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The Effect of Using Discovery Learning Model in High School Physics Learning: A Meta-Analysis

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Abstract *– Discovery learning is one of the learning models recommended by the 2013 Indonesian curriculum to meet the demands of 21st-century learning. The purpose of this study is to determine the effect of the discovery learning model based on class level, learning materials, student learning competencies, and learning media used. This type of research is a meta-analysis by calculating the value of effect size (ES). The data collection technique in this study is using documentation techniques. The analytical techniques used are quantitative analysis for value and qualitative analysis to analyze research data. The study used 26 articles consisting of 21 national articles and 5 international articles. The results of this study indicate that, first, the discovery learning model is more effectively applied to class X with an ES of 1.38, which is in the high category. Second, the discovery learning model is more effectively applied to measurement material with an ES of 3.24, which is in the high category. Third, the discovery learning model is more effective for increasing learning competence in the form of mastery of concepts and critical thinking skills of students with an ES of 1.70, which is in the high category. Finally, the tracker software media is more effective in learning physics with ES 2.32, which is in the high category. Overall, it can be concluded that the discovery learning model has a positive effect on physics learning.*

Keywords: *discovery learning; meta-analysis; physics learning*

I. INTRODUCTION

The 21st century is known for its century of globalization. In the 21st century, it demands the creation of quality human resources. The skills demanded in the 21st century are skills that combine and integrate all skills such as critical thinking skills and problem-solving, creative and innovative skills, communication and collaborative skills by placing the measurement of students' abilities from lower thinking to higher levels (Hidayat et al., 2020). Based on the Indonesian National Education Standards (Badan Standar Nasional Pendidikan, 2010), the skills emphasized in the 21st century are students can think critically and problem-solve, communicate and cooperate, create and renew, contextual learning, and information

and media literacy skills. 21st-century learning combines literacy skills, knowledge, attitudes, and mastery of information and communication technology (Nurhafifah et al., 2021). It can be said that students are required to be able to balance the competence of attitudes, knowledge, and skills that are appropriate to learning in the 21st century.

The demands and challenges of 21st-century learning affect the changing learning system in Indonesia. One of the concerns of the government is to make improvements to the curriculum. The KTSP curriculum was changed to the 2013 curriculum and further refined into the revised 2013 curriculum (Ramadhani et al., 2021). The 2013 curriculum is a curriculum that changes student learning patterns from passive to active and also changes the teacher as the only source of learning to learn from various learning sources (Anori et al., 2021).

Physics is a science that is very close to everyday life. In physics learning, student activities do not only receive knowledge products from the teacher but also have to undergo a process to acquire that knowledge (Gusnedi et al., 2020). Physics is a science formed through a series of scientific methods that study natural phenomena in terms of energy and matter (Farid et al., 2018). Physics also studies the universe, including matter and energy on a small scale and the solar system on a large scale (Mufit et al., 2020). Learning physics requires students to understand and apply it in everyday life.

The reality in everyday life has not fully met the desired expectations. There are some problems that still occur in learning physics. Based on previous research, it is known that students' interest and motivation in learning physics are relatively low, which has an impact on their learning outcomes (Oktalia et al., 2017; Fitri & Derlina, 2015). During classroom learning, many physics teachers have not implemented varied learning models to improve student learning outcomes (Putri et al., 2017). The learning activities in the classroom are still dominant using the lecture method, which causes students to be passive in learning (Aprilia et al., 2020). In addition, physics learning still tends to only focus on the aspect of remembering, which results in the low thinking ability of students (Zulmi & Akhlis, 2020).

The gap between reality at school and what is expected can be overcome by implementing appropriate learning models. The learning model serves as a guideline for teachers in planning and implementing the learning process in class (Nurlina, 2019). One of the learning models recommended in the 2013 Indonesian curriculum is the discovery learning model. The discovery model was developed based on constructivism theory (Sudirman et al., 2020) and gave students the freedom to find concepts on their own (Masril et al., 2018). Discovery learning focuses on direct active learning opportunities for students (Arafah, 2020), and teachers encourage and guide them to discover

concepts, meanings, and relationships through experimentation or investigation (Purnamasari et al., 2021). The advantage of discovery learning is that it helps students to improve skills and cognitive processes (Safitri & Setiawan, 2020; Yuliana, 2018). The discovery learning model can also improve students' skills and knowledge (Rahmayanti, 2021).

