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Meta-analysis of the effect of applying scientifically oriented learning models on physics learning outcomes

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Abstract

The aim of this research is to review the influence of implementing scientifically oriented learning models on students' physics learning outcomes. This research method summaries relevant research published in 2013-2023. The subject of this research is 71 relevant articles that have been published in SINTA and international accredited journals. The results show that: 1) based on the four models analyzed; there are project-based learning (PjBL), inquiry and discovery model, which has ES in high category. The problem-based learning PBL model has an ES in the medium category. 2) Based on physics material units, show that there are two PBL models, namely thermodynamic material units and others that have an ES in the high category. There are two PjBL models, namely thermodynamic material units and waves, which have an ES in very high category. There are three inquiry models; mechanics, thermodynamics, and other material units with ES in the high and very high categories. There are four discovery models ; mechanics, thermodynamics, electricity, magnetism, and optical waves, which have ES in the high and very high categories. 3) Based on high school class level analysis, show that there is one PBL model, namely class X which has ES in the high category. There are two PjBL models; class X and XII which has ES in very high, and high categories. There are two inquiry models, namely classes X and XI which have ES in the high category. There is one discovery model, class X which has ES in the high category.

Keywords: meta-analysis; scientific; effect size; learning outcomes

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INTRODUCTION

Physics learning outcomes for high school students are at the bottom among other subjects in high school. Physics learning is a branch of science that discusses matters related to natural phenomena that appear around us (Aprianti, Desnita, & Budi, 2015). Since physics is a discipline that is closely related to everyday life, physics education is built on the ideas of active learning, which gives students the chance to reach their full potential (Desnita & Susanti, 2017).

To overcome the problem of low physics learning outcomes, a number of researchers have made various efforts, one of which is by implementing sanitary-oriented learning models. These efforts can improve learning outcomes significantly. There are also types of scientifically oriented learning that

are used, namely: (1) problem-based learning model, (2) project-based learning model, (3) discovery learning model, (4) inquiry learning model (inquiry based learning).

In the first research there are 15 articles that use problem based learning to improve physics learning outcomes, including: Putri and Gumay (2021), Andryani Hutabarat and Eva Marlina Ginting (2014), Handayani and Sinulingga (2021), …., Andryani Hutabarat and Eva Marlina Ginting (2014)

In second study, there are 15 articles that use project based learning to improve physics learning outcomes, including: Lu Fonseca Soares, Lia Felizarda Freitas, and Amaral (2023), Nusa, Lumentah, and Mambu (2022), Ismail (2022),…, Yance et al., (2013).

In the next study, there are 20 articles that use inquiry based learning to improve physics learning outcomes, including: Syafriyanti (2023), Pardamean and Abubakar (2021), Zuhra et al. (2022),…, Siregar & ., (2015).

The last study have 20 articles that use Discoveri-based learning to improve physics learning outcomes, including: Muhammad Kadri (2015), Devi Permata Sari (2016), Masril et al (2018),...., Febri Jaunauli (2022).

All learning models that have been applied by previous researchers can significantly improve physics learning outcomes. However, each research result is still local and the conclusions are not yet general. To generalize the results of existing research, it is necessary to carry out meta-analysis research to obtain general conclusions.

Meta-analysis is a statistical technique that combines 2 or more similar studies to obtain quantitative data. In accordance with Glass's opinion in (Botella & Zamora, 2017) meta-analysis is a quantitative analysis using quite a large amount of data and applying statistical methods. (Meta, 2018) suggests that meta-analysis is a way to integrate, combine and interpret the results of selected research in a particular field of science. So it can be concluded that meta-analysis is an activity of collecting, processing and presenting data that is carried out systematically and objectively in solving a problem by conducting an investigation into existing research to obtain conclusions and an in-depth understanding of the research being studied.

Based on the background above, it is necessary to carry out research entitled "Meta-Analysis of the Effect of Implementing Scientifically Oriented Learning Models on Physics Learning Outcomes". The aim of this study is to summarize several studies that have the same variables by calculating the effect size of each and answering doubts about various similar studies that have an influence in different categories on improving student physics learning outcomes.

