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Meta-Analysis of Discovery Learning Model in Physics Learning

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Abstract

This study aims to analyze the effect of the Discovery Learning learning model on physics learning which is reviewed based on all verified articles, education level, research results or response variables, media used, and learning materials. The research method used is meta-analysis. The flow of the meta-analysis research is the first to determine the research topic, the second to determine the criteria for selecting the data, the third to search for the data, the fourth to classify the data information, and finally to analyze and conclude. The data collected is secondary data derived from previous research in the form of 22 scientific publication articles. The data analysis technique uses effect size values. The results of this meta-analysis obtained an average effect size value of 0.852. The application of Discovery Learning in learning physics has a big effect when applied at the high school level and can improve science process skills in students. Discovery Learning has a big influence on the kinetic theory of gases with rocky virtual lab learning media.

Keywords: 21st century competence; discovery learning; meta-analisis

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INTRODUCTION

The 21st century is marked by the rapid development of technology, information, and communication that affect human activities worldwide. It will automatically impact the ongoing education system, including the applied teaching model (Akib & Muhsin, 2019). The 21st-century competency includes creativity, critical thinking and problem solving, collaborative skills, information technology skills, new forms of literacy, and social, cultural, and metacognitive awareness (Patrick Griffin and Esther Care, 2015).

Mastery of the main subjects and themes of the 21st century is essential for students (Redhana, 2019). Research to improve 21st-century skills for both students and prospective teacher students have been carried out a lot (Pilia et al., 2020). All disciplines can develop 21st-century skills, one of which is learning physics, a subject in the science family. Physical theories and their application can change and develop the worldview around us (Yuliani, 2017). Physics learning emphasizes understanding rather than remembering concepts (Mursalin, 2014). Based on the description above, the discovery learning model is one of the learning models that can be applied to improve the quality of education and develop 21st-century skills in physics learning.

Discovery learning is a series of learning where the teacher presents learning material, but not in finished form, but provides opportunities to find and find their concepts of the material being studied. Discovery learning directs students to build knowledge-based on information and data collected through a lesson (Wicaksono et al., 2021). The discovery learning model gives students can ask questions, observe, gather information, process information, and conclude (Sopiah & Marlina, 2020). This discovery learning model focuses on students mental and physical abilities, strengthening their enthusiasm and concentration in learning activities (Rosarina, 2020). Most researchers explained that this learning model was effectively applied to physics teaching in senior high school students. In studying physics, the most important thing is that students are actively studying physics. So that all teacher efforts should be directed to help and encourage students to learn physics on their own (Suparno, 2013). The results of experimental studies regarding the discovery learning model have been widely published. Based on the research conducted by Grahito et al. (2020) in (Figure 1), it can be seen that a graph of the development of Discovery Learning research was obtained. In 2018, an exponential increase in publications began, and the highest publication of 168 occurred in 2019.

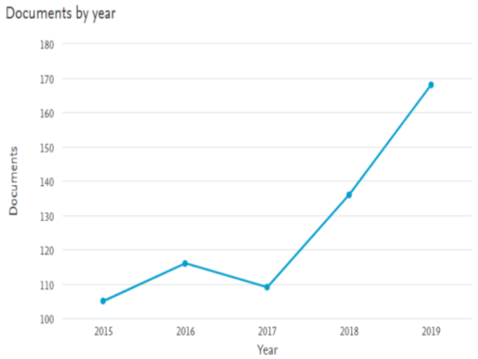
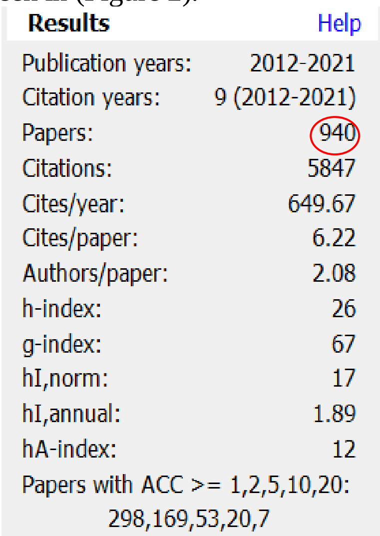


Figure 1 Chart of Discovery Learning Research Development (Wicaksono et al., 2021)

The discovery learning topic article was published in the 1997-2021 range based on the publish or perish data with the Google Scholar search engine. While in 2012-2021, using the keywords "discovery learning" and "physics", there were 940 articles. The search results can be seen in (Figure 2).



