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Meta Analysis of the Effect of Applying the Problem Based Learning Model in Physics Learning to Improve Students' Ability to Solve Problems

Aulia Ulfa[1], Fadhillah Janna[1], Ismi Gustia Adinda[1], Desnita[1*]

[1]*Department of Physics, Padang State University, Jl. Prof. Dr. Hamka Freshwater Padang 25131, Indonesia*
Corresponding author. E-mail: desnita@fmipa.unp.ac.id

ABSTRACT

The meta-analysis method in this research was used to determine how problem-based learning activities influence problem-solving abilities. Analysis is carried out based on material units and levels/classes. Based on the results of the analysis, it was found that the mechanical material unit had an effect size of 0.83 in the high category, for the electric magnetic material unit it had an effect size value of 1.12 in the very high category, for the optical wave material unit it had an effect size of 1.66 with very high category, for thermodynamic material units it has an effect size of 1.41 in the very high category, and for fluid material units it has an effect size of 1.56 in the very high category. Then for class X it has an effect size of 1.19 in the very high category, for class XI it has an effect size of 1.35 in the very high category and for class In conclusion, for the optical wave material unit, it has an effect size of 1.81 which has a very high influence on students' ability to solve problems and for class XI level it has an effect size of 1.35 which has a very high influence on students' ability to solve problems.

Keywords :*Meta Analysis*; *Problem Based Learning; Problem Solving Abilities; Effect Size.*

I. INTRODUCTION

Students in the 21st century must have the 4C skills, namely creative thinking, critical thinking and problem solving, communication and collaboration to be able to face increasingly rapid technological developments like today (Septikasari, R., & Frasandy, 2018). In studying physics, students must not only understand the material, but also use it to solve various problems in the real world. Many academics and educators have recognized the value of problem solving, and problem-based learning (PBL) has been used in various fields (Sujanem et al., 2016).

Various studies have found that students' problem solving abilities in the field of physics are still low. In 2022, PISA releases data related to problem solving, and Indonesia is ranked 69th out of 81 countries, with an average score of 369.3 points, where the maximum score is 485. This PISA study is useful for evaluating problem solving abilities students in the real world and the future, as well as the application of previously studied material. This shows that learning outcomes in Indonesia are still low, especially in reading, mathematics and science. In reality, the level of student

independence in learning and solving problems is still very low. The low competency and learning outcomes of students who continue to show attention and focus on teachers seem to be unable to represent this low level of ability. As a result, learning independence and problem solving abilities are still low (Nasution & Mujib, 2022).

One of the causes of low problem solving abilities is learning strategies that are boring and make students uninterested in the learning process (Hastuti et al., 2016). The learning system in the classroom is still teacher-centered, making students not actively involved in the learning process. Teachers still use traditional teaching techniques, such as lectures and questions and answers, and their teaching methods are also less diverse (Onikarini et al., 2019).

Various approaches have been used by various researchers, such as the use of problem-based learning models (Hastuti et al., 2016), interactive multimedia learning media (Mirayani, P., Suharta, IGP, & Suweken, 2023), and learning modules (Hudha et al. ., 2017). The results of research using models, media and learning modules have proven to provide positive value for improving high school students' problem solving abilities.

In this article, researchers only analyze the effect of applying problem based learning to hone students' abilities in solving problems. The results obtained by several researchers show that there has been an increase in students' ability to solve problems using the problem based learning model. However, the results shown do not show clear results, the number of samples used in the research is still limited. Therefore, it is necessary to carry out meta analysis research entitled "Meta Analysis of the Effect of Problem Based Learning Models on Students' Ability to Solve Problems". Where this research aims to obtain conclusions about the influence of the PBL model in increasing students' abilities in solving problems at material and class levels in high school physics learning.

The need for more valid and accurate data to identify risk variables associated with a phenomenon or problem makes meta-analysis research important. By combining findings from various related studies and conducting a more thorough analysis, meta-analysis allows researchers to increase the level of validity and reliability of their findings. By combining findings from various related studies, meta-analysis allows researchers to increase the validity and reliability of their findings so as to obtain clear results. (Retnawati et al., 2018).