Previous studies have shown that the discovery learning model has been discussed by many researchers. In the studies that have been done, there are several similarities and differences in the application of discovery learning models. Based on this, readers can less see the broader influence on the application of discovery learning models in learning physics. Therefore, a summary is needed on the effect of the application of discovery learning models in physical learning activities through meta-analysis by looking at the value of effect size (ES). There are three basic types of ES: the difference in standard averages, correlation coefficients, and log odds ratios (Demirel & Dağyar, 2016). ES moderators to explore how to study characteristics such as samples, methods, study design quality, and/or settings. This can be attributed to variations in ES throughout the study (Pigott & Polanin, 2020).

This study aims to determine the effect of the discovery learning model based on class level, learning materials, student learning competencies, and learning media. The research questions were 1) how is the effect of the application of the discovery learning model based on the grade level?; 2) how is the effect of the application of the discovery learning model based on the learning material?; 3) how is the effect of the application of the discovery learning model based on the student's learning competence?; 4) how is the effect of the application of the discovery learning model based on the learning media used?

II. METHODS

The research was conducted using the meta-analysis method through ES calculation. Research meta-analysis is a quantitative and systematic approach to reviewing research that has been done. The data collection technique in this study is to use documentation techniques so that the data obtained is secondary data. The stages carried out in this research consist of two stages, namely the stage of preparation and implementation. The research procedure can be seen in Figure 1.

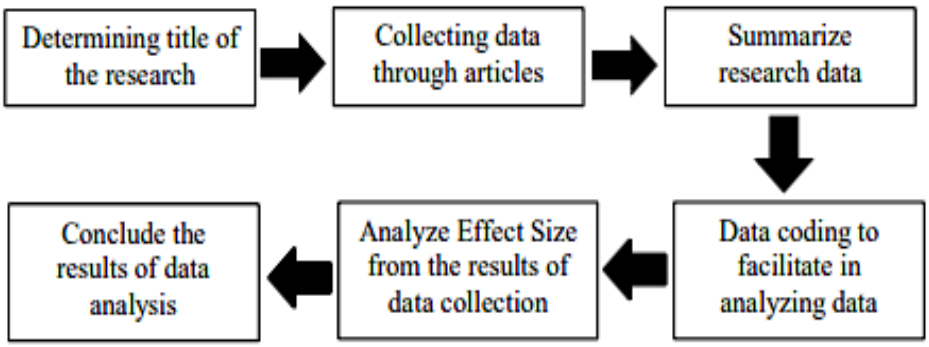

Figure 1. The research procedure of meta-analysis

In this research, the preparatory stage includes determining the title of the research and the formulation of the problem. Then, data is collected through published articles that are relevant to the topic. The articles used are in the range of 2016-2020. Data collection is found from various sources such as google scholar, IOP, and so on. Articles were searched using the keywords "the influence of discovery learning models", and "the impact of discovery learning on physics".

In the implementation stage, the researchers summarize the research data in the form of statistical data used and then perform coding to make it easier to analyze the data. After analyzing the ES from the results of data collection, it is followed up with conclusions. In this meta-analysis, study results were expressed by ES.

Based on Becker and Park (2011), data analysis techniques in determining the ES value can use the following equations:

1. Average on one group

$$ES = \frac{\bar{X}_{post} - \bar{X}_{pre}}{SD_{pre}} \quad (1)$$

2. Average of each group

$$ES = \frac{\bar{X}_E - \bar{X}_C}{SD_C} \quad (2)$$

3. Average of each group

$$ES = \frac{\left(\bar{X}_{post} - \bar{X}_{pre}\right)_E - \left(\bar{X}_{post} - \bar{X}_{pre}\right)_C}{\left(\frac{SD_{preC} + SD_{preE} + SD_{postC}}{3}\right)} \quad (3)$$

4. Chi-square

$$ES = \frac{2r}{\sqrt{1-r^2}}; r = \sqrt{\frac{\chi^2}{n}} \quad (4)$$

5. t-count

$$ES = t\sqrt{\frac{1}{n_E} + \frac{1}{n_C}} \quad (5)$$

Description :

ES = Effect size

$\bar{X}_{post}$ = Posttestaverage

$\bar{X}_{\text{pre}}$ = Pretestaverage

SD_{pre} = Pretest standard deviation

$\bar{X}_E$ = Experiment group average

$\bar{X}_C$ = Control group average

SD_C = Control group standard deviation

r = Correlation index

χ^2 = Chi-quadrate parameter

t = t count

n_E = Quantity experiment group

n_C = Quantity control group

After obtaining the ES, the results can be interpreted into categories in Table 1.

