World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

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# Meta-analysis: The effect of the discovery learning model on indonesian students' mathematics reasoning

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World Journal of Advanced Research and Reviews, 2024, 21(02), 1380–1386

Publication history: Received on 12 January 2024; revised on 20 February 2024; accepted on 22 February 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.2.0608

## Abstract

The ability of mathematical reasoning is one of the important skills for students. The discovery learning model is a suitable learning model to enhance students' mathematical reasoning abilities. The research uses meta-analysis methods through a review of articles in Indonesian national journals. From Google Scholar, Portal Garuda, and Sinta ristekbrin, the author obtained 10 studies that met the inclusion criteria for analysis on the Meta-Mar website to obtain a combined effect size. From the interpretation of this combined effect size, it can be concluded that the overall implementation of the discovery learning model has a moderate effect on students' mathematical reasoning abilities. The characteristics of this research study include educational level, year of research, and sample size. From the statistics, it was found that implementing the discovery learning model to improve students' mathematical reasoning abilities is influenced by educational level, year of research, and sample size.

**Keywords:** Discovery learning; Mathematical Reasoning; Meta-Analysis; Indonesian students

## 1. Introduction

In the process of learning mathematics, skillfulness plays an important role because math trains students to think and draw conclusions. According to Togi & Sagala [1], reasoning refers to a thinking activity that results in a new conclusion or statement that is true. In the context of mathematics, mathematical reasoning is defined as the activity of analyzing mathematic situations, followed by constructing logical arguments to associate new knowledge with existing knowledge, linking ideas, and even connecting them with other objects outside of mathematics [2]. Students' reasoning skills can be improved by giving questions designed so that students are accustomed to solving questions. National Council of Teachers of Mathematics (NCTM) explains that one of the standard abilities of the mathematical learning process is the ability to reason.

Several aspects are indicators of mathematical reasoning ability. First, being able to make assumptions, second, being capable of manipulating mathematics. Thirdly, the ability to conclude, compile evidence, justify, or give evidence that supports the truth of a solution. Fourthly, the capacity to examine the truthfulness of an argument. Fifthly, it can find patterns or properties of mathematical symptoms to generalize [3].

Previous research has studied the ability of mathematical reasoning using of the discovery learning model in the context of learning mathematics. Discovery learning is a learning model that focuses on discovering previously unknown concepts or principles, as well as developing problem-solving skills, which are then followed by strengthening skills [4]. Furthermore, according to Kemdikbud [5], discovery learning can be described as a learning method in which students are actively involved in acquiring knowledge and understanding by indirectly receiving the material in the finished form. Application of the discovery learning model has several advantages, including: (1) discovery strategies can motivate students because they have an active role in their way of learning; (2) allow students to develop their abilities

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according to their circumstances; (3) help students understand basic concepts and ideas better; and (4) encourage students to think and work independently. As for the measures covered by the discovery learning model, they include: (1) providing incentives or stimulus; (2) presenting a statement or identification of a problem; (3) collecting data; (4) processing or processing the data; (5) performing verification or proof; and (6) concluding results.

Meta-analysis research on the impact of discovery learning on students' mathematical abilities has been undertaken, such as research into the meta-analyses of the influence of discovery learning on students' critical thinking [6] and even studies on the application of discovery learning in mathematics learning for deaf special junior high schools [7]. Based on this, the authors need to undertake meta-analytical research on discovery learning's influence on student's mathematical reasoning. This research aims to investigate the influences of the discovery learning model on student mathematics reasoning capabilities by comparing them to conventional learning models based on the characteristics of education, the year of study, and the number of samples selected. It is hoped that the results of this study will provide accurate information to teachers about the application of the discovery learning model to mathematical learning.

## 2. Material and methods

The research uses meta-analysis methods through a review of articles in Indonesian national journals. Meta-analysis is a statistical method that aims to analyze, synthesize, and systematically combine several studies to obtain the latest findings and conclude them with a study effect [8]. According to Borenstein et al., [9], the stage of meta-analysis is the determination of inclusion criteria for study analysis, empirical data collection procedures, as well as explaining the coding of study variables, and explains statistical techniques. Primary study of the following research on the discovery learning model against the mathematical reasoning ability of students. The articles in the primary study are then selected to meet the established inclusion criteria namely:

- The year of publication of the article is from 2015 to 2022.
- Articles conducting research studies in Indonesia that have been published in a journal that has been indexed by Science and Technology Index (SINTA). SINTA is an online scientific portal managed by the Ministry of Education and Culture of Research and Technology in Indonesia and presents a list of accredited Indonesia national journals.
- Articles with experimental research methods with research designs such as randomized control group pretest-posttest design, randomized control group posttest only design, nonequivalent group pretest-posttest design, dan nonequivalent group design posttest only.
- The sample in the primary study used is research at the elementary school, junior high school, senior high school, and university levels in Indonesia.
- Statistical data available in the primary study include sample size, mean, and standard deviation.

