solutions, definitions, and others, which are used to convey one's thought processes through specific methods, either conventional or unconventional, as an interpretation of their thinking. Meanwhile, mathematical representation ability refers to the skill of expressing these mathematical ideas in one of the following forms representation images, diagrams, graphs, or tables; representation mathematical notations, numerical or algebraic symbols; and representation written texts or narratives, as an interpretation of one's thoughts.

This ability enables students to comprehend abstract concepts, connect various mathematical ideas, and solve problems logically. However, numerous studies indicate that students' mathematical representation abilities remain low, particularly in conventional learning environments that lack support for active exploration and student engagement (Komala, 2021). In today's digital era, where technology is rapidly advancing, mathematics education must incorporate innovative approaches that not only enhance conceptual understanding but also improve students' mathematical representation abilities.

Discovery Learning is an instructional approach recognized as effective in improving mathematical representation abilities. First introduced by Bruner (1961), this method encourages students to independently discover mathematical concepts through exploration, investigation, and problem-solving. In this model, students actively engage in the learning progression, which fosters the enhancement of critical and creative thinking skills, ultimately aiding in the construction of more accurate mathematical representations (Putri & Zulkardi, 2020).

Research on Discovery Learning and its impact on mathematical representation abilities has been conducted in various educational contexts. However, the effectiveness of the Discovery Learning in improving mathematical representation abilities faces several challenges in its implementation. Therefore, a systematic synthesis is needed to attain a deeper insight of the patterns and effectiveness of this model. This can be achieved through a meta-analysis approach, which integrates findings from multiple studies to draw stronger general conclusions (Mathew, 2022). This study aims to identify and analyze published research on the effectiveness of the Discovery Learning in enhancing students' mathematical representation abilities using a meta-analysis approach.

This study aims to provide stronger empirical evidence regarding the effectiveness of the Discovery Learning in enhancing students' mathematical representation abilities. The results of this meta-analysis are expected to serve as a foundation for

curricula development and future teaching models. Additionally, the findings aim to guide educators and policymakers in selecting appropriate instructional strategies to improve students' mathematical competencies, emphasizing the importance of implementing the Discovery Learning to enhance their mathematical representation abilities.

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METHOD

This research is a meta-analysis study. Meta-analysis is a statistical technique that systematically collects quantitative data from multiple studies on the same topic, analysis the data, and compiles a summary of conclusions (Mathew, 2022). The steps of this meta-analysis research include:

a) Step Literature Collection

The first step of this research involves collecting published articles from online journals. The articles used in this stage must meet the following criteria:

- Articles are published nationally or internationally,
- Articles are published within the time frame of 2014 to 2024,
- Articles focus on Discovery Learning,
- Articles focus on mathematical representation ability,
- Articles provide pretest and posttest scores, effect size values, N-Gain scores, or other relevant statistical data,
- The sample in the articles ranges from JHS, SHS, to University level.

Based on these criteria, 10 relevant articles were selected for analysis in this meta-analysis research. The data from the 10 articles were then coded. Data coding facilitates the process of data collection and analysis. Each article is assigned a code ranging from D1 to D10 based on information such as the research title, author name, journal name, year of publication, educational level, and the required statistical data.

b) Step Calculation and Analysis

The Normalized Gain test is performed to measure the level of improvement or effectiveness of mathematical representation abilities in this study, as follows (Hake, 1999).

$$NGain = \frac{Posttest\ Score - \ Pretest\ Score}{Max\ Score\ - Pretest\ Score}$$

The Cohen's d formula is performed to determine the effect size in this study. Effect size serves as an indicator of the extent to which the Discovery Learning influences mathematical representation ability. The statistical analysis for calculating the effect size is as follows (Cohen, 1988).

$$d = \frac{Posttest\ Average - Pretest\ Average}{Standard\ Deviation}$$

The results of the Normalized Gain test from each article are then categorized based on the interpretation presented in Table 1. The effect size values from each article are then categorized based on the interpretation

presented in Table 2.