METHODS

This research applies meta-analysis research methods. Meta-analysis is a technique used to summarize various research results quantitatively by calculating effect size values (Sugiyono, 2013). Using the standard division of the control class as a comparison, the difference between the averages of the experimental and control classes is found to determine the effect magnitude. This meta-analysis research used 71 scientific articles selected based the article selection criteria. Data collection was carried out online from Google Scholar in period 2013-2023. This article has been indexed nationally and internationallly. The population in this study is research articles on scientifically oriented learning models on physics learning outcomes. The learning models in question are problem-based learning (PBL), project-based learning models (PjBL), inquiry-based learning models, and discovery-based learning models taken at the high school level.

The steps that will be followed in carrying out this meta-analysis research are as follows: The first step is selecting articles according to the criteria, the results obtained are 71 relevant articles which are presented in Table 1.

Table 1. List of Selected Articles

No	Code	Writer	Reference
1	PBL-1	Azmi Aziz, Joni Rahmat, Kosim	(Aziz, Rokhmat, and Kosim 2014)
2	PBL- 2	Andryani Hutabarat Dan Eva Marlina Ginting	(Andryani Hutabarat dan Eva Marlina Ginting, 2014)
3	PBL-3	Adelyna Oktavia Nst Dan Rahmatsyah	(Adelyna Oktavia Nst, 2016)
4	PBL-4	Nuning Apriani, Syahrial Ayub, Hikmawati	(Apriani and Ayub 2017)
5	PBL-5	Angga P, H. Fihrin Dan H. M. Ali	(Pabenteng, Fihrin, & Ali, 2018)
6	PBL-6	Era Mairani Dan Sehat Simatupang	(Mairani & Simatupang, 2018)
7	PBL-7	Sherly Anjar Pratiwi, Joni Rokhmat, Sutrio	(Sherly Anjar Pratiwi, Joni Rokhmat, 2018)
8	PBL-8	Desi Paradina, Connie, Rosane Medriati	(Paradina, Connie, & Medriati, 2019)
9	PBL-9	Juni Nasution, Izkar Hadiya, Faradhillah	(Nasution, Hadiya, & Faradhillah, 2020)
10	PBL-10	Baiq Henny Helyandari, Hairunnisyah Sahidu, Hikmawati	(Helyandari, Hikmawati, & Sahidu, 2020)
11	PBL-11	Asdar, Nurlina, Yusri Handayani	(Asdar, Nurlina, & Handayani, 2020)
12	PBL-12	Ika T. Simangunson, Jelita P, A. Giawa, Krisdayani Maria E. S.	(Simangunsong, Panjaitan, Giawa, Loi, & Sitompul, 2021)
13	PBL-13	Fitri Handayani dan Karya Sinulingga	(F. Handayani & Sinulingga, 2021)
14	PBL-14	Marlina Paska Anisa H, Ady Frenly S, Fine Eirene S	(Bela, Frenly, & Ady Fine Eirene Siahaan, 2023)
15	PBL-15	Ovilia Putri Utami Gumay	(O. Putri & Gumay, 2021)
16	PjBL-1	Rinta Doski Yance, Ermaniati Ramli, Fatni Mufit	(Yance, Ramli, & Mufit, 2013)
17	PjBL-2	Pintor Simamora dan Masitoh	(Pintor Simamora, 2015)
18	PjBL-3	Ni Made Yeni Suranti, Gunawan, Hairunnisyah Sahidu	(Yeni Suranti 2016)
19	PjBL-4	N Khoiri, A Marinia, dan W Kurniawan	(Khoiri, Marinia, & Kurniawan, 2017)
20	PjBL-5	Dian Hardianti, Muhammad Ali, dan Syamsu	(Hardianti, Ali, and Syamsu 2017)
21	PjBL -6	Jonathan Hutapea dan Mariati P. Simanjuntak	(Hutapea & Simanjuntak, 2017)
22	PjBL-7	Muh. Fatkhul Ma'arij	(Ma'arij, 2017)
23	PjBL-8	Vivi Nainggolan Dan Betty M. Turnip	2017
24	PjBL-9	Rosviana Manik Dan Syahwin	(Manik & Syahwin, 2018)
25	PjBL-10	Tira Selviana Putri, Muliati Syam, Laili Komariyah	(Selviana Putri, Syam, & Komariyah, 2020)
26	PjBL-11	M. A. Jatmiko, A. Hatibe, Dan Darsikin	(Jatmiko, Habite, & Darsikin, 2021)
27	PjBL-12	Selty A Tindige, Jeane C Rende, Alfrits K	(Tindige, Rende, & Komansilan, 2021)
28	PjBL-13	Susi Ismail	(Ismail, 2022)
29	PjBL-14	Jeilen G. Nusa, Lenda L, Marcellino C. M	(Nusa, Lumentah, & Mambu, 2022)
30	PjBL-15	Manuel Lu F Soares, Maria Lia F. Freitas, dan Estaquio A	(Lu Fonseca Soares, Lia Felizarda Freitas, & Amaral, 2023)
31	Inkuiri-1	Lia Anggraini Siregar & Motlan	(Siregar & ., 2015)