II. METHOD

This research aims to find a general conclusion. The meta-analysis research method is a statistical technique for combining the results of 2 or more similar studies to obtain a quantitative combination of data.

The stages of meta analysis research adapted to the stages of meta analysis research by Glass are (9):

2.1 Planning stages

a. Determine the research domain
    1) Independent variable: Problem Based Learning (PBL) learning model
    2) Dependent variable: Students' ability to solve problems
b. Determine research criteria
    1) Type of research article: articles from national and international journals
    2) Year of publication: 2014-2024

2.2 Stages of data collection or research implementation

a. Collecting and selecting articles
b. Summarize research with similar variables

c. Identify similar research based
   1) Researcher variable: identity of the name of the author or researcher in the article
   2) Target variable: high school students and equivalent
d. Group research from articles based on
   1) Material units
   2) Grade Level
e. Calculate the effect size value for each study from the articles collected
f. Determine and analyze the relationship of each research variable
g. Write down the results and conclusions

2.3 Stages of analyzing research data

a. Analyze the results of calculating the effect size value according to the target variable
b. Carry out an analysis of the relationship between each research variable
   1) Learning material in the problem based learning (PBL) model
   2) Problem based learning (PBL) model testing class levels

Based on the search for articles in journals that have been carried out, there are 27 article titles that are suitable for this meta-analysis research. The articles obtained are detailed in table 1.

Table 1. List of articles

Article number	Source	Title	Journal Name	Researcher
A1	[1]	The Influence of PBL Models Assisted by Virtual Media on Physics Problem Solving Ability	Journal of Physics and Technology Education	Andriyani Hastuti, Hairunnisyah Sahidu, and Gunawan
A2	[2]	The Influence of Phet-Assisted Pbl Models on Physics Problem Solving Ability on the Main Materials of Elasticity and Hooke's Law of Class Xi Semester I SMA Muhammadiyah 18 Sunggal TP 2019/2020	Journal of Physicist Research	Irwan Susanto
A3	[3]	The Influence of the Problem Based Learning (Pbl) Learning Model on the Physics Problem Solving Ability of Students at SMA Negeri 11 Muaro Jambi	Physics and Science Education Journal (PSEJ)	Firmansyah, Sukarno, Nova Kafrita, and Salman Al Farisi
A4	(Physics Education Study FKIP Sriwijaya University Jl	The Influence of the Problem Based Learning Model on Students' Problem Solving Ability in Class Xi Physics Learning at SMA Negeri 1 Tanjung Lubuk	JOURNAL OF PHYSICS INNOVATION AND LEARNING	Emi Destianingsih, Abidin Pasaribu, and Ismet

	Palembang Prabumulih et al., nd)			
A5	(Swistoro and Eko Risdianto Page & Swistoro and Eko Risdianto, 2017)	The Influence of the Problem Based Learning (Pbl) Model on Learning Outcomes, Physics Problem Solving Ability and Students' Interest in Learning in Static Fluid Material at SMAN 1 Lebong Sakti	Journal of Physics Learning	Herlinda, Eko Swistoro and Eko Risdianto
A6	[6]	The Influence of the Problem-Based Learning Model on the Physics Problem Solving Ability and Scientific Attitude of Students at SMAN2 Bengkulu City	Journal of Coil Physics	Silvia Anggri Wijaya, Rosane Medriati, and Eko Swistoro
A7	[7]	Effectiveness of the Problem Based Learning Model with an Open Ended Approach on Physics Problem Solving Abilities in High School Students	Physics Learning Research Journal	C Umamah and H Jufri Andi
A8	(Science et al., 2014)	The Influence of the Problem Based Learning Model Accompanied by Phet Simulation on Science Process Skills and Physics Problem Solving Abilities in High School Topics: Temperature and Heat	Journal of Physics Learning	Sri Ayu Lestari, Bambang Supriadi, and Alex Harijanto
A9	[9]	The Influence of the Problem-Based Learning Model on Students' Physics Problem Solving Ability on Work and Energy Material	Journal of Physics and Technology Education (JPFT)	Izzatul Muna Aulia, Hikmawati, & Susilawati
A10	[10]	The Influence of the Problem-Based Learning Model Assisted by Mobile Pocket Book Physics on Students' Problem Solving Ability	Journal of Physics and Technology Education	Rindayu Noviatika, Gunawan, and Joni Rokhmat
A11	[11]	The Influence of the Problem Based Learning Model Assisted by the Canva Application on the Physics Problem Solving Ability of High School Students	Physics Learning Research Journal	AD Cintami, A Purwanto and Hamdani
A12	[12]	The Influence of the Problem Based Learning Model on the Physics	INNOVATIVE: Journal Of Social	Mellyana Manullang