Table 1. Interpretation of N-Gain

N-Gain	Criteria
NGain $<$ 0,3	Low (Hake, 1999)
0,3 $\leq$ NGain $<$ 0,7	Medium (Hake, 1999)
NGain $\geq$ 0,7	High (Hake, 1999)

Table 2. Interpretation of Cohen's d

d	Criteria
0,2 $\leq$ d $<$ 0,5	Small (Cohen, 1988)
0,5 $\leq$ d $<$ 0,8	Medium (Cohen, 1988)
d $\geq$ 0,8	Large (Cohen, 1988)
d $\geq$ 1,2	Very Large (Sawilowsky, 2009

The Paired Sample T-Test is performed to analyze students' mathematical representation abilities before and after the implementation of the Discovery Learning. This test is based on the average pretest and posttest. In this study the analysis was conduct using software SPSS.

c) Step Conclusions

The final step of this study involves drawing conclusions from the results. The conclusion involves integrating the findings from various studies that have been analyzed to provide a broader and clearer understanding of the phenomenon being investigated. However it is important to consider the limitations and potential biases in this process to ensure that the conclusions drawn remain valid and useful for future research.

RESULTS AND DISCUSSION

This study meta-analysis utilizes 10 articles related to Discovery Learning and mathematical representation abilitiy. The data from the analysis of previous research article are presented in Table 3.

Table 3. Data Analysis of Previous Research Articles

No	Code	Research Title	Author	Journal	Year of Publication	Education Level
1	D1	Penerapan Metode Penemuan Terbimbing Untuk Meningkatkan Kemampuan Representasi Matematis Materi Trigonometri	Viantri, N. Y., Hudiono, B., Nursangaji, A.	Jurnal Pendidikan dan Pembelajaran Khatulistiwa	2014	SHS
2	D2	Pengaruh Metode Discovery Learning untuk Matematis dan Percaya Diri Siswa	Muhamad, N.	Jurnal Pendidikan Uniga	2016	JHS
3	D3	Pengaruh Model Discovery Learning Terhadap Kemampuan Representasi Matematis Siswa	Diba, S. F., Bharata, H., Widyastuti.	Jurnal Pendidikan Matematika Unila	2018	JHS
4	D4	Pengaruh Penggunaan Lembar Aktivitas Siswa Berbasis Metode Penemuan Terbimbing terhadap Peningkatan Kemampuan Representasi Matematis Siswa	Annajmi, Afri, E.	Mosharafa: Jurnal Pendidikan Matematika	2019	JHS
5	D5	The Effectiveness Of The Use Of The Android	Rahayu, M. S. I, Kuswanto, H.	Journal of Technology	2021	SHS

No	Code	Research Title	Author	Journal	Year of Publication	Education Level
		Based Carom Games Comic Integrated To Discovery Learning In Improving Critical Thinking And Mathematical Representation Abilities		and Science Education		
6	D6	Model Pembelajaran Inkuiri Dan Discovery Dalam Kemampuan Representasi Matematis Siswa	Putra, I. S.	Jurnal Pembelajaran Matematika Inovatif	2022	SHS
7	D7	The Effect of Guided Discovery Learning Model on Students' Mathematical Representation Ability	Pramesti, R., Sutiarso, S., Setiawati, S., Asnawati, R.	International Journal of Progressive Sciences and Technologies	2024	JHS
8	D8	Pengaruh Model Discovery Learning Terhadap Kemampuan Representasi Matematis Siswa	Wisda, A. R., Lambertus, Indrawati, W. A	Jurnal Penelitian Pendidikan Matematika	2024	SHS
9	D9	The Effect of the Discovery Learning Model with a Scientific Approach on Student Representation Ability in the Buffer Solution	Santoso, T., Ahmar, D. S., Tukaedja, S. V., Haetami, A.	Jurnal Penelitian Pendidikan IPA	2024	SHS
10	D10	Efektivitas Model Discovery Learning Berbasis Kemampuan Koneksi Matematika Berpikir Reflektif dan Representasi Matematis Mahasiswa dalam Pembelajaran Online	Listyotami, M. K., Anwar, Y., Bramana, S. M.	Trigonometri Jurnal Matematika	2024	University

Based on Table 3. of the 10 articles analyzed, 4 are focused on JHS level, 5 are focused on SHS level, and 1 are focused on University level. The data indicate that the Discovery Learning as the independent variable and mathematical representation ability as the dependent variable.