Table 1. Effect size classification

Effect Size	Standard Category
$0 \leq ES \leq 0.2$	Low
$0.2 < ES < 0.8$	Medium
$ES \geq 0.8$	High

(Cohen, 1988)

III. RESULTS AND DISCUSSION

This meta-analysis research was conducted by reviewing relevant articles in the 2016-2020 period. There were 26 articles reviewed in the national and international categories. These articles are then grouped by variables, and the ES value is calculated for each article. The grouping of articles is based on moderator variables, namely grade level, learning materials, student learning competencies, and learning media. Grouping is done to facilitate data analysis in determining the ES value. For more details, the description of the analyzed articles can be seen in Table 2.

Based on the year of publication, the use of discovery learning models in physics learning has increased every year. Based on Figure 2, the highest number of publications on discovery learning models in 2020 was 10 articles. The year of publication indicates the novelty and updating of research results that have been carried out in the last 5 years. This increase illustrates that the discovery learning model is relevant to the demands of 21st-century learning, especially in physics.

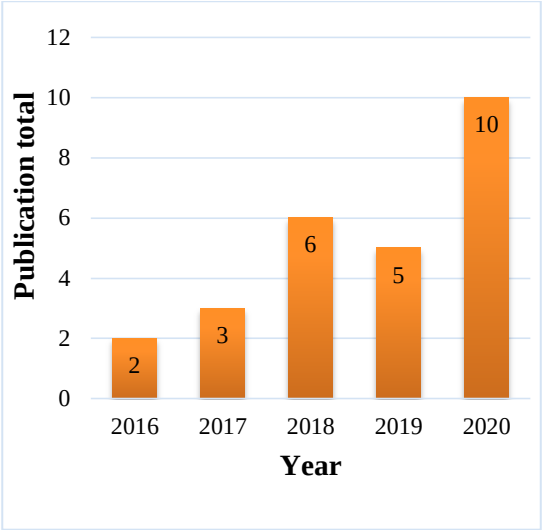

Figure 2. The number of publications on the use of discovery learning models in physics learning by year

The first aim of this research is to analyze the effect of the discovery learning model in physics learning based on class level. To achieve this goal, the average ES grade by class level was calculated for each article. From all the articles collected, the use of the discovery learning model in physics learning is carried out in classes X and XI only, without class XII. Therefore, this study only compares the effectiveness of the use of discovery learning models in learning physics between grades X and XI. The following Table 3 presents the average ES scores by class level.

Table 3. ES of using the discovery learning model based on class level

Class	N	Percentage (%)	ES	Category
X	15	57.7	1.38	High
XI	11	42.3	0.90	High
Average			1.14	High

