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Meta-Analysis: The Effect of Discovery Learning Models on Students' Mathematical Ability

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ABSTRACT

This research aimed to determine the magnitude of the influence of the discovery learning model on students' mathematical abilities. The students' mathematical abilities included were problem solving skills, critical thinking, understanding, and mathematical reasoning. This study used a quantitative approach to Systematic Literature Review (SLR) with a Meta-Analysis method. Data were collected from experimental research connected to the application of discovery learning models to the mathematical abilities of students at the elementary, junior high, and high school levels in papers indexed from 2012 to 2021. From the search and study selection results, 48 articles were obtained. The research found that there was an increase in the number of publications every year, most of which were on mathematical reasoning abilities. It is also known that researchers conduct more research at the junior high school education level, with more than 30 of a sample size. Meanwhile, viewing the demographic aspect, this study was more centralized in Java island. The application of the discovery learning model to students' mathematical abilities has an overall effect size of 0.815 with the high effect category.

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INTRODUCTION

Education is a place to educate the life of nation because it will promote well-educated human resources, which are able to adapt the accelerated change. Without education, a person will be difficult to adjust to the environment and will be hard to maximize their contribution in their lives. Good education is an education that is not only preparing its students for a profession or position but also enables them to overcome the various problems they face in everyday life (Sagala, 2012, p. 11). In line with that, Law No. 20 of 2003 on the National Education System, education is a conscious and planned effort to promote a good learning environment and learning process so that learners could actively develop their intelligence, personality, spiritual power, self-control, and noble morals, as well as the necessary skills for themselves, society, nation, and state.

Mathematics is one of the compulsory subjects in Indonesian national education curriculum. Mathematics, according to Cockroft, should be taught to students because (1) it is used in all aspects of life; (2) it is required in all fields of study; (3) it is a powerful, concise, and precise means of communication; (4) it can be used to present information in a various ways; (5) it improves the ability to think logically, thoroughly, full of awareness; and (6) it gives satisfied efforts to solve complex problems (Abdurrahman, 2018, p. 254). As a result, learners should comprehend mathematics.

Students are required to have basic competencies in mathematics to achieve the objectives of learning such as problem-solving, understanding, reasoning, and critical thinking (JDIH, 2022, p. 18). In line with that, the National Council of Teachers of Mathematics (NCTM, 2000, p. 8) explained that there are five standards of mathematics education, which consists of content standards and process standards. The standard process of mathematics education is the process of problem-solving, reasoning and proof, connection, communication, and representation. These abilities become capital for students to face the future challenges. Moreover, the era of technology is rapidly developing and humans are demanded to think better than an existing technology. Thus, students need to own and improve their mathematical abilities.

As it explained, problem-solving skills are one of the important abilities in mathematical learning goals. With the ability to solve problems, a person could obtain a solution to a difficult problem (Hendriana et al., 2017, p. 5). This is because the problem presented is not only a common problem. So, to gain such ability, students should have a lot of experience. In addition, solving a mathematical problem also needs understanding, reasoning, and the ability to think critically.

Without understanding, a person will not be able to solve the problems he faces. Understanding is a level of ability where students are expected to understand the concepts, situations, and facts they know (Al-Siyam & Sundayana, 2014, p. 57). Mathematical understanding ability is a fundamental ability in mathematics that involves connecting, generalizing, and synthesizing internal and external representations of mathematical objects (Bakar et al., 2018, p. 1). Putra (2017, p. 129) stated that learning before the subject is being taught can increase understanding towards the study material. When they are studying, and there is material that has not been understood, students could ask their teacher during the class so they could improve their level of understanding.

In addition to mathematical understanding, reasoning abilities are also important in the problem-solving process. From the reasoning abilities presented, it can be seen to what extent students have understood, solved problems, and appreciated the benefits of mathematics in everyday life (Hadi, 2016, p. 97). Mathematical reasoning ability is the ability to make logical decisions that can be explained and proven true based on concepts or understanding previously obtained (Khairunnisa & Amry, 2021, p. 315). With this ability, a person is not only able to solve existing problems but also has logical and accurate evidence to account for the answers he gives.