The data indicate that the Discovery Learning as the independent variable and mathematical representation ability as the dependent variable. In this study, Discovery Learning is used to enhance students' mathematical representation abilities. The research employed pretest and posttest to measure students' mathematical representation abilities before and after the implementation of the Discovery Learning, showing that the changes in ability occurred as a result of this teaching model.

The relationship between the Discovery Learning and students' mathematical representation ability suggests that when students actively engage in the learning process through discovery, they are better able to

translate abstract mathematical ideas into various forms of representation, enhancing both their understanding and their ability to solve mathematical problems.

Table 4. N-Gain Results of Mathematical Representation Ability

No	Code	N-Gain	Criteria
1	D1	0,71	High
2	D2	0,87	High
3	D3	0,59	Medium
4	D4	0,62	Medium
5	D5	0,79	High
6	D6	0,79	High
7	D7	0,77	High
8	D8	0,60	Medium
9	D9	0,68	Medium
10	D10	0,56	Medium
Average		**0,69**	**Medium**

Based on Table 4. the data show an improvement in students' mathematical representation abilities, as indicated by the N-Gain calculation from pretest and posttest results, with a value of 0,69. Specifically, the data reveal that 5 articles fall into the medium improvement category, suggesting a moderate but significant increase in students' mathematical representation abilities. Meanwhile, the remaining 5 articles are categorized the high improvement category, indicating a more substantial and impressive gain in students' ability to mathematical representation. This distribution highlights the effectiveness of the Discovery Learning in fostering students' mathematical representation skills, with varying degrees of success across different studies.

Table 5. Effect Size of Discovery Learning on Mathematical Representation Ability

No	Code	Average		Effect Size	Criteria
		Pretest	Posttest		
1	D1	45,71	80,47	3,23	Very Large
2	D2	30,67	82,27	3,98	Very Large
3	D3	37,79	74,11	2,88	Very Large
4	D4	16,34	76,76	3,24	Very Large
5	D5	32,42	86,13	0,68	Medium
6	D6	48,20	87,80	2,99	Very Large
7	D7	13,00	57,00	3,16	Very Large
8	D8	51,00	80,00	2,62	Very Large
9	D9	26,52	60,32	2,91	Very Large
10	D10	29,60	74,50	5,13	Very Large
		Average		**3,08**	**Very Large**

Based on Table 5. the data reveals that 1 article has a medium effect size, and 9 articles have a very large effect size. The overall average effect size the meta-analysis is 3,08 in the very large category. This indicates that the implementation Discovery Learning has a highly significant impact on enhancing students' mathematical representation abilities. The fact that the majority of the studies show a very large effect size suggests that Discovery Learning is an exceptionally effective model for enhancing students' mathematical representation abilities. The consistency of these findings across multiple studies highlights the robustness of Discovery Learning in fostering mathematical skills, making it a highly promising approach for educators aiming to improve students' mathematical reasoning and representation abilities.