Table 2. Description of articles analyzed

Article source	Article code	Article criteria	Class	Materials	Test	Learning competence	Fr	ES
(Simbolon & Situmorang, 2018)	A1	National	X	Work and energy	MC	Knowledge	Fr-3	2.05
(Sartika & Abubakar, 2019)	A2	National	XI	Hooke's law & elasticity	MC	Knowledge	Fr-3	0.47
(Masril et al., 2019)	A3	International	X	Vector	MC	Knowledge	Fr-2	0.89
(Fadlilah et al., 2020)	A4	International	XI	Balance & dynamics rotation	-	Knowledge	-	0.74
(Syahputri & Derlina, 2016)	A5	National	XI	Dynamic fluid	MC	Knowledge	Fr-5	0.58
(Irawan et al., 2020)	A6	National	X	Straight motion	MC	Knowledge	Fr-5	1.23
(Ririn et al., 2020)	A7	National	XI	Elasticity	Essay	Knowledge	Fr-2	1.27
(Rawanti et al., 2020)	A8	National	X	Straight motion	MC	Knowledge	Fr-5	0.49
(Wati & Sartiman, 2019)	A9	National	X	Momentum, impulse, collision	MC	Knowledge	Fr-5	0.66
(Turrahmah et al., 2019)	A10	National	X	Work and energy	Description	Mastery of concepts	Fr-5	0.59
(Simatupang & Simamora, 2018)	A11	National	X	Momentum,impulse, collision	Essay	Knowledge	Fr-5	1.63
(Farid et al., 2018)	A12	National	XI	Newton's gravitational force	-	Knowledge	Fr-3	0.36
(Masril et al., 2018)	A13	National	X	Straight motion	MC	Knowledge	Fr-2	0.47
(Putri et al., 2017)	A14	National	XI	Temperature & heat		Knowledge	Fr-5	0.62
(Sari et al., 2016)	A15	National	X	Dynamic electricity	MC	Mastery of concepts	Fr-5	1.13
(Pratiwi et al., 2017)	A16	National	X	-	Essay	Creative thinking	Fr-5	0.62
(Komariyah & Karimah, 2019)	A17	International	XI	Dynamic fluid	Essay	Critical thinking	Fr-4	1.76
(Jawad et al., 2017)	A18	National	X	Straight motion	Essay	Critical thinking	Fr-5	1.10
(Puspitasari et al.,2020)	A19	National	X	Straight motion	Description	Critical thinking	Fr-1	3.24
(Zulmi et al., 2020)	A20	National	XI	Hooke's law &elasticity	Description	Critical thinking	Fr-5	0.70
(Anawati et al., 2020)	A21	National	X	Work and energy	Essay	HOTS	-	1.03
(Rosmiati et al., 2020)	A22	National	XI	Static fluid	MC	Mastery of concepts	Fr-5	1.29
(Aprilia et al., 2020)	A23	National	X	Simple harmonic vibration	Essay	Mastery of concepts	Fr-5	2.32
(Sahara et al., 2020)	A24	International	X	Measurement	Essay	Mastery of concepts	Fr-1	3.24
(Handayani & Simamora, 2019)	A25	National	XI	Dynamic fluid	Essay	Problem-solving	Fr-5	1.48
(Yuliati & Munfaridah, 2018)	A26	International	X1	Rotational dynamics & rigid body equilibrium	Essay	Problem-solving	Fr-5	0.66

Based on Table 3, it can be known that the application of the discovery learning model in physics learning is more widely applied to class X. This is indicated by the percentage of articles for class X of 57.7%. The results of the ES calculation show that in class X, it is 1.38, while in class XI, the ES is 0.90. Both of these values are in the high category range. The average ES for both classes is 1.14 in the high category. Based on the ES value, it is known that the application of the discovery learning model has a positive impact when used in physics learning. According to Laila and Budhi (2017), the discovery learning model can improve the achievement of learning physics and can be used as a proper learning model in teaching physics. The discovery learning model has a positive influence on the physics learning outcomes of class X students (Irawan et al., 2020)

The second aim of this research is to analyze the effect of the discovery learning model in physics learning based on learning materials applied. To achieve this goal, an average ES based on physics materials is calculated for each article. From all the articles collected, the use of the discovery learning model in physics learning is classified into 13 materials. We can see these physics materials in Table 4.

Table 4. ES of using the discovery learning model based on learning materials

Materials	N	Percentage (%)	ES	Category
Measurement	1	4	3.24	High
Vector	1	4	0.89	High
Straight motion	5	20	1.31	High
Newton’s gravitational force	1	4	0.36	Medium
Work and energy	3	12	1.22	High
Momentum, impulse, collision	2	8	1.14	High
Simple harmonic vibration	1	4	2.32	High
Balance and dynamics rotation	2	8	0.70	Medium
Hooke’s law & elasticity	3	12	0.81	High
Static fluid	1	4	1.29	High
Dynamic fluid	3	12	1.27	High
Temperature & heat	1	4	0.62	Medium
Dynamic electricity	1	4	1.13	High
Average			1.25	High

Based on Table 4, it is known that the discovery learning model is widely used in learning physics with diverse materials. The material tested was of class X. Based on the ES calculation, the highest score is the measuring material with a score of 3.24 in the high category, while the lowest score is on Newton's gravitation force material with a score of 0.36 in the medium category. Newton's Law of Gravity is a material that contains many abstract and highly theoretical concepts (Ridwan, 2020). The average ES

score based on all physics learning materials is 1.25, which belongs to the high category. This shows that the discovery learning model is suitable for use in physics learning, especially in measurement, simple harmonic oscillators, work, and energy materials.