In line with the ability of mathematical reasoning, critical thinking is also a process that aims at enabling us to make reasonable decisions and what we think is best about the truth can be analysed correctly. Mathematical critical thinking ability is the ability that involve existing knowledge, reasoning, and the use of cognitive strategies in generalizing, proving, or reflectively evaluating unfamiliar mathematical situations (Abdullah, 2013, p. 66). In connection with learning mathematics in at school, students' critical thinking skills are needed in the aspects of identifying, connecting, evaluating, analyzing, and solving various mathematical problems and their applications. This is also in line with the opinion which states that students who have mathematical critical thinking skills will find it easier to follow mathematics learning (Syafira et al., 2021, p. 408).

If students have these abilities, they will be able to solve problems that exist both in school assignments and outside of school. However, the mathematical ability of students in Indonesia is still relatively low. This can be seen from the results of the Trends in International Mathematics and Science Study (TIMSS) 2015, where Indonesia got 397 score in mathematics, which placed Indonesia at number 44 out of 49 countries listed. Meanwhile, the results of the Programme for International Student Assessment (PISA) in 2018 showed that Indonesia's average math score was 379, which was ranked 36 out of 41 participating countries (Asmianti & Agustyarini, 2021, p. 289). The low mathematical ability of these students encouraged researchers to conduct studies to improve students' mathematical skills in Indonesia. So, it can be used as a reference for prospective educators in implementing the results of studies obtained directly into the learning process.

It is believed that an alternative to improve and to develop these abilities is by the discovery learning model. Discovery Learning provides opportunities for students to develop and find their understanding so that learning mathematics becomes more meaningful. The information presented is easily absorbed, processed, and stored properly by the student's memory system and provides opportunities for students to play a more active role in class (Ahmad, 2015, p. 300). In discovery learning, teachers provide opportunities for students to become mathematicians, problem solvers, historians, or scientists. Teaching materials are not offered in the final form. Instead, students must

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complete several exercises such as comparing, evaluating, integrating, and organizing to acquire knowledge and develop conclusions. So, in this learning model students are trying to be able to live the entire cognitive realm to its highest realm, namely creating.

Discovery learning has many things to do with its effect on students' mathematical abilities. Some studies explained that discovery learning had a significant effect on students' problem-solving abilities (Shumini & Apriani, 2020, p. 112). Similarly, other abilities such as mathematical reasoning skills, found that guided discovery learning can improve students' mathematical reasoning skills (Asmianti & Agustyarini, 2021, p. 287), then critical thinking skills (Umayah, 2019, p. 780), and also mathematical understanding skills (Bakar et al., 2020, p. 277). Of course, one study cannot be used to guide all educational cases. Some studies may have bias potential, so a more in-depth study related to the implementation of discovery learning on students' mathematical abilities is needed. Therefore, research can be conducted using the Systematic Literature Review (SLR) with a Meta-Analysis method.

Gough et al. explained that meta-analysis is one the proofs of studies that reviewing existing primary studies using rigorous and systematic research methods to answer the research questions (Zawacki-Richter et al., 2020, p. 4). From this explanation, this study aims to determine the magnitude influence of the guided discovery learning model on students' mathematical abilities which include problem solving skills, critical thinking, understanding, and mathematical reasoning. The selected studies were characteristised by the year of publication, education level, sample size, and demographics. Thus, in this research, data collection was carried out in the form of experimental research related to the application of the guided discovery learning model to students' mathematical abilities.

Through the data obtained, the researcher focused on several research questions;

1. How is the description of the research results on the application of discovery learning models to students' mathematical abilities in terms of the year of publication?
2. How is the description of the results on the application of discovery learning models to students' mathematical abilities in terms of education level?
3. How is the description of the research results on the application of discovery learning models to students' mathematical abilities in terms of samples size?
4. How is the description of the results on the application of discovery learning models to students' mathematical abilities in terms of research demographics?
5. Does the implementation of discovery learning models have a significant effect on students' mathematical abilities from the primary data analyzed?
6. How is the diversity of media and student learning activities in the discovery learning model from the research reviewed?

METHOD

Research design

This study uses a quantitative approach Systematic Literature Review (SLR) with the Meta-Analysis method. A Systematic Literature Review is a review of all relevant studies to answer certain questions. It is carried out comprehensively and systematically to assess the validity (feasibility) of each relevant study and reduce bias at each stage by identifying, critically evaluating, and providing a synthesis of relevant studies and improved synthesis clarity (Juandi, 2021, p. 2). The analysis was carried out on secondary data in the form of primary research results regarding the application of the discovery learning model to mathematical abilities, particularly problem solving, critical thinking, understanding, and mathematical reasoning abilities of students.