The article search was done in databases such as Google Cendekia, Portal Garuda, and Sinta Ristekbrin with the keyword "Discovery learning, Mathematical Analysis". Based on the search for primary studies conducted in 2015-2022, 10 articles met the inclusion criteria at the level of elementary school, junior high school, high school, and university.

The next process is implementing the study code. The coding of this study is in the form of information in the meta-analysis process, namely the study code; writer; year of publication; mean, standard deviation, number of samples of the experimental group; mean, standard deviation, number of control group samples; educational level, year of research, and sample size. The process after coding is calculating the effect size, the calculation uses the standardized mean difference, namely Hedges's g [10]. Hedges's g formula is:

$$\text{Hedges'g} = \frac{M_1 - M_2}{SD^*_{pooled}}$$

explanation:
$M_1$-$M_2$ = difference in means,
$SD^*_{pooled}$ = pooled and weighted standard deviation

The interpretation of the effect size that will be used in this research is the following classification according to Cohen [11].

**Table 1** Interpretation of Effect Sizes

| Effect Size | ES Interpretation |
|---|---|
| $0 \leq ES \leq 0.20$ | Low effect |
| $0.20 < ES \leq 0.50$ | Simple effect |
| $0.50 < ES \leq 1.00$ | Medium effect |
| $ES > 1.00$ | Strong effect |

The next process will be carried out with a homogeneity test using p-value to determine the analysis model [12]. If the p-value < 0,05, when it has a heterogeneous nature, with the analysis model using a random effects model and if the p-value > 0,05, then it has a homogeneous, with the analysis model using a fixed effects model [12]. In order to prevent incorrect representation in the findings, it is necessary to check for publication bias.

Studies that have been published are more likely to be included in the meta-analysis than their unpublished counterparts, which raises concerns that meta-analyses can overestimate the original effect size [9]. Methods for detecting and resolving publication bias include funnel plots and Rosenthal's Fail-Safe N [12]. The initial way to detect publication bias is to use a funnel pot. If the distribution of study effect sizes is asymmetrical or not completely symmetrical, Rosenthal's FSN will be used to make it easier to determine the presence of publication bias [13]. When the value of FSN / (5k + 10) > 1 where k is the number of studies in the meta-analysis, the study is held against publication bias [14]. If there is no publication bias, the analysis process will continue. Through the analysis model, the author can test H0 [12]. If the p-value < 0,05, then H0 will be accepted. If the analysis model uses random effects where there are different research characters, then the author can analyze the research character and interpret the results of the analysis [9].

## 3. Results and discussion

This research aims to determine the size of the combined effect of applying the discovery learning model on students' mathematical reasoning abilities to obtain results regarding the effect of applying the discovery learning model on students' mathematical reasoning abilities. The following is a list of studies that meet the inclusion criteria for this research.

**Table 2** Studies Used in Meta-Analysis

| Study Code | Year of publication | Experiment Class | | | Control Class | | |
|---|---|---|---|---|---|---|---|
| | | Sample | Mean | SD | Sample | Mean | SD |
| Samsul Pahmi [15] | 2020 | 67 | 73.6 | 6.23 | 71 | 63.8 | 7.02 |
| Glory Indira D. Purba, dkk. [16] | 2017 | 64 | 34.6 | 9.54 | 66 | 22.7 | 8.15 |
| Netti Kariana M., Ratna Natalia M. [17] | 2022 | 32 | 77.7 | 14.8 | 32 | 62.9 | 16.7 |
| Inggri Adriyati, Erlinawaty Simanjuntak [18] | 2016 | 32 | 65.5 | 12 | 32 | 46.7 | 14.4 |
| Lela Agustina Panjaitan, dkk. [19] | 2022 | 29 | 51 | 23.2 | 29 | 43.6 | 21.3 |
| Mohamad Salam, Salim [20] | 2020 | 26 | 82 | 10.7 | 22 | 69.9 | 12.7 |
| Selvi Megia, Ahmad Fauzan [21] | 2022 | 30 | 69.4 | 14.5 | 26 | 38.6 | 14.2 |
| Mahrifah, Katrina Samosir [22] | 2019 | 30 | 64.6 | 16.7 | 30 | 56.9 | 18.1 |
| Vina Irmawati [23] | 2022 | 18 | 93 | 6.78 | 18 | 74 | 24.6 |
| Risa Nurmala, dkk. [4] | 2018 | 21 | 79.2 | 12.1 | 22 | 71.6 | 13.5 |

