JPPIPA 9(4) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect of Problem-Based Learning Model on Students' Physics Problem Solving Ability: A Meta-Analysis

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Received: February 27, 2023
Revised: April 26, 2023
Accepted: April 29, 2023
Published: April 30, 2023

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DOI: 10.29303/jppipa.v9i4.3291

Abstract: In the 21st century, the improvement of science and technology leads humans to master various skills, one of which is problem solving. Physics learning can be one of the means in improving students' problem-solving ability (PSA). The purposes of this research are determine the effect of PBL model on students' physics PSA, determine the effect of PBL model on students' physics PSA based on subject matter, and determine the effect of PBL model on students' physics PSA based on teaching materials. This research is a meta-analysis by analysing 17 articles from national journals indexed at least Sinta 4 and international journals or proceedings. The results showed that there is an effect of PBL model on the ability to solve physics problems of students as a whole equal to 1.985 with a very high category. Based on the subject matter, the most effective effect of PBL on PSA is on temperature and heat material which is 4.135 with a very high category. In the material of effort and energy, the influence of PBL on PSA is the lowest compared to other materials with an effect size value of 0.365. While based on teaching materials, the effect of PBL on physics PSA is low with an effect size of 0.315. Digital teaching materials are the best teaching materials applied in PBL learning to improve students' physics PSA.

Keywords: Meta-analysis; Problem-based learning model; Problem-solving ability.

Introduction

Human life today has entered the 21st century. In this century, the improvement of science and technology is growing rapidly (Rahmatullah et al., 2022). This has an impact on various activities carried out by humans always in tandem with science and technology (Santi et al., 2022). This development must be followed by an increase in human resources (Niati et al., 2019). Excellent human resources are needed to face the current era of digitalization (Sabrina, 2021). To realize superior human beings, education has an important role in it because education is a means of creating quality human resources that become valuable assets for a nation (Akbar, 2021; Ningsi & Iskandar, 2023).

In relation to the 21st century, education has a great responsibility in preparing and realizing superior generations to be able to compete globally by having the abilities required in this era (Afifah et al., 2022; Mairizwan et al., 2022; Rahayu & Muhtar, 2022). So that the education system that is organized refers to efforts to improve the skills of students needed to face the challenges of this century.

According to (Zubaidah, 2019) to adjust and adapt to today's very dynamic developments, students must master several skills including communication and collaboration, problem solving, creative and innovative and critical thinking. Based on this, one of the skills that is the standard of competence of graduates in Indonesia is problem solving ability (PSA). Problem solving is a person's ability to find solutions to the problems they face through obtaining and organising information based on their understanding and knowledge (Koswara et al., 2019; Susanti et al., 2021). Problem solving is closely related to life because in real life, students will find problems that require the ability to find solutions as a way out, especially those related to physics concepts (Samani & Pan, 2021; Yuberti et al., 2020).

Problem solving has 4 stages according to Polya's procedure, namely recognizing or understanding the problem, developing a solution plan, implementing the plan, and checking back (Simpol et al., 2018). Learning

How to Cite:
Dewi, W.S., Siregar, R., Putra, A., & Hidayati, H. (2023). The Effect of Problem-Based Learning Model on Students' Physics Problem Solving Ability: A Meta-Analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 2103–2109. https://doi.org/10.29303/jppipa.v9i4.3291

that starts with problems and ends with problem solving is a feature of 21st century learning (Astuti, 2019).

Physics has a big role in the advancement of science and technology. It is inseparable from physics which is close to real life. Almost every aspect of human life is closely related to the concept of physics (Sari et al., 2021). According to Yuniani et al. (2019) physics learning aims to improve critical thinking and ability to solve problems, communication, collaboration, and creativity and innovation. Another opinion assumes that the purpose of learning physics in school is to get ready people who have life aptitudes as people and citizens who are critical, creative, analytical, logical, able to unravel issues and have communication aptitudes, autonomous and have a sense of obligation for social life in society (Hidaayatullaah et al., 2020).