No	Code	Writer	Reference
32	Inkuiri-2	Dita Puspitasari, Marungkil Pasaribu, Yusuf Kendek	(Puspitasari, Pasaribu, & Kendek, 2017)
33	Inkuiri-3	Roni Wahyuni, Hikmawati, Muhammad Taufik	(R. Wahyuni & Taufik, 2016)
34	Inkuiri-4	Sri Novita, Ida Wahyuni	(Sri Novita, 2016)
35	Inkuiri-5	Wildah Maulidatul Hosnah, Sudarti, Subiki	(Wildah Maulidatul Hosnah, Sudarti, 2017)
36	Inkuiri-6	Endang Lovisia	(Lovisia, 2018)
37	Inkuiri-7	Lia N, Aris Doyan, Ni Nyoman Sri Putu V.	(Lia N 2018)
38	Inkuiri-8	Erna Fitriani Pertiwi	(Pertiwi, 2018)
39	Inkuiri-9	Muliana, S. Salmiah Sari, Jarak Patandean	(Muliana, S. Salmiah Sari, 2018)
40	Inkuiri-10	Handy Faishal Rahim, Agus Suyudi, Dwi Haryoto	(Rahim, Suyudi, & Haryoto, 2019)
41	Inkuiri-11	Yulpi Lorenza, Petri Reni Sasmita, Shabrina Amalia	(Lorenza, Sasmita, & Amalia, 2020)
42	Inkuiri-12	Nurfarida, Bahtiar, dan Nevi Ernita	(Nurfarida, Bahtiar, & Ernita, 2019)
43	Inkuiri-13	Tri Yanti Marbun dan Karya Sinulingga	(Tri Yanti & Sinulingga, 2019)
44	Inkuiri-14	Kusuma, M Siahaan, N Andriani	(Kusuma, Siahaan, & Andriani, 2019)
45	Inkuiri-15	Mahzin Ali Akbar, H. Hikmawati, Joni Rokhmat	(Akbar, Hikmawati, & Rokhmat, 2020)
46	Inkuiri-16	Nisrin Zuhra, Wahyudi, Ahmad Harjono, dan Muhammad Zuhdi	(Nisrina Zuhra, Wahyudi, Ahmad Harjono, 2021)
47	Inkuiri-17	Riscy Dewi Ramadani, Trapsilo Prihandono, dan Bambang Supriadi	(Fisika et al., 2021)
48	Inkuiri-18	Gonggom Pardamean Tampubolon & Abu Bakar	(Pardamean & Abubakar, 2021)
49	Inkuiri-19	Aulia Syafriyanti	(Syafriyanti, 2023)
50	Inkuiri-20	Eva Rahayu Febniani, Muhammad Taufik, Hikmawati, Susilawati	(Eva Rahayu Febniani, Muhammad Taufik, Hikmawati, 2022)
51	Discovery-1	Jeperis Nahampun	(Jeperis Nahampun, 2014)
52	Discovery-2	Muhammad Kadri, Meika Rahmawati	(Kadri & Rahmawati, 2015)
53	Discovery-3	Rika Sari Indah Harahap dan Eidi Sihombing	(Harahap & Sihombing, 2015)
54	Discovery -4	Yosi Farah dan Ratna Tanjung	(Farah & Tanjung, 2015)
55	Discovery-5	Marizafitri dan Derlina	(Fitri & ., 2015)
56	Discovery-6	Ayu Syahputri	(Ayu Syahputri, 2015)
57	Discovery-7	Devi Permata Sari dan Mariati P Simanjuntak	(Sari & Simanjuntak, 2016)
58	Discovery-8	Masril, Hidayati, dan Y Darvina	(Masril, Hidayati, and Darvina 2018)
59	Discovery-9	Hamidah Lidiana, Gunawan, Muhammad Taufik	(Lidiana, Gunawan, & Taufik, 2018)
60	Discovery-10	Ruth Fika Ronauli Simbolon dan Rappel Situmorang	(Simbolon & Situmorang, 2018)
61	Discovery-11	Jujur Monasari Simatupang dan Pintor Simamora	(Simatupang & Simamora, 2019)
62	Discovery-12	Samuel M H Sitanggang dan Mukti Hamjah Harahap	(Samuel M H Sitanggang, 2019)