Results	Help
Publication years:	2012-2021
Citation years:	9 (2012-2021)
Papers:	940
Citations:	5847
Cites/year:	649.67
Cites/paper:	6.22
Authors/paper:	2.08
h-index:	26
g-index:	67
hI,norm:	17
hI,annual:	1.89
hA-index:	12
Papers with ACC >= 1,2,5,10,20:	298,169,53,20,7

Figure 2 Search Result on Publishing or Perish with Google Scholar

Based on these findings, discovery learning research has different research results and affects the abilities and skills of students. The results of these studies stated that learning with the discovery model can improve student's learning abilities, including critical thinking; creative thinking; solution to the problem; and others (Masril, 2018; Sapitri et al., 2016; Sari et al., 2017; Sumianingrum et al., 2017). Previous article searches can also be searched using the VOSviewer application, where you can see visualizations based on the keyword "discovery learning" by the publishing or perish.

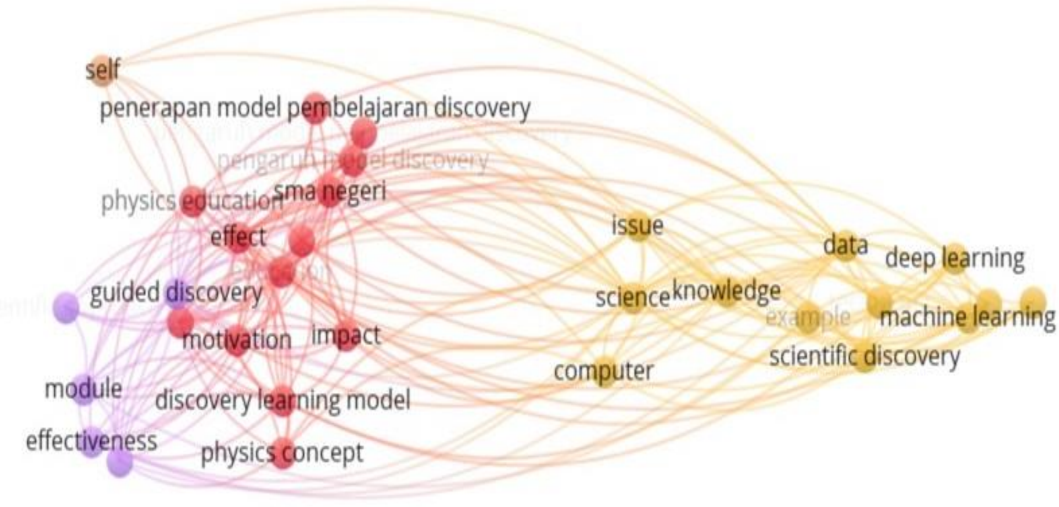


Figure 3 Visualization of Discovery Learning on VOSviewer with Network Visualization