The meta-analysis method is carried out by identifying, reviewing, evaluating, and systematically interpreting articles that have a set of standards where in each process, follow the steps that have been set (Afsari et al., 2021; Triandini et al., 2019). The design of the meta-analysis research procedure begins with developing research questions and selection criteria, developing the search strategy, the study selection process, and appraising the quality of studies (Cohen et al., 2018, p. 432). The data collected are primary studies that have been published by indexed publishers.

Inclusion criteria

To obtain data for the research objectives, inclusion criteria were determined for the primary data collected. The inclusion criteria were involving;

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1. The article is the result of research on mathematics education in Indonesia.
2. Articles published between 2012 and 2021
3. Articles in the form of journals and proceedings have been indexed.
4. The research uses experimental methods with the application of Discovery Learning to students' problem-solving, critical thinking, understanding, and mathematical reasoning abilities.
5. The sample used is research at the elementary, junior high, and high school levels.

Literature search strategy

The search begins by opening the Google Scholar website (www.scholar.google.com), then typing the keywords "discovery learning, mathematical ability, "penemuan terbimbing" and "kemampuan matematis". Then, an interval of publication was made from 2012-2021. After that each article were reviewed and those that met the inclusion criteria would be taken as research subjects.

Research instruments

The research instrument was a coding form containing statistical data (number of samples, average, standard deviation, p-value, t-value) and study characteristics (year of publication of the journal, education level, sample size used, demographics) from the primary data obtained.

Research subject

The subjects of this research are previous studies published in national and international mathematics education research articles found using electronic database searches such as SINTA, Garuda Portal, Google Scholar, DOAJ, Crossref, IPI, and URLs of national journals in the period 2012-2021. The data collected used as research subjects are regarding the application of the Discovery Learning model to the mathematical abilities of students at the elementary, junior high, and high school levels. From the search results, 48 relevant articles deserve for further analysis.

Data analysis technique

To obtain the magnitude effect of the application towards the discovery learning model on students' mathematical abilities, an analysis was carried out using the Hedges formula:

$$\boldsymbol{Hedges's\ g} = \frac{\bar{X}_1 - \bar{X}_2}{S_{within}}$$

The g values obtained can be categorized into five categories presented in the Table 1.

Table 1. Category Effect Size

Interval *Effect Size* (ES)	Category
$-0.15 \leq ES < 0.15$	Neglected effect
$0.15 \leq ES < 0.40$	Low effect
$0.40 \leq ES < 0.75$	Medium effect
$0.75 \leq ES < 1.10$	High effect
$1.10 \leq ES < 1.45$	Very high effect
$ES \geq 1.45$	Very good effect

The data analysis of this research was carried out with the help of the Comprehensive Meta Analysis (CMA) application.

RESULTS AND DISCUSSION

Research by category

The journals collected were categorized into 4 categories, namely the year of journal publication, education level, sample size, and demographics. Each category has specified to find out some journals collected related to 4 mathematical abilities used; problem-solving skills, critical thinking, understanding, and mathematical reasoning. A description of the data is presented in Table 2.

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Table 2. Number of Studies by Category

Category	Criteria	Mathematical Ability			
		Problem-Solving	Critical Thinking	Understanding	Reasoning
Publication Year	2012-2013	1	0	0	0
	2014-2015	1	0	1	3
	2016-2017	1	1	1	6
	2018-2019	5	6	5	3
	2020-2021	4	3	3	4
Education Level	Elementary	2	1	2	2
	Junior High	8	6	6	13
	Senior High	2	3	2	1
Sample Size	< 30	3	3	2	4
	≥ 30	9	7	8	12
Demographics	Sumatera	6	1	2	5
	Java	5	8	6	10
	Kalimantan and Sulawesi	1	0	1	1
	Nusa Nenggara and Maluku	0	1	1	0

Based on Table 2, within 9 years of the research on the application of discovery learning models to mathematical was dominated by reasoning skills, 16 out of the 48 articles or about 33.3% discussed about mathematical reasoning skills. Meanwhile, for the application of discovery learning to the ability of critical thinking and mathematical understanding were only 10 articles or about 20.8%. The amount of research on reasoning ability is a basic ability needed to improve mathematics skills in general (Sukirwan et al., 2018, p. 1). Thus, the importance of this ability encourages researchers to conduct a research.