No	Code	Writer	Reference
63	Discovery-13	Elsa Handayani dan Pintor Simamora	(E. Handayani & Simamora, 2019)
64	Discovery-14	Adlina, Sondang R. Manurung dan Yuli Apriani	(Adlina, Manurung, & Apriani, 2019)
65	Discovery-15	Sartika Harahap dan Abu bakar	(Abubakar, 2019)
66	Discovery-16	Elia Putri	(E. Putri, 2020)
67	Discovery-17	Sri Wahyuni, Adrianus Nasar, Melkyanus Umbu Kaleka	(S. Wahyuni, Nasar, & Kaleka, 2020)
68	Discovery-18	Cinta Gustina dan Ridwan A. Sani	(Gustina & Sani, 2020)
69	Discovery-19	Irnawati, Marungkil Pasaribu, dan Sahrul Saehana	(Irnawati, Pasaribu, & Saehana, 2020)
70	Discovery-20	Sesarius Walo, Ilyas, Ana Silfiani Rahmawati	(Walo, Rahmawati, Education, & Program, 2021)
71	Discovery-21	Febri Jounauli M, Purwanto	(Febri Jounauli M, 2022)

The second step is conducting qualitative analysis which aimed at generating controlled variables and moderator variables in the research. So, qualitative analysis can be grouped based on learning models, subject matter units and class levels.

The next step is to carry out quantitative analysis to obtain research data based on the statistical information contained in each article. This information can be in the form of average value (mean), standard deviation, number of samples, t test value, f test and so on.

The fourth step is to determine the impact size of every article. The following formulas can be used to determine each article's effect size

1. Pre-pos contrass

$$ES = \frac{\bar{\bar{X}}\,\text{post} - \bar{X}\text{pre}}{SD} \quad (1)$$

2. Grup contrass

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

3. Two group pre post tests

$$ES = \frac{(\bar{X}_{post} - \bar{X}_{pre})\text{E} - (\bar{X}_{post} - \bar{X}_{pre})C}{\frac{SD_{preC} + SD_{preE} + SD_{postC}}{3}} \quad (3)$$

4. t calculate

$$ES = \frac{t}{\sqrt{2n}} \quad (4)$$

The overall effect size calculation findings are then divided into a number of categories, as ahown in the Table 2.

Table 2. Effect size criteria

ES	Criteria
ES ≤ 0,15	Negligible
0,15 <*ES* ≤ 0,40	Low

ES	Criteria
0,40 <*ES* ≤ 0,75	Medium
0,75 <*ES* ≤ 1,10	High
ES> 1,10	Very High

(Retnawati, Apino, Kartianom, Djidu, & Anazifa, 2018)

The fifth step is to determine the average effect size of each group of articles, the aim is to determine how large the effect size obtained by each group is and which category it falls into.

The last step is to draw conclusions from the meta-analysis research. This category of stages can be carried out at the last stage, all stages that have been carried out can be reported as the results of scientific research.

RESULTS AND DISCUSSION

In this research, 71 articles were analyzed. All articles collected are articles that are relevant to the influence of implementing scientifically oriented learning models. The results of calculating the effect size for each article are presented in Table 3.