By using the website https://www.meta-mar.com/, the study effect, standard error, and confidence interval for each study were obtained based on the standardized mean difference namely Hedges's g, which is presented in Table 3 below.

**Table 3** Effect Size, Interpretation, Standard Error, and Confidence Interval of Each Study

| Study Code | Effect size | Interpretation of Effect Sizes | SE | Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower limit | Upper limit |
| S1 | 1.4659 | Strong | 0.1920 | 1.0895 | 1.8423 |
| S2 | 1.3350 | Strong | 0.1942 | 0.9544 | 1.7156 |
| S3 | 0.9266 | Medium | 0.2634 | 0.4104 | 1.4428 |
| S4 | 1.4012 | Strong | 0.2797 | 0.8530 | 1.9493 |
| S5 | 0.3278 | Simple | 0.2644 | -0.1904 | 0.8461 |
| S6 | 1.0211 | Strong | 0.3085 | 0.4165 | 1.6257 |
| S7 | 2.1146 | Strong | 0.3359 | 1.4562 | 2.7731 |
| S8 | 0.4364 | Simple | 0.2613 | -0.0758 | 0.9486 |
| S9 | 1.0296 | Strong | 0.3557 | 0.3325 | 1.7267 |
| S10 | 0.5812 | Medium | 0.3117 | -0.0297 | 1.1921 |

Based on Table 3, each study has an effect size that varies between 0,3278 to 2,1146. Interpretation of the effect size according to the classification, it was found that six studies have strong effects meaning that the application of the discovery learning model has a strong influence on the ability of mathematical reasoning of students. Two studies have medium effects, meaning that the application of the discovery learning model has a medium effect on students' mathematical reasoning abilities. Two studies have a simple effect size, meaning that the application of the discovery learning model has a modest influence on students' mathematical reasoning abilities.

To determine the combined effect size across all primary studies, authors must create an estimation model through testing homogeneity across studies. Table 4 provides information regarding the homogeneity test of all primary studies.

**Table 4** Heterogeneity of Effect Size Distributions

| Chi-Squared | Degree of freedom | Value | I-Squared | $\sigma^2$ |
|---|---|---|---|---|
| 33.47 | 9 | 0.00 | 73% | 0.2013 |

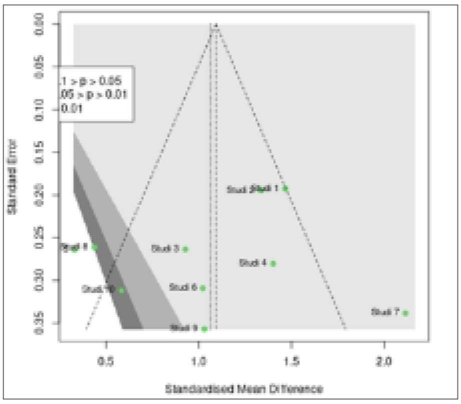


**Figure 1** Funnel Plot

Based on Table 4, there is a p-value < 0,01, meaning that the distribution of the effect sizes of the meta-analyzed primary studies is heterogeneous. Therefore, the estimation model to determine the combined effect size is a random effects model. The identification of publication bias was carried out using the funnel plot shown in the image below.

Based on Figure 1, the study effect size has an asymmetric distribution. So, the authors detected publication bias with Fail-Safe N (FSN) 479 of the observed studies (k) of 10. By using the formula $FSN/_{5.k+10} = {}^{587}/_{60} = 9{,}78 > 1$. Thus, it was concluded that the study of this meta-analysis was quite tolerant of publication bias [13].

Table 5 shows the meta-results of primary studies modeling fixed effects and random effects.