This research deserves to be conducted more deeply because it has reviewed each student's mathematical competence and it is not only on mathematical learning outcomes that are too complex. Then to be more specific, the explanation of each category is presented.

Year of Publication

Grouping by the year of publication is divided into five periods; from the year 2012-2013, 2014-2015, 2016-2017, 2018-2019, and 2020-2021. During the period, the following data were obtained.

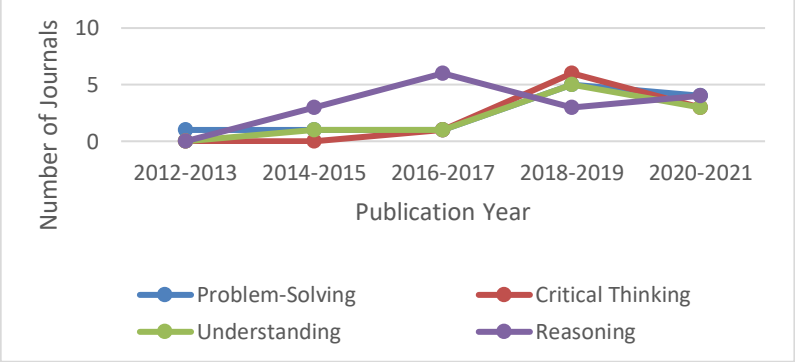

Figure 1. Data by Publication Year

Based on Figure 1, it can be seen that research on discovery learning models was most widely published in 2018–2019. Research on various mathematical abilities tends to increase each year. However, in the last two years, there has been a slight decrease in the number of studies published in the idealized article.

This data collection show that learning with the discovery learning model is likely more suitable for assessing mathematical abilities. Referring to the existing data, it is clear that to assess students'

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mathematical reasoning skills, teachers can use discovery learning models. Indeed, it does not rule out the possibility of using other learning models but this can be used as a reference for the selection of the right learning model for the teaching and learning process.

Education level

Grouping based on the level of study is divided into three categories; elementary, junior high, and senior high school. A graph related to the level of education is presented in Figure 2.

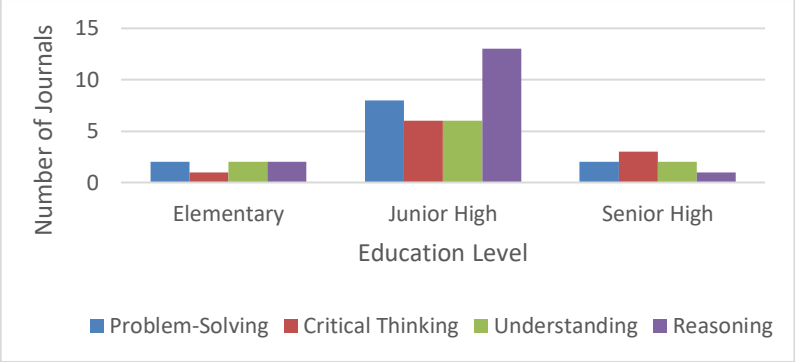

Figure 2. Data by Education Level

From Figure 2, it can be seen that research related to the application of discovery learning models is most widely carried out at the Junior High School level. The junior high school level is indeed a transitional level from a concrete thinking process to a more abstract level that allows researchers to review more deeply the mathematical abilities of students using one of the existing learning models. At this level, most researchers are interested in viewing the application of discovery learning models to students' mathematical reasoning skills. Research at the junior high school level is more demanding by researchers (Paloloang et al., 2020, p. 858).

It is also found that at the elementary school level, there is only one research on the application of discovery learning models to students' critical thinking. This might be due to the student's the level of thinking process that is seen as in a concrete level, and this makes it difficult to produce a critical thinking. In addition, according the previous data presented, it is clear that there is still a lack of research related to problem-solving skills at the high school level. However, the students' problem-solving abilities should be encouraged and improved as their main capital in facing the world challenges ahead.

Sample size

Studies based on sample sizes are grouped into two groups including samples with sizes less than 30 and with samples of 30 or more. The data is presented in Figure 3.