The facts in the field do not fully illustrate the ideal physics learning conditions. Studies conducted by Aulia et al. (2022) found several physics learning problems, namely the lack of active students in physics learning due to the physics paradigm that is difficult, the lack of mastery of students' physics material, and the role of teachers who are more active than students. The problem with physics learning is the lack of exploration of solving skills so that students do not have good skills in solving problems (Umamah & Andi, 2020).

Wardani et al. (2021) also revealed that many students are passive, indifferent, and do not care about the physics learning process which marks the weak problem-solving ability of students. Simarmata & Sirait (2019) observation of physics learning in their research found that 54% of students could not identify problems, 33% of students could identify problems but could not solve problems and others could identify and solve problems.

Various parties have offered solutions to this situation. Among them through the implementation of other learning models. One of the them that improve the ability to solve problems for students is the problem based learning or PBL model (Hidayati & Wagiran, 2020). The PBL model is a model that can be used in learning with the characteristics of giving students to learn to prioritize using the scientific method in solving problems so that they have knowledge of the problem and skills in solving problems Jiniarti in (Aripin et al., 2021).

There have been many studies conducted to reveal the application of the PBL may be a solution in overcoming the physics PSA of students. Research by Sihaloho et al., (2017) shows that there is an effect of applying a PBL model on physics PSA of students. The same thing is also found in the research of Sahyar & Noveri (2017) which reveals that the PSA of students is more influential using the PBL model than the conventional model.

This research uses meta-analysis to summarize research results from studies with the same topic. This research study is the effect of PBL model on students' physics PSA. The level of education chosen in this study is senior high school. By doing this meta-analysis it will be very useful to get more detailed information, because the meta-analysis aims to summarize some of the results about the effect of PBL models on students' physics PSA and the extent of the relationship between variables in the research conducted.

Meta-analysis research was chosen as a method in this study for several reasons. First, there has been no meta-analysis research on the effect of PBL model on students' physics PSA using journal articles accredited nationally at least sinta 4 and journal articles or proceedings accredited internationally. Second, to determine the effect of PBL model on physics PSA of students based on statistical data. Third, meta-analysis produces a summary of experimental research that is not possible in various schools spread in several places. Therefore, meta-analysis is a research method that can obtain a broad overview of various research results on a research topic.

Meta analysis is research using studies that have existed before and used by other researchers in their research systematically and quantitatively. So that Meta analysis is a quantitative research method by analyzing relevant research data to get an accurate conclusion (Retnawati et al., 2018). According to Glass in (Nugroho et al., 2020) there are several steps in meta-analysis, namely: 1) determine the study domain to be analyzed 2) select the publication criteria to be used 3) collect study results 4) record information on study results 5) determine the effect size of the overall study results. Effect size is a quantitative number to summarize research results in meta-analysis. Effect size is a statistical number that describes how strong the relationship between variables in research is. The choice of effect size number depends on the type of data a study chooses (Retnawati et al., 2018).

The objectives of this study are determine the effect of the PBL model on students' physics PSA as a whole, based on subject matter and teaching materials.

Method

This research is a meta-analysis study using a quantitative approach. Meta-analysis research is research that combines secondary data in the form of previous research. Meta-analysis research is often referred to as meta research which uses articles as its data source. Meta analysis is quantitative research because in this study using numbers to organize and extract information from the data found and it is impossible to solve by other methods.

This study used 3 research variables, namely: independent variable is PBL model, dependent variable is physics PSA, moderator variable is subject matter and teaching materials. This research uses articles found in national and international journals or proceedings. After conducting a search to get the articles needed in this study, the articles that will be used are those that meet the predetermined criteria. The articles used in the research are the latest published articles in accredited national journals of at least Sinta 4 and international journals or proceedings with a time span between 2016-2022 (the last 6 years). This research procedure can be seen in Figure 1.