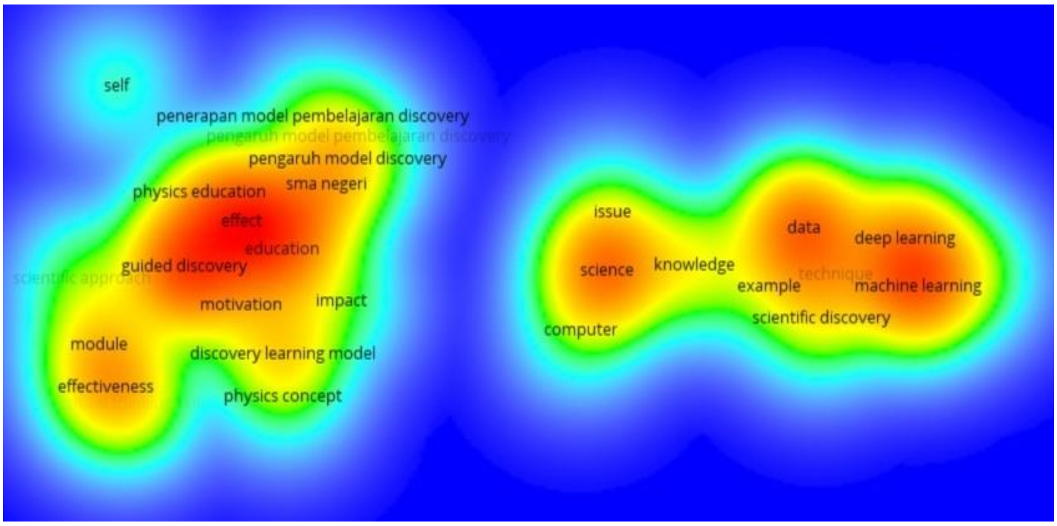


Figure 4 Visualization of Discovery Learning on VOSviewer with Density Visualization

Figure 3, the distance between the points represents the strength between the two. The shorter the distance between the two, the closer the relationship between the two. The lines formed indicate how often they are connected. Figure 3 shows that discovery learning is closely related to the concepts of physics, motivation, effectiveness, impact, learning physics, and others. Figure 4 has a colour gradation for each keyword to a dark colour which indicates the density or number of keywords in a study. Figure 4 shows that there is a significant influence of discovery learning on physics learning. Physics learning is also closely related to physics, concepts, effectiveness, motivation, the impact of discovery models, high school, learning outcomes, machine learning, computers, and deep learning. It can be seen that the discovery learning model has a significant impact on the learning process. The use of learning machines or learning media as supports is also closely related to improving student learning outcomes.

Teachers are expected to package learning effectively and creatively to practice 21st-century skills needed today to support the fulfillment of 21st-century competitions for students in the global era, (Hidayat et al., 2019). Various learning models will be successful if implemented with appropriate learning materials and media assistance (Lidiana et al., 2018). One of the learning models that can be used is the discovery learning model. From the results of experimental studies regarding discovery learning models in physics learning that have been carried out, mapping the effects of existing implementations has not been carried out. Re-analysis is needed to find out how much influence the discovery learning model has on physics learning. Based on this description, research was conducted with a meta-analysis study of discovery learning models in physics learning. The research was conducted by examining the results of the existing analysis in-depth. The results are expected to be a reference for educators to implement the discovery learning model appropriately and effectively.

METHOD

This type of library research describes the mapping of the implementation of discovery learning models in physics learning based on learning outcomes, learning materials, and learning media using meta-analysis. Meta-analysis is a statistical analysis that combines several similar studies to obtain a quantitative blend. Meta-analysis describes the results of two or more similar studies to get a quantitative mix of data. Meta-analysis is also used to systematically assess similar studies to obtain conclusions from the research frame (Kartika, 2010). The research flow is as Figure 5.