Table 3. Effect size categories

Code	Formula	Effect size
PBL-1	3	2,27
PBL-2	3	0,45
PBL-3	3	0,71
PBL-4	2	0,77
PBL-5	3	1,17
PBL-6	4	1,75
PBL-7	3	0,70
PBL-8	4	0,17
PBL-9	4	0,39
PBL-10	4	0,25
PBL-11	1	1,03
PBL-12	3	0,52
PBL-13	4	0,10
PBL-14	4	0,34
PBL-15	3	0,58
PjBL-1	1	0,38
PjBL-2	4	0,41
PjBL-3	4	0,20
PjBL-4	4	1,59
PjBL-5	3	0,30
PjBL-6	4	0,37
PjBL-7	2	0,35
PjBL-8	4	0,50
PjBL-9	4	0,34
PjBL-10	4	1,71
PjBL-11	4	0,57
PjBL-12	1	3,56

Code	Formula	Effect size
PjBL-13	3	0,42
PjBL-14	4	0,60
PjBL-15	4	2,11
Inkuiri-1	4	0,44
Inkuiri-2	3	0,92
Inkuiri-3	4	0,50
Inkuiri-4	4	0,21
Inkuiri-5	4	0
Inkuiri-6	3	0,85
Inkuiri-7	4	0,55
Inkuiri-8	1	3,98
Inkuiri-9	2	0,85
Inkuiri-10	3	1,96
Inkuiri-11	1	3,59
Inkuiri-12	3	2,42
Inkuiri-13	4	0,33
Inkuiri-14	4	0,32
Inkuiri-15	4	0,23
Inkuiri-16	4	0,37
Inkuiri-17	4	0,14
Inkuiri-18	3	1,79
Inkuiri-19	3	1,15
Inkuiri-20	4	0,47
Discovery-1	3	3,50
Discovery-2	4	0,25
Discovery-3	4	0,14
Discovery-4	3	2,09
Discovery-5	1	3,07
Discovery-6	3	0,26
Discovery-7	4	0,22
Discovery-8	2	0,88
Discovery-9	4	0,52
Discovery-10	3	1,64
Discovery-11	3	1,86
Discovery-12	3	0,29
Discovery-13	4	0,52
Discovery-14	3	0,47
Discovery-15	3	0,47
Discovery-16	2	0,94
Discovery-17	4	1,21
Discovery-18	4	0,57
Discovery-19	2	0,85
Discovery-20	4	0,30
Discovery-21	4	0,38

The first result of this study is the average effect size value of the influence of implementing

scientifically oriented learning models on physics learning outcomes. There are 4 learning models analyzed including: PBL, PjBL, inquiry and discovery. Each of these models is able to significantly improve learning outcomes. The test results for the average are show in following table 4.

Table 4. Average ES based on mode

Learning model	n	M	SEM	category
PBL	15	0,64	0,04	Medium
PjBL	15	0,79	0,05	High
Inquiry	21	0,99	0,04	High
Discovery	20	1,04	0,04	High

According to the findings of the calculations and the average effect size category for every learning model, the PjBL, enquiry, and discovery models are recognised as the most successful models when it comes to enhancing learning. These three models are in the high category so they are considered effective when applied in physics learning. However, even though they are in the same category, they have different average effect size values. Based on three models, the discovery model has the highest average effect size of 1.04. Meanwhile, the PBL model is in the medium category. Overall, the application of this model is not as effective as the scientific model in the high category.

The second result of this study is the average effect size value of how applying scientifically oriented learning models affected the learning outcomes of physics based on material units. the average effect size value of the influence of implementing scientifically oriented learning models on physics learning outcomes based on material units. Material units are grouped into 5 groups, namely: mechanics, thermodynamics, electricity, magnetism, optical waves, and others (physics). The results of the average effect size calculation test on the influence of the model based on material units are presented in table 5.

Table 5. Average ES based on material units

Unit materi	Model			
	PBL	PjBL	Inquiry	discovery
Mekanika	0,39	0,68	0,89	0,96
Termodinamika	0,92	0,59	1,25	1,72
Listrik magnet	0,66	1,24	0,23	1,09
Gelombang optik	-	2,21	0,14	0,93
Lainnya	1,00	-	1,08	-

Based on the calculation results and the average effect size category for each learning material unit, it is known that: the PBL model is most effectively applied to other material units (physics). In this material unit, the PBL model has an average effect size of 1.00, which is in the high category. Meanwhile, the material units for mechanics, thermodynamics and electricity and magnetism are still in the medium category and some are even in the low category. It can be concluded, the application of this material unit is not as effective as the high category material unit.