The third aim of this research is to analyze the effect of the discovery learning model in physics learning based on students' learning competencies. To achieve this aim, an average ES based on learning competencies is calculated for each article. From all the articles collected, the use of the discovery learning model in physics learning based on student learning competencies is classified into 6 competencies. Table 5 shows the types of students' learning competencies and their ES results.

Table 5. ES of using the discovery learning model based on students' learning competencies

Learning competence	N	Percentage (%)	ES	Category
Knowledge	13	50	0.88	High
Mastery of concepts	5	19.2	1.70	High
Creative thinking	1	3.85	0.62	Medium
Critical thinking	4	15.4	1.70	High
Problem-solving	2	7.7	1.07	High
HOTS	1	3.85	1.03	High
Average			1.17	High

Based on Table 5, it can be seen that various students' learning competencies are measured by applying the discovery learning model in learning physics. The results showed that 50% of the articles on the application of discovery learning models in physics learning discussed its relationship with learning outcomes or increasing students' knowledge. On the other hand, the least learning competencies are creative thinking and HOTS, with only 1 article discussing each. Furthermore, the calculation of the value obtained that the highest ES in the category of mastery of concepts and critical thinking, with a score of 1.70 in the high category. In contrast, the lowest ES in the category of creative thinking with a score of 0.62 in the medium category. Overall, the average ES score for all categories is 1.17 which is in the high category range. ES shows that the discovery learning model has a positive impact on various physics research results, especially on students' mastery of concepts and critical thinking skills. The discovery learning model has a significant influence on improving students' critical thinking skills (Yosefa et al., 2021) and students' learning outcomes (Irawan et al., 2020).

The fourth aim of this research is to analyze the effect of the discovery learning model in physics learning based on the learning media used. To achieve this aim, an average ES based on learning media is calculated for each article. From all the

articles collected, the use of the discovery learning model in physics learning based on learning media is classified into 8 categories. Table 6 shows the types of learning media and their ES results.

Table 6. ES of using the discovery learning model based on learning media

Learning media	N	Percentage (%)	ES	Category
Mind mapping	3	17.6	1.98	High
Virtual laboratory	3	17.6	0.83	High
Video	2	11.8	0.68	Medium
PhET	3	17.6	1.04	High
Practical tools	2	11.8	0.81	High
Worksheet	2	11.8	1.23	High
Interactive multimedia handout	1	5.9	1.10	High
Software tracker	1	5.9	2.32	High
Average			1.25	High

Based on Table 6, it can be seen that there are various kinds of learning media used to support learning activities by applying the discovery learning model. The results of data analysis showed that the most frequently used learning media to support the discovery learning model were mind mapping, virtual laboratories, and PhET. The learning media that has the highest ES is using software tracker 2.32 in the high category. Furthermore, data analysis also shows that the learning media that has the highest ES score is the software tracker with a score of 2.32 and is in the high category. On the other hand, the learning media that has the lowest ES score is a video, with a score of 0.68, which is in the medium category. Overall, the average ES score for all categories is 1.25, which is in the high category range.

In sum, the results of this study indicate that the use of the discovery learning model has a positive effect on learning physics. Learning using discovery learning models assisted by software trackers has the potential effect of increasing students' understanding of concepts (Anjarwati et al., 2021). The use of this tracker software is able to display the result data practical work that is accurate so that it has a positive impact on students' understanding of concepts (Aprilia et al., 2020). The use of the discovery learning model can also help students improve their critical thinking skills because this model facilitates students to think independently in finding out the concept being studied (Yosefa et al., 2021).

The results of this study contribute to the development of physics education research, especially physics learning and teaching. This study provides information for teachers about the use of discovery learning models in physics learning. This can be a consideration for physics teachers in schools about physics materials and effective learning media if the

discovery learning model is used. In addition, this study also provides information about students' learning competencies that are effectively enhanced by the discovery learning model.

IV. CONCLUSION AND SUGGESTION

Based on the articles that have been analyzed, it can be concluded that the discovery learning model is more effectively applied to class X for physics materials such as measurement, simple harmonic oscillators, work, and energy materials. In addition, the discovery learning model is more effectively used to improve mastery of concepts and critical thinking skills. For learning media, media tracking software is more effectively used to support discovery learning models in physics learning.

For further researchers, it is necessary to conduct a broader analysis of various aspects that influence the use of discovery learning models in physics learning. Use of article sources for meta-analysis in order to get more with similar themes from accredited national and international articles in order to produce better research.

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