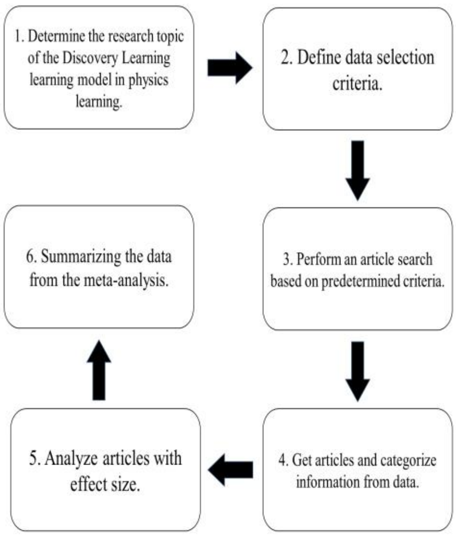


Figure 5 Meta-Analysis Research Flow

The data collected in this research is secondary data derived from previous research in the form of scientific publication articles with the following criteria: (1) Discovery Learning topic articles in physics learning; (2) articles from SINTA accredited journals ranked one to four; (3) articles published in the period 2012-2021; (4) the article uses a quasi-experimental type; (5) the article meets the statistical data in the calculation of effect size; and (6) have information on research results or learning outcomes, subject matter, learning media, and education levels.

The information obtained is then grouped in table 1. The analysis technique in this study is a descriptive statistical technique that uses the effect size calculation. Effect size is an indicator used to determine how much influence a treatment has between variables in the study. If a study uses two groups, namely the control class and the experimental class and uses the t-test as a comparative analysis, then the effect size can be found through the eta-square equation (η^2).

$$\eta^2 = r^2 = \frac{t_0^{\ 2}}{t_0^{\ 2} + db} \qquad (1)$$

(Kadir, 2017)

If an experimental study is obtained, the assumption of a heterogeneous group with two-group variables is received, the calculation of the effect size can be calculated through the following equation :

$$\Delta = \frac{\bar{X}_E - \bar{X}_K}{s_K} \quad (2)$$

(Kadir, 2017)

Table 1 Grouping of data information

Information	Level	Subject Matter	Media
SMP	4		
SMA	18		
Measurement and Quantity	2		
Temperature and Heat	4		
Kinetic Theory Of Gas	2		
Optics	1		
Effort and Energy	1		
Newton's Law	1		
Fluid	1		
Waves and Sounds		2	
Electromagnetic Wave		1	
Elasticity		3	
Straight Motion		1	
Dynamic Electricity		1	
Temperature, Pressure, and Energy		1	
Global Warming		1	
Practical Tools			2
Virtual Laboratory			5
Macromedia Flash and Student Worksheet			2
Computer Simulation			1
Applications of Electromagnetic Waves			1
Concept maps			1
Interactive Demonstration			1
Non Media			9

The result of the effect size calculation can be interpreted in terms of criteria by using the reference from Gravetter and Walnau in Table 2 (Anadiroh, 2019).

Tabel 2 Indicator Effect Size

Effect Size	Kategori
0.01 < *Effect Size* ≤ 0.09	Small Effect
0.09 < *Effect Size* ≤ 0.25	Medium Effect
Effect Size > 0.25	Big Effect

RESULTS AND DISCUSSIONS

This meta-analysis study used 22 articles relevant to the research objectives and data selection criteria. The data collected were analyzed using effect size to determine how much influence the discovery learning model has in learning physics. In Table 3, the effect size data for the whole article is presented. Each piece is grouped into three categories based on the magnitude of the effect size. There are thirteen articles with the category of large effect size, five articles in the medium effect size category, and four pieces in the small effect size category. At the same time, the average value of the effect size of all articles is 0.852, with a large effect size category. These results indicate that the discovery learning model has a significant influence on physics learning. Research obtained an effect size value of

2.240 with a large category (Laila & Budhi, 2017).

Table 3 Effect Size of the Whole Article

No	Code	***Effect Size***	Category	N
1.	1C	1.249	Big Effect	13
2.	2C	3.954		
3.	3C	0.470		
4.	7C	0.820		
5.	25C	2.240		
6.	28C	0.407		
7.	33C	1.307		
8.	34D	0.678		
9.	35D	0.358		
10.	41D	0.652		
11.	42C	5.035		
12.	44C	0.565		
13.	48C	0.104		
14.	20B	0.209	Medium Effect	5
15.	37D	0.100		
16.	38D	0.162		
17.	39D	0.115		
18.	40D	0.106		
19.	36D	0.065	Small Effect	4
20.	43C	0.073		
21.	46D	0.025		
22.	50B	0.048		
Average		0.852	Big Effect	

In Table 4, each article is also grouped by education level. Of the 22 verified articles, there are two levels of education, namely junior high school and senior high school. The discovery learning model for elementary and college levels is very rarely used. It is evident from the 940 articles, with a range of 2012 – 2021, there are less than three articles for the elementary level and no articles for the tertiary level.