The PjBL model is most effectively applied to material units such as electricity, magnetism and optical waves. In this material unit, the PjBL model is classified in the very high category. Even though they are in the same category, they have different average effect size values. From two material units, the optical wave material unit has the highest average effect size of 2.21. Meanwhile, for the

mechanics, thermodynamics material unit, it is still in the medium category. In conclusion, the application of this material unit is not as effective as material units in the very high category.

For the most effective inquiry model, it is applied to thermodynamic and electric-magnetic material units. In this material unit, the inquiry model has an average effect size in the very high category. Even though they are in the same category, they have different average effect size values. Based on the two material units, the thermodynamic material unit has the highest average effect size of 1.25. Meanwhile, for the mechanics material unit, it is in the high category and for the optical waves and other material units it is in the low category and is ignored. In addition, the application of this material unit is not as effective as material units in the very high category.

All material units can be efficiently applied with the discovery model. because the four average effect sizes of material units are classified in the very high and high categories. However, it is not as effective as material units with an average effect size which is in the very high category.

The results of these three studies are the average effect size value of the influence of implementing scientifically oriented learning models on physics learning outcomes based on class level. The three level groupings that comprise the class levels are classes X, XI, and XII. Table 6 below shows the findings of the average impact size calculation test on the model's influence based on class level.

Table 6. Average ES based on class level

Tingkatan kelas	Model			
	PBL	**PjBL**	**Inquiry**	**discovery**
X	0,85	1,28	0,96	1,02
XI	0,52	0,74	0,89	0,46
XII	-	0,99	-	0,14

Based on the calculation results and the average effect size category at each class level, it is known that: the PBL model is most effectively applied in class X. In there, class X level the PBL model has an average effect size in the high category of 0.85. Meanwhile for class XI the average effect size is still moderate at 0.52. So the PBL model is most effectively applied in class X.

The PjBL model is effectively applied to all three classes. At these three levels, the PjBL model has an average effect size in the very high and high categories. However, it is not as effective as in the very high category. The very high category at class X level has an average effect size of 1.28.

The inquiry model is effectively applied to classes X and XI. At this level the inquiry model has an average effect size in the high category. Even though they are in the same category, they have different average effect size values. From the two class levels, class X has the highest average effect size of 0.96. Meanwhile, class XI has the highest average effect size of 0.89. So the inquiry model is most effectively applied in class X.

The most effective discovery model is applied in class X. At this level the discovery model has an average effect size in the very high category. Class XI and XII levels are still classified as medium and low in the meantime. In order for class X to benefit from the implementation of the discovery model.

CONCLUSION

Three conclusions can be drawn from the analysis's findings. First, the project-based learning, enquiry, and discovery models have ES of 0.78, 0.99, and 1.04 in the high category out of the four

models that were examined. The problem based learning model has an ES of 0.64 in the category of medium. the medium category. Second, the results of the analysis based on physics material units show that there are two problems based learning models; thermodynamics material units and others that have an ES of 0.92 and 1.00 in the high category. There are two project based learning models, namely thermodynamic and wave material units which have an ES of 1.24 and 2.21 in the very high category. There are three inquiry models, namely mechanics, thermodynamics and other material units with ES of 0.89, 1.25 and 1.08 in the high and very high categories. There are four discovery models; mechanics, thermodynamics, electricity, magnetism and optical waves, which have an ES of 0.96, 1.72, 1.09 and 0.93 in high to extremely high categories. Third, the results of the analysis based on high school class levels show that there is one problem based learning model, namely class X which has an ES of 0.85 in the high category. There are two PjBL models; class X and XII which has ES 1,28 and 0,29 in very high, and high categories. There are two inquiry models, namely classes X and XI which have an ES of 0.96 and 0.89 in the high category. There is one discovery model, class X which has ES ES of 1.02 in the high category.

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