		Problem Solving Ability of Rantau Utara 1 Public High School Students	Science Research	, Andriono Manalu , and Sudirman Togu P. Lumbangaol
A13	(Zahra et al., nd)	Application of the Problem Based Learning Model to Improve High School Students' Problem Solving Ability in Simple Harmonic Motion Material	VIDYA KARYA JOURNAL |	Ince Raudhiah Zahra, Benyamin Matius, and Abdul Hakim
A14	(Nursita , nd)	The Influence of the Problem-Based Learning Model on Newton's Law Problem Solving Ability in Class X Students of SMA Negeri 4 Palu	Journal of Tadulako Physics Education (JPFT)	Nursita, Darsikin, and Syamsu
A15	[15]	The Influence of Experiment-Assisted Problem Based Learning Models on Physics Problem Solving Ability on Quantities and Measurements	Educational Research Journal	Irwan Susanto
A16	[16]	The Influence of Problem-Based Learning on Concept Understanding and Problem Solving in Archimedes' Law Material	Education: Journal of Education	Rupus Kertinus, Yudi Darma, and Wahyudi
A17	(Rappel Situmorang and Awal Mulia Rejeki Tumanggor, 2016)	The Influence of the Problem Based Learning Model Using Macromedia Flash on Students' Problem Solving Ability in Static Fluid Subject Matter in Class XI Semester II SMA Negeri 11 Medan TP 2015/2016	*INPAFI (Physics Learning Innovation*	Rappel Situmorang and the Noble Beginning of Rejeki Tumanggor
A18	[18]	The Effect of Implementing Microsoft Teams on Students' Problem Solving Abilities Using the Problem Based Learning Model on Harmonious Vibration Material	Jambura Physics Journal	Indrawan Hermanto Abdjul, Mohamad Jahja, Abd Wahidin Nuayi, and Asri Arbie
A19	[19]	The Influence of the Problem Based Learning Model on the Physics Problem Solving Ability of Class X Students at SMK Negeri 1 Batang Angkola	JOURNAL OF NATURAL SCIENCE EDUCATION	Yeni Sara Rangkuti, Sri Utami Khoilla Mora Siregar, and Eni Sumanti Nasution
A20	(Sinaga &	Model Influence Problem Based Learning (Pbl) on	Journal of Physics Learning	Rafles Sinaga and Eidi