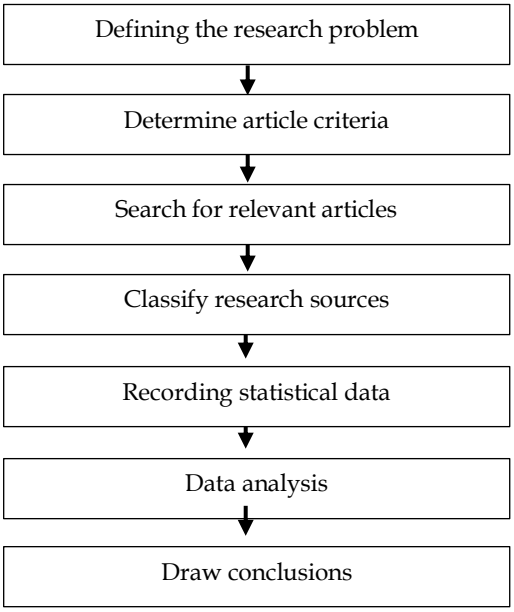

Figure 1. Procedure Of Research

Data analysis used effect size calculation techniques for each article using Cohen's equation and summarized the results of the study using the fixed effect model and random effect model. Interpretation of effect size using interval analysis in Table 1 (Davison & Smith, 2018).

Table 1. Interpretation of the Effect Size Value

ES	Category
$ES \leq 0.15$	Negligible
$0.15 < ES \leq 0.40$	Low
$0.40 < Es \leq 0.75$	Medium
$0.75 < Es \leq 1.10$	High
$Es > 1.10$	Very high

Result and Discussion

After searching for primary data, a total of 17 articles that met the criteria were obtained. Furthermore, the statistical data of each article was processed to be used as research results. Statistical data were processed to obtain the effect size. The results of the calculation of each study were used to calculate the summary effect size. The results of the calculation of the effect size of each article can be seen in Table 2.

Table 2. Effect Size of Each Article

Article Code	Effect Size	Category
J 1	4.407	Very High
J 2	8.276	Very High
J 3	1.175	Very High
J 4	0.691	Medium
J 5	0.169	Low
J 6	0.652	Medium
J 7	0.833	High
J 8	8.647	Very High
J 9	0.985	High
J 10	0.339	Low
J 11	3.170	Very High
J 12	0.370	Low
J 13	1.517	Very High
J 14	3.783	Very High
J 15	0.939	High
J 16	1.795	Very High
J 17	1.232	Very High

These results show the effect size of the PBL model's influence on students' physics PSA for each study. The effect size value is the hedge's value obtained through the correction factor. The distribution of the data varies from low to very high categories.

From this distribution, it can be seen that almost all articles are in the high to very high category effect size. For the very high category, there are 9 articles in that category. The very high category is the most article effect size category with a percentage of 52.94%. The high and low categories are the second most article categories with a percentage of 17.65% or the number of articles each, namely 3 articles. While the low category there are 2 articles or 11.76% with the effect size of the category.

The number of articles in the high to very high category indicates the impact of the PBL model on students' physics PSA. However, the overall effect size cannot be determined through the average of all articles. This is because the overall population of articles needs to be tested whether it is uniform or varied. In obtaining the overall effect size value, then the calculation of the summary is something that is done with a fixed effect model or random effect model. The implementation effect of PBL model on PSA as shown in Table 3.

Table 3. Summary effect size of the effect of PBL model on students' physics PSA

N	(M^*)	SE^*_M	Category	P	$\alpha = 0{,}05$	
					Lower	Upper
17	1.985	0.335	Very High	0.000	1.328	2.642

The results of data processing in table 3 show that the implementation effect of the PBL model on students' physics PSA has an effect size of 1.985 in the very high category based on Cohen's size. The lower limit value is

at 1.328 and the upper limit is 2.642. The range is in the very high category, the p-value test value obtained is 0 and the 95% confidence interval, p < α so that h_0 is rejected. Rejection of h_0 means that there is an effect of PBL model on students' physics PSA.