Table 6. Effect Size Based on Education Level

No	Level	Total of Articles	Average Effect Size	Criteria
1	JHS	4	3,32	Very Large
2	SHS	5	2,48	Very Large
3	University	1	5,13	Very Large

Based on Table 6. data shows that the implementation of the Discovery Learning to students' mathematical representation abilities at each educational level falls within the very large effect size category. The data reveals that the effect size for JHS is 3,32 which falls within the very large effect size category, suggesting a strong

and notable improvement in students' mathematical representation ability concepts. Similarly, the effect size for SHS is 2,48 also falling within the very large effect size range, reflecting a substantial enhancement in the students' mathematical representation abilities at this level. The most striking result, however, is observed at the University level, where the effect size reaches 5,13 signifying an exceptionally large and highly significant improvement in students' mathematical representation abilities. In addition to these individual results, the overall average effect size across all educational levels is 3.08, which also falls within the very large category, further emphasizing the effectiveness of Discovery Learning in fostering improved mathematical representation abilities across all levels of education. These findings highlight the widespread applicability and success of Discovery Learning in enhancing students' representation mathematical abilities, making it a powerful pedagogical approach across all levels of education.

Table 7. Effect Size Based on Year of Publication

No	Year	Total of Articles	Average Effect Size	Criteria
1	2014	1	3,23	Very Large
2	2016	1	3,98	Very Large
3	2018	1	2,88	Very Large
4	2019	1	3,24	Very Large
5	2021	1	0,68	Medium
6	2022	1	2,99	Very Large
7	2024	4	3,46	Very Large

Based on Table 7. the data reveal that students' mathematical representation abilities, taught using the Discovery Learning, consistently fall into the very large effect size category each year from 2014 to 2024. This consistent trend highlights the effectiveness of the Discovery Learning in enhancing students' mathematical representation abilities. The data reveals that across 6 of 7, the effect sizes remain remarkably high, underscoring the robustness of this teaching model. Specifically, the average effect size based on the year of publication, is 2,92 further confirming the substantial impact of the Discovery Learning on students' mathematical representation abilities. This indicates that over the span of a decade (10 years), the use of the Discovery Learning has consistently contributed to significant improvements in students' mathematical representation abilities, making it a highly effective pedagogical strategy.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	33.1250	10	12.80730	4.05003
	Posttest	75.9360	10	10.16733	3.21519

Picture 1. Output Paired Sample Statistics

Based on Picture 1. the application of Discovery Learning has a significant and positive impact on students' mathematical representation abilities. This is clearly indicated by the progress in students' scores from pretest to posttest. The pretest scores which initially averaged 33,1250 were followed by a notable increase to a averaged posttest score of 75,9360. This remarkable change indicates a substantial improvement of 42,8110 score (75,9360–33,1250) after the intervention. Such a significant gain highlights the effectiveness of the Discovery Learning in enhancing students' mathematical representation abilities. The data not only shows the immediate impact of the teaching model but also suggests that the approach plays a key role in fostering long-term improvements in students' mathematical abilities. Therefore, the data supports the notion that the Discovery Learning is an effective and valuable model for

promoting the development of mathematical representation abilities in students.

		N	Correlation	Sig.
Pair 1	Pretest & Posttest	10	.642	.045

Picture 2.Output Paired Sample Correlation

Based on Picture 2. there is a correlation between mathematical representation abilities before and after the intervention the Discovery Learning. This correlation is reflected in a value of 0,642, with a p-value of 0,045 (which is less than the significance level of 0,050), indicating that the relationship between the pretest and posttest scores is statistically significant. The correlation is categorized as moderate, suggesting that while the relationship between the pretest and posttest is not exceptionally strong, it is still meaningful and demonstrates a fairly significant improvement in students' mathematical representation abilities following the intervention. This finding supports the effectiveness of the Discovery Learning in enhancing students' mathematical representation abilities and provides valuable evidence of the model's positive impact on students' learning outcomes. The statistically significant result reinforces the idea that the Discovery Learning is a reliable model for improving students' mathematical understanding and performance. This evidence also underscores the positive impact of the approach, confirming its role in fostering meaningful learning outcomes and improving mathematical skills in a measurable and effective way.