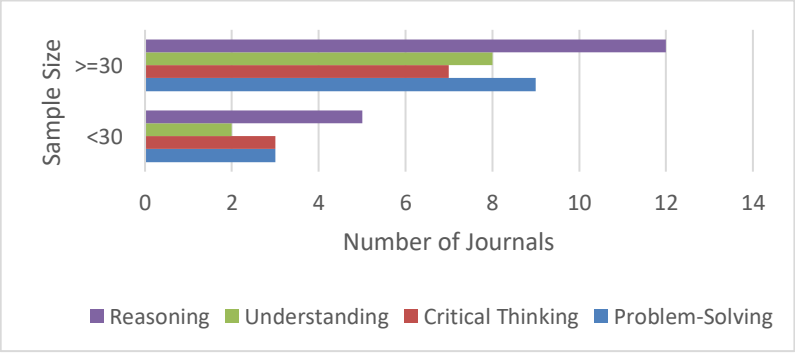

Figure 3. Data by Sample Size

Based on Figure 3, it can be seen that research on the application of discovery learning models to the four mathematical abilities above is dominated by research with a sample count of more than 30. This is because the inclusion criteria limit the research type to experimental research. Experimental and comparative research required a sample of 30 respondents for each group to be compared (Alwi, 2012, p. 141). So, most of the studies above have a sample size of more than 30 for each group.

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The selection of samples depends on the population studied. The more samples selected, the more representative the research results from the research population used. For example, taking a sample of all class XI students will be different from just taking a sample of students from one class XI only. If a larger sample used, the research results produced can be used more and the vice versa.

Demographics

Research based on demographics is grouped into four islands, namely Sumatera, Java, Kalimantan & Sulawesi, and Nusa Tenggara & Maluku. The data is presented in Figure 4.

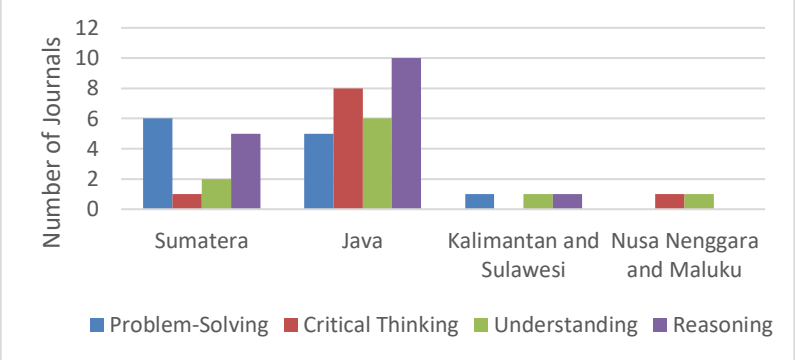

Figure 4. Data by Demographics

Based on Figure 4, it is clear that research on the application of discovery learning models to the four mathematical abilities of students is most widely researched in Java island. This could be due to the number of residents on Java island was the largest population in Indonesia. Likewise, the island of Sumatra occupies the second position after Java island. Meanwhile, for the islands of Kalimantan, Sulawesi, or other islands in Indonesia the research related to mathematics education, especially the experimental studies on the application of discovery learning models for students' mathematical abilities was still little.

Researchers could conduct the research in other Indonesian islands so that data on the application of learning models can have more general effects among students in Indonesia.

Combined effect size

Before calculating the overall effect size, it is necessary to check the publication bias. From all data, it was obtained 5 studies that are biased. Thus, from 48 data collected, only 43 data which were analyzed further. Then, the 43 data were tested for heterogeneity to determine the effect model of the Meta-Analysis. The results of this heterogeneity test are presented in Table 3.

Table 3. Heterogeneity Test Results

Hetergenity			
Q-value	df (Q)	P-value	I-squared
360,847	42	0,000	88,361

Based on table 3, it is found that the p-value (0.000) < α (0.05). Thus, it is obtained that the data analyzed is a random effect model. Thus, for the overall effect size analysis, it is seen from the value in the random effect model. The results of the overall effect size calculation are presented in table 4.

Table 4. Result of Combined Effect Size Test

		Effect size 95% confidence interval				
Model	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit
Fixed	43	0,709	0,039	0,001	0,633	0,784
Random	43	0,815	0,114	0,013	0,592	1,038

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Based on Table 4, the combined effect size in this meta-analysis is 0.815, which then can be categorized into the "high effect" category. It can be stated that the application of the discovery learning model has a significant effect on students' mathematical abilities from the primary data analyzed with a high effect size.