**Table 5** Meta-Analysis Results Based on Estimate Model

| **Model** | **n** | **Effect Size and Confidence Interval 95%** | | | **Test of null (2-Tail)** | |
|---|---|---|---|---|---|---|
| | | Effect size | Lower limit | Upper limit | Z-value | P-value |
| Fixed effects model | 10 | 1.092 | 0.9302 | 1.2539 | 13.23 | <0.0001 |
| Random effects model | 10 | 1.062 | 0.6807 | 1.4437 | 6.30 | 0.0001 |

Through the homogeneity test of primary studies that have been carried out, there is a heterogeneous distribution of study effects, so the analysis uses a random effects model. Based on Table 5 in the random effects model row, the p-value obtained in the Z test is 0,00. Because the p-value is <0,05 it can be concluded that overall, the application of the discovery learning model from each primary study has a more significant influence on students' mathematical reasoning abilities compared to the application of conventional learning models. In addition, in this study, a combined effect size was obtained of 1,062, so based on Cohen's classification, the combined effect size is classified as a strong effect. Thus, it can also be concluded that overall the application of the discovery learning model from each study has a strong effect on students' mathematical reasoning abilities [24].

It is known that the distribution of primary study effects is heterogeneous, so analysis of study characteristics is then carried out to create heterogeneity in students' mathematical reasoning abilities. The meta-analysis results for study characteristics on educational level and year of research are presented in Table 6.

**Table 6** Meta-Analysis Results of Each Study Characteristic

| **Study characteristics** | **Category** | **n** | **Hedges'g** | **Test of null (2-tail)** | **95% CI** | |
|---|---|---|---|---|---|---|
| | | | | P-value | Lower limit | Upper limit |
| Educational level | Elementary and Junior high | 8 | 0.96 | 0.00 | 0.48 | 1.44 |
| | Senior High and Universitas | 2 | 1.40 | 0.63 | 0.57 | 2.23 |
| Year of research | 2016-2019 | 4 | 0.96 | 0.00 | 0.16 | 1.75 |
| | 2020-2022 | 6 | 1.14 | 0.00 | 0.52 | 1.76 |
| Sample size | $\leq 30$ | 6 | 0.90 | 0.00 | 0.21 | 1.58 |
| | $> 30$ | 4 | 1.32 | 0.41 | 0.97 | 1.66 |

Based on Table 6, the study of characteristics at the educational level concluded that students' mathematical reasoning abilities at all educational levels had a medium effect size. The information obtained also shows the total p-value between the heterogeneity sections is 0,039. Because the p-value is < 0,05 , the distribution of effects in the two categories in the educational level study characteristics is heterogeneous. Thus, it can be concluded that students' mathematical reasoning abilities by applying the discovery learning model are influenced by educational level and are suitable for use at elementary, junior high, senior high, and even university levels with moderate influence.

Based on study characteristics, information was obtained that the study effect size in 2016-2019 is medium effect size and 2020-2022 is strong effect size. Then, if you look at the data, the lower and upper limits for 2016-2019 are in the interval 0,16-1,75, and for 2020-2022 the interval is 0,52-1,76. From these two intervals there is a lower limit and an upper limit, so it can be concluded that there is no significant difference in the influence of discovery learning on students' mathematical reasoning abilities based on the year of research.

Study characteristics based on the number of samples, information was obtained that the lowest study effect size was in samples of ≤30 at 0,9, which is classified as a medium effect size. Meanwhile, the highest study effect size is the effect size that has several samples >30, which is 1,32, which is classified as a strong effect size. In addition, information was obtained that the lower and upper limits for samples of ≤30 in the interval 0,21 to 1,58, while the lower and upper limits for samples of >30 or more were in the interval 0,97 to 1,66. Because there is an intersection between these two intervals, this means that there is no significant difference in the influence of the discovery learning learning model on students' mathematical reasoning abilities based on the number of samples.

## 4. Conclusion

The results of a meta-analysis conducted on 10 studies related to the influence of the discovery learning model on Indonesian students' mathematical reasoning abilities, obtained information that the combined effect size of primary studies was 1,062, which is included in the strong effect category based on Cohen's classification. Thus, it can be concluded that overall, the application of the discovery learning model has a strong influence on students' mathematical reasoning abilities compared to the application of conventional learning models. Apart from that, in terms of several study characteristics, the application of the discovery learning model is to increase students' mathematical reasoning abilities in several research characteristics which are influenced by education level, year of study, and the number of samples selected. These findings can contribute to Indonesian teachers implementing the discovery learning model as an alternative learning method that helps educators improve Indonesian students' mathematical reasoning abilities.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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