Table 4 Effect Size Based on Educational Level

No	Kode	***Effect Size***	Category
1.	Junior High School	0.417	Big Effect
2.	Senior High School	0.949	Big Effect

The effect size value was obtained in a large category at the junior and senior high school education levels. There are school level has a more significant effect size value than the junior high school level. It is by the research of Hartini et al., 2018 for the high school level on temperature and heat material. The effect size value is 5.035. While the analysis of Iman et al., 2016 for the junior high school level on temperature and heat material obtained an effect size value of 1.249.

The use of discovery learning models helps students build knowledge and skills based on previous knowledge and skills (Masril, 2018). The weakness in discovery learning is that its implementation takes quite a lot of time. If it is not directed, it can lead to chaos and confusion over the studied material (Sari et al., 2017). High school students have more basic and experience learning about the material so that the learning outcomes obtained tend to be better than junior high school students. According to Piaget, every child has different cognitive development, classified into four stages, namely sensorimotor, pre-operational, concrete operational, and formal operational stages (Mu'min, 2013). The active sound stage is the age of 12 years and over. At this stage, the individual already has complex cognitive development, thinks abstractly, ideally, logically in solving problems, and can imagine the possibilities (Mu'min, 2013). According to Piaget's theory of cognitive development, high school students aged 15-19 years are already able to think rationally and irrationally, so that in learning science, apart from being able to develop analytical thinking skills, imaginary ways of thinking must also be created (Handayani, 2016).

According to Piaget, three processes underlie individual development, namely assimilation, accommodation, and equilibration. Assimilation integrates new data or information with existing cognitive structures, accommodation adjustment of existing cognitive systems to new situations, and equilibration is a balanced, continuous adjustment between assimilation and accommodation (Sutarto, 2017). At the high school level, students have more experience, then the process of assimilation, capacity, and equilibrium can continue to occur compared to students at the previous level.

Table 5 shows that each article is grouped based on the results obtained after learning. The learning outcomes obtained are knowledge and science process skills, analytical skills, critical thinking skills, and others. Implementing the discovery learning model on learning outcomes, science process skills, analytical skills, necessary thinking skills, and disciplines has an enormous effect size value (Patrick Griffin and Esther Care, 2015).

Table 5 Effect Size Based on The Results of Article Research

No	Result	Effect Size	Category
1.	Learning outcomes	0.576	Big Effect
2.	Science Process Skills	2.322	Big Effect
3.	Concept Mastery	0.152	Medium Effect
4.	Analysis Ability	0.288	Big Effect
5.	Critical thinking	0.358	Big Effect
6.	Discipline	0.565	Big Effect

However, this learning model will be challenging to apply without students' initial knowledge, leading to a lack of mastery of concepts. The study results are 21st-century skills; these include creativity, critical thinking and problem solving, collaborative skills, information technology skills, new forms of literacy, and social, cultural, and metacognitive awareness (Patrick Griffin and Esther Care, 2015). It obtained an effect size value of 0.358 on critical thinking skills. The value of effect size is 2.322 on science process skills, and the importance of effect size is 0.288 on the ability to analyze the two skills related to students' creativity and problem-solving.

Table 6 shows the data in each article grouped based on the learning media used to support learning, then calculated and categorized based on the effect size. The use of learning media in supporting discovery learning has a significant influence on student learning outcomes. It can be seen in the table that almost all of the media used to obtain a considerable effect size value, both virtual and real learning media. Discovery learning models can also be carried out well without the help of learning media; it can be seen in the table that the effect size value obtained is immense even without supporting media. However, learning outcomes will be maximized when using learning media as support (Galla et al., 2020). Under the research of Winda et al., 2020 on the material of gas kinetic theory assisted by learning media, the value of effect size is 3.954.