		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	-42.81100	10.00607	3.16420	-49.96891	-35.65309	-13.530	9	<,001

Picture 3. Output Paired Sample Test

Based on Picture 3. a significant difference is observed between students' mathematical representation abilities before and after the application of the Discovery Learning. This difference is validated by the statistical result, where the significance value (sig. 2-tailed) is less than 0,001 which is well below the threshold of 0,050 indicating that the difference between the pretest and posttest scores is statistically significant. The mean difference of −42,81100 clearly shows that the posttest scores are considerably higher than the pretest scores, reflecting a substantial improvement in students' mathematical representation abilities following the intervention. Furthermore, the t-value of −13,530 represents the magnitude of deviation from zero (the null hypothesis), with a larger absolute value of t suggesting a stronger and more significant difference. The further the t-value is from zero, the stronger the evidence against the null hypothesis, reinforcing the conclusion that the Discovery Learning intervention had a significant and positive impact on students' mathematical representation abilities. The high magnitude of the t-value further emphasizes the strength of the intervention's effect, highlighting the effectiveness of the Discovery Learning model in improving students' mathematical skills. This statistical evidence not only supports the effectiveness of the intervention but also suggests that the changes in students' performance are both meaningful and robust, providing strong validation for the use of Discovery Learning in enhancing mathematical representation.

The results of this meta-analysis discussion are supported by research conducted by (Mulyani et al., 2024) which found that the Discovery Learning effectively enhances the mathematical representation skills of Grade 7 students at MTsN 1 Banda Aceh. This effectiveness is evident from the high test scores in mathematical representation and the students' active engagement and positive feedback throughout the learning process. This finding is consistent with the research by (Maharani et al., 2019) concluded that Discovery Learning has a significant influence on the mathematical representation skills of Grade 7 students at SMPN 23 Bandar Lampung. The research showed that students engaged in Discovery Learning experienced greater progress in their mathematical representation abilities compared to those taught through conventional methods. Similarly, the research by (Alawiyah and Dahlan, 2019) showed that implementing Discovery Learning in mathematics enhanced the mathematical representation abilities of Grade 9 students at SMPN 2 Bandung. The average percentage of student activity demonstrated a substantial improvement, classified as excellent. These findings are further supported by a literature review conducted by (Simangunsong, 2022) the study concluded that Discovery Learning significantly influences students' mathematical representation skills. Its implementation has been proven effective in substantially improving these abilities to a higher level. Taken together, the evidence suggests that the Discovery Learning is an effective and valuable teaching approach for improving students' mathematical skills across various grade levels and educational contexts.

Overall, the Discovery Learning is an instructional approach recognized as effective in improving mathematical representation abilities. Jerome Bruner, who first developed the theory of Discovery Learning, also provides a strong foundation for the Discovery Learning model. Bruner (1961) argued that learning is more effective when students discover new concepts on their own through exploration and problem-solving. In this regard, the Discovery Learning enables students to build strong mental representations of mathematical concepts, which is consistent with research findings that show a very large effect size in enhancing mathematical representation abilities. What's more, this approach is solidly supported by evidence from research that shows a large effect size in enhancing students' mathematical representation abilities.

CONCLUSION

Based on the results and analysis of the meta-analysis conducted, it can be concluded that the Discovery Learning is effective in enhancing students' mathematical representation abilities. This is supported by the average effect size of 3,08 from the 10 articles analyzed, which falls into the very large category. This indicates that the Discovery Learning is both effective and well-suited for improving students' mathematical representation abilities. The evidence suggests that the Discovery Learning is an effective and valuable teaching approach for improving students' mathematical skills across various grade levels and educational contexts. The findings of this meta-analysis also highlight the importance of incorporating the Discovery Learning into mathematics curricula to better prepare students for global challenges and the rapid advancements of the modern era.

For future research, it is

recommended to apply stricter selection criteria for the studies included in the meta-analysis. This would help enhance the quality and reliability of the results, ensuring that only the most relevant and high-quality studies are considered. Refining these criteria would provide even stronger evidence and allow for a more accurate assessment of the Discovery Learning's impact. Additionally, expanding the scope of future research to include diverse educational contexts and populations could further validate the generalizability of the findings, strengthening the case for implementing Discovery Learning across a wide range of learning environments.

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