	Sihombing, nd)	Ability Problem Solving in Static Fluid Subject Matter At SMA Negeri 1 Silima Punggapungga	Innovation (INPAFI)	Sihombing
A21	[21]	The Effect of Problem Based Learning (PBL) Instruction on Students' Motivation and Problem Solving Skills of Physics	EURASIA Journal of Mathematics Science and Technology Education	Aweke Shishigu Argaw, Beyene Bashu Haile, Beyene Tesfaw Ayalew, Shiferaw Girlsa Kuma
A22	[22]	The Ability of Problem-based Learning (PBL) to Improve Problem-solving Skills on Hot Topic Among High School Students	ICITEP International Conference on Innovation and Teacher Professionalism	Aprilita Ekasari, Markus Diantoro, and Parno
A23	[23]	The Effect of STEM Approach in Problem-based Learning for Increasing Students' Problem Solving Ability in the Topic of Environmental Pollution	ICMScE International Conference On Mathematics And Science Education	Parno, Novida Pratiwi, Faizza Amaliah Putri, and Marlina Ali
A24	[24]	The Effect of Web-Assisted Problem Based Learning Model Towards Physics Problem Solving Ability of Class X Students	Journal of Physics: Conference Series	Rizky Nur Apriliasari
A25	[25]	Implementation Of Online Problem-Based Learning Assisted By Digital Book With 3d Animations To Improve Student's Physics Problem-Solving Skills In Magnetic Field Subject	Journal of Technology and Science Education	Binar Kurnia Prahani, Iqbal Ainur Rizki, Khoirun Nisa1, Nina Fajriyah Citra, Hanan Zaki Alhusni, Firmanul Catur Wibowo
A26	[26]	Approaching Problem-Solving Skills of Momentum and Impulse Phenomena Using Context and Problem-Based Learning	European Journal of Educational Research	Yuberti, Latifah, S., Anugrah, A., Saregar, A., Misbah, & Jermsittiparsert, K
A27	[27]	The Effect of Problem Based Learning (PBL) Model toward Student's Creative Thinking and Problem Solving Ability in	IOSR Journal of Research & Methods in Education (IOSR-	Roni Rohana Sihaloho, Sahyar, and Eva Marlina Ginting

Senior High School	JRME)

The articles are grouped based on material units and given article codes which are written in table 2.

Table 2. Based on Material Units

Article number	Article Code	Material Units
A1	M1	Mechanics (Momentum and Impulse)
A2	M2	Mechanics (Elasticity and Hook's Law)
A3		
A4	F1	Fluid (Static Fluid)
A5	F2	Fluid (Static Fluid)
A6	GO1	Optical Waves (Harmonic Vibrations)
A7		
A8	T1	Thermodynamics (Temperature and Heat)
A9	M3	Mechanics (Work and Energy)
A10	M4	Mechanics (Momentum and Impulse)
A11	F3	Fluid (Static Fluid)
A12	F4	Fluid (Static Fluid)
A13	GO2	Optical Waves (Simple Harmonic Motion)
A14	M5	Mechanics (Newton's Laws)
A15	M6	Mechanics (Quantities and Measurements)
A16	F5	Fluids (Archimedes' Law)
A17	F6	Fluid (Static Fluid)
A18	GO3	Optical Waves (Harmonic Vibrations)
A19	M7	Mechanics (Measurement of Quantities and Units)
A20	F7	Fluid (Static Fluid)
A21	LM1	Magnetic Electricity (Static Electricity)
A22	T2	Thermodynamics (Heat)
A23		
A24	GO4	Optical Waves (Harmonic Vibrations)
A25	LM2	Magnetic Electricity (Magnetic Field)
A26	M8	Mechanics (Momentum and Impulse)
A27	T3	Thermodynamics (Temperature and Heat)

As for the grouping of articles based on grade level, below are the articles written in table 3.

Table 3. Based on Class Level

Article number	Article Code	Grade Level
A1	M1	Class X
A2	M2	Class XI
A3		Class XI
A4	F1	Class XI
A5	F2	Class XI
A6	GO1	Class X
A7		Class XI

A8	T1	Class XI
A9	M3	Class X
A10	M4	Class X
A11	F3	Class XI
A12	F4	Class X
A13	GO2	Class XI
A14	M5	Class X
A15	M6	Class X
A16	F5	Class XI
A17	F6	Class XI
A18	GO3	Class XI
A19	M7	Class X
A20	F7	Class XI
A21	LM1	Class XII
A22	T2	Class X
A23		Class X
A24	GO4	Class X
A25	LM2	Class XI
A26	M8	Class XI
A27	T3	Class X

To determine the effect size (ES) value for each article above, you can use the following equation.

Table 4. Effect Size Value Formula.