Meanwhile, Jamhal (2015) research on gas kinetic theory material without learning media obtained an effect size value of 0.565. It can be seen from both studies with the same learning material, research with learning media receives a more significant effect size value than research without teaching media. Virtual learning media has an enormous effect size value compared to real learning media; this happens because virtual media can represent natural physical phenomena so that it is easier for students to understand (Astutik & Jauhariyah, 2021). The advantages of using virtual media are that it attracts students attention, is more complex, and can explain abstract concepts to be authentic. In addition, virtual media is an alternative when laboratory conditions are inadequate in schools (Galla et al., 2020).

Table 6 Effect Size Article Based on Learning Media

No	Media	Effect Size	Category
1.	Practical Tools	0.705	Big Effect
2.	Virtual Laboratory	1.045	Big Effect
3.	Macromedia Flash and Worksheet	1.064	Big Effect
4.	Computer Simulation	0.652	Big Effect
5.	Applications of Electromagnetic Waves	0.115	Medium Effect
6.	Concept Maps	0.591	Big Effect
7.	Interactive Demonstration	0.358	Big Effect
8.	Non Media	0.415	Big Effect

Table 7 shows the data in each article grouped by subject matter, then calculated and categorized by effect size. Materials of measurement and quantity, temperature and heat, kinetic theory of gases, optics, work and energy, Newton's laws, fluids, waves and sound, elasticity have an enormous effect size value in implementing discovery learning models in physics learning. Material electromagnetic waves, temperature; pressure; and energy have a moderate effect size value in implementing the discovery learning model in physics learning.

In comparison, the material of straight motion, dynamic electricity, and global warming have a negligible effect size value in implementing discovery learning models in physics learning. The highest effect size value is obtained from the kinetic theory of gases. It can happen because of the media used to support education; even though the kinetic theory of gases is abstract, it can be represented well through the help of the media (Galla et al., 2020). At the same time, the smallest effect size value is obtained in dynamic electrical materials. Because the learning stage is carried out less than optimally, misconceptions occur in students (N. Sari et al., 2015).

Table 7 Effect Size Based on Subject Matter

No	Subject Matter	Effect Size	Category
1.	Measurement and Quantity	0.399	Big Effect
2.	Temperature and Heat	1.677	Big Effect
3.	Kinetic Theory of Gas	2.260	Big Effect
4.	Optics	0.820	Big Effect
5.	Effort and Energy	2.240	Big Effect
6.	Newton's Law	0.407	Big Effect
7.	Fluid	1.307	Big Effect
9.	Waves and Sounds	0.420	Big Effect
10.	Electromagnet ic Wave	0.115	Medium Effect
11.	Elasticity	0.286	Big Effect
12.	Straight Motion	0.073	Small Effect
13.	Dynamic Electricity	0.025	Small Effect
14.	Temperature, Pressure, and Energy	0.104	Medium Effect
15.	Global Warming	0.048	Small Effect

CONCLUSION

Based on the mapping and analysis conducted, it can be concluded that the discovery learning model has a significant influence on physics learning, with an average effect size value of 0.852. The application of the discovery learning model is mainly carried out at the junior high and high school levels. The effect size values obtained in both groups are in a large category. At the high school level, the effect size value is more significant than at the junior high school level. Meanwhile, at the elementary and college levels, this model is rarely used. The highest effect size value was obtained in the learning of gas kinetic theory material. The use of this learning model can improve students science process skills. In addition, the use of virtual learning media is also very supportive of student learning outcomes so that it is easier for students to understand. Because virtual media can represent physical phenomena in real terms, learning media is also the application of 21st-century competencies, namely information technology skills. The results of this study are expected to be a recommendation for educators when applying the discovery learning model in learning physics. Then it can be used as a reference for other research so that further studies are more in-depth and complete.

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