The diversity of the learning process in the discovery learning model

From the primary data obtained, it can be seen that there is diversity in the learning process carried out in each research. The diversity is including student learning activities or the media used by the teachers in their learning. Some studies used media, some did not. Nugraha et al. (2020, p. 132) used rope (track a line idea) media in detecting critical thinking skills of sixth grade elementary school students. In the results of his research, it was found that the motivation and activities of students in conducting discovery learning based on rope were interpreted in high criteria with a percentage range of 84.12% - 88.24%. This is supported by the exposure of the activities of students who are racing in time to be able to solve the problems given and are able to make their own tactics in measuring objects classified as having complex shapes. These activities create a sense of pleasure, enthusiasm, and focus in learning.

In addition, Pramaeda & Ningsih (2020, p. 126) used the edmodo.com website as an E-Learning-assisted learning medium. With this E-Learning-assisted learning, it was found that the students were very enthusiastic. Students were active in the discussion forum provided and they also downloaded the worksheets provided on the website before the lesson is started, so the students become ready with the material discussed. This learning is also effective for teachers, where they could check the data on assignments and did not afraid loosing assessment documents.

Kurniati et al. (2017, p. 109) who used the smart stickers also explains that the use of this learning can improve students' mathematical abilities. Students were given awards not only in the form of prize but also in the form of paper sticks in their books. This makes students compete to be the student with the most stickers. The help of the math module is no less effective in improving students' mathematical abilities. This was explained by Rintoyo (2017, p. 62) that there was a positive influence of the Math Module-assisted Discovery Learning learning model on students' mathematical reasoning abilities with 81.4%. Other studies related to the effectiveness of learning media have also been published in many other journals, such as Fitria et al. (2014, p. 1) and Kurniadi & Purwaningrum (2018, p. 8).

Although there are many studies that described the effectiveness of media to supports learning, a research by Agustya et al. (2018, p. 140) with discovery learning based on ethnomathematics show that her research found that the use of media was not effective on students' critical thinking skills. This is because students are not accustomed to group learning, where students who have low skill were lack self-confidence so that they did not express their opinions and depend on those with higher abilities in group activities. Whereas group learning is designed to provide a forum for students to discuss and exchange ideas. So that the use of group learning can make students become more knowledgeable by transferring knowledge from peers.

Not only the explanation of the research above, the research of Septiani et al. (2018, p. 14) also explained that the effectiveness of discovery learning model learning did not occur on students' mathematical problem-solving abilities. This is because students are not used to using the discovery learning model in their learning activities. Many students were not focused during their learning and did not take part in the group discussions formed. This results in a less conducive learning within the classroom. Therefore, it is necessary to re-adapt the lesson and give a socialization in advance regarding how the learning will be carried out so that the implementation discovery model could run more smoothly.

It was found that, although the learning model used was the same, the learning process carried out will be different. Teachers can use additional media during learning. Likewise, student activities during learning were different because of differences in culture and environment. The effectiveness of a learning does not only depend on the model used, but also depends on the addition of media and student activities. Good media is also not enough to support learning, there must be an active role of students who support the learning. Both must go hand in hand, not only dominated by a certain group or member but all should participate in improving better learning. The teacher's expertise in choosing media and designing appropriate learning is one of the factors that determine the success of students'

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mathematical competence. Likewise, the awareness of students to take part in a more active learning process is the key to the success of their competence improvment.

CONCLUSION

From the data, it was concluded that research on the application of discovery learning models leads more to students' mathematical reasoning abilities. Every year, the number of published studies of each mathematical skill increases. With the development of technology, more and more researchers are discussing the phenomena of life, especially in education. From the data collection of several studies, it is also known that researchers conducted more research at the junior high school education level, with a sample number of more than 30. Meanwhile, when viewed from the demographic aspect, this study was more located on Jave island, while for the islands of Nusa Tenggara and Maluku, there was still a lack of experimental research related to the application of the Discovery Learning model in improving students' mathematical abilities.

From the analysis of 48 data, the effect of the discovery learning model on students' mathematical abilities with an overall effect size of 0.815 was obtained in the high effect category. There is a diversity of media and student learning activities in the discovery learning model from the results of the research reviewed. Some studies have added learning media and some have not. The activities of students when learning takes place were also different. From the results of this review of the diversity of the learning process, it is found that a learning is categorized to be effective not only depending on the model used, but also on the addition of media and student activities. Each component must work in balance, it is not enough that the media is good however; student activities must also support for an increase of learning.

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