No	Data Collection Method	Effect Size Formula
1	Average in one group	$\frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$
2	*Two groups posttest only*	$\frac{\bar{x}_E - \bar{x}_c}{SD_c}$
3	t count	$ES = t_h \sqrt{\frac{1}{n_E} + \frac{1}{n_c}}$
4	Chi-square	$ES = \frac{2r}{\sqrt{1 - r^2}}; r = \sqrt{\frac{\chi^2}{n}}$
5	*Two group pre-post tests*	$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})_E - (\bar{x}_{post} - \bar{x}_{pre})_c}{SD_{preC} + SD_{preE} + SD_{postC}}$

The effect size value criteria in table 5 are grouped as written in table 5.

Table 5. Groups of Effect Size Values

Range Effect Size	Effect Size Value Criteria
ES ≤ 0.15	Very low
0.15 < ES ≤ 0.40	Small
0.40 < ES ≤ 0.75	Currently
0.75 < ES ≤ 1.10	Tall

ES > 1.10	Very high

[28]

III. RESULTS AND DISCUSSION

Based on a search for articles that were in accordance with the research objectives of the PBL (problem based learning) learning model, 27 articles were obtained. Following are the details of the Effect Size category for each article in table 6:

Table 6. Effect Size Value for Each Article

No	Article Code	*Effect Size*	Effect Size Criteria
1	A12	3.45	Very high
2	A18	2.63	
3	A16	2.44	
4	A11	2.11	
5	A25	1.96	
6	A13	1.96	
7	A22	1.66	
8	A10	1.53	
9	A8	1.41	
10	A24	1,2	
11	A3	1.19	
12	A17	1.18	
13	A27	1.14	
14	A15	0.99	
15	A4	0.95	
16	A6	0.86	Tall
17	A9	0.86	
18	A14	0.85	
19	A2	0.79	
20	A23	0.78	
21	A7	0.77	
22	A26	0.69	
23	A5	0.66	Currently
24	A19	0.58	
25	A1	0.41	
26	A21	0, 28	Low
27	A20	0.19	

From the effect size calculations for 27 articles regarding problem based learning, the average was 1.24 in the very high category, and the highest effect size was in the 12th article, namely 3.45. Based on these results, increasing students' problem solving abilities is influenced by the use of problem-based learning models.

Then the 27 existing articles were also grouped into effect sizes based on learning material that used the PBL model. The following is the explanation in table 7:

Table 7. Effect Size Values Based on Material Units

No	Material Units	Number of Articles	*Effect Size*	Category
1	Mechanics	8	0.83	Tall
2	Magnetic Electricity	2	1.12	Very high
3	Waves and Optics	4	1.66	Very high
4	Thermodynamics	3	1.41	Very high
5	Fluid	7	1.56	Very high

Based on the table, the material used greatly influences students' skills when implementing the PBL model in learning, but not all learning material can be applied in a model. In calculating the effect size, the optical wave material unit has the highest effect size value, with a value of 1.66 in the very high category compared to other material units. It can be concluded that the optical wave material unit is an appropriate material unit when using the PBL model and can improve students' skills in solving problems.

Furthermore, the 27 articles collected were also differentiated based on the class level where the PBL (problem based learning) learning model was applied. The following is the effect size calculation based on class level in table 8:

Table 8. Effect Size Value Based on Class Level

No	**Class**	**Number of Articles**	***Effect Size***	**Category**
1	X	12	1.19	Very high
2	XI	14	1.35	Very high
3	XII	1	0.28	Low

Dividing the articles based on class level, it was found that the class level where problem based learning was most widely applied was in class XI the effect size value was 1.35 in the very high category, in class X the value was 1.19 in the very high category and in class

IV. CONCLUSION

The average impact size in the very high category, based on research utilizing the meta analysis method on 27 articles with the same variables, 1.24 in the very high category. grouping articles according to material units produced an average effect size of 1.31. Optical waves, with an effect size of 1.66 in the very high category, are the unit of material with the biggest effect size. These findings demonstrate that the greatest impact on the optical waves material unit is achieved through the application of the problem-based learning paradigm, which enhances students' problem-solving skills.

In the high category, class-based article grouping produced an average impact size of 0.94. Class XI had the highest effect size results, ranking in the very high category with an impact size of 1.35. These findings indicate that the class XI level is where the use of the problem-based learning paradigm has the most impact on students' problem-solving skills.

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