This shows that the effect of PBL model is very high in progressing physics PSA. This is same the results of research conducted by Kertinus et al., (2019); Sahyar & Yulia Fitri, (2017), namely there is an increase in the physics PSA of students after the implementation of the PBL model. Another study by Sahyar & Noveri (2017) which states that there is a noteworthy distinction between class of experiment by the PBL model and class of control by the conventional model.

So that PBL has a syntax that is the PBL model is very suitable for use in improving students' physics PSA identical to the problem so that the application of PBL will greatly assist teachers in improving students' physics problem solving skills (Santyasa et al., 2019).

The second result of this research shows the PBL model on students' physics PSA based on subject matter. Analysis of the subject matter of 17 articles obtained 8 materials identified. Of the eight materials, only 5 materials meet the criteria so that the calculation of summary effect size can be calculated. The following is the summary of the implementation effect of PBL model on students' physics PSA based on subject matter as in Table 4.

Table 4. Summary effect size based on subject matter

Lesson Materials	N	M^*	SE_M^*	P	$\alpha = 0{,}05$	
					Lower	Upper
Momentum and impulse	4	2.758	0.722	0.000	1.343	3.173
Simple Harmonic Vibration	2	0.650	0.503	0.1	-0.949	2.845
Temperature and Heat	2	4.315	1.391	0.000	1.589	7.041
Static Fluid	2	2.226	1.077	0.02	-0.027	4.6
Effort and Energy	2	0.365	0.429	0.2	-0.461	1.201

From table 4 regarding the summary of the effect size of each subject matter, it is found that the range of each material is different. The smallest effect size summary is in the material of effort and energy while the largest is in the material of temperature and heat.

The summary effect size of the implementation effect of the PBL model on students' physics PSA on temperature and heat material is 4.315 with a very high category. The lower limit value obtained is 1.589 and the upper limit is 7.041 with a very high category. If the confidence interval used is 95% and based on the p-value test value obtained a value of 0 so that the p-value < α means h_0 is rejected, thus there is an effect of PBL models on students' physics PSA on temperature and heat material.

These results are based on research conducted by Ekasari et al., (2018) that physics PSA on temperature and heat material can be done with 4 topics, namely expansion of substances, the effect of heat on changes in form, black principle, and heat transfer. The results of another study by Sihaloho et al., (2017) showed that in temperature and heat material there was a significant distinction in physics PSA between the implementation of the PBL model and the conventional model.

Summary effect size of the implementation effect of PBL model on students' physics PSA on effort and energy material is 0.365 with a low category. The lower limit value obtained is -0.476 and the upper limit is 0.851. If the confidence interval used is 95% and based on the p-value test value obtained 0.2 so that the p-value > α means h_0 is accepted or in other words there is no effect of the PBL model on the physics PSA of students on the material of effort and energy. This can be viewed from the low summary effect size value of effort and energy material of 0.365 in the low category.

These results are an analysis of two previous studies which state that the application of the PBL model is a solution in honing students' PSA on effort and energy material. However, compared to other physics materials, the PBL model has the lowest effectiveness compared to other models (Halim et al., 2021; Aulia et al., 2022).

The third research result is the summary effect size of the implementation effect of PBL model on students' physics PSA based on teaching materials. Based on the results of data analysis, 4 teaching materials were obtained that were classified as moderator variables. The four teaching materials are digital teaching materials. The distribution of these teaching materials as shown in Table 5.

Table 5. Summary effect size based on teaching materials.

Teaching Materials	N	M^*	SE_M^*	P	$\alpha = 0{,}05$	
					Lower	Upper
Digital	4	0.331	0.212	0.06	-0.085	0.747

Summary effect size of the implementation effect of the PBL model on the physics PSA of students based on teaching materials, namely digital teaching materials of 0.331 with a low category. The lower limit value obtained is -0.085 and the upper limit is 0.747. If the confidence interval used is 95% and based on the p-value test value obtained 0.6, the p-value> α means that h_0 is accepted, thus there is no effect of the PBL model on the physics PSA of students on teaching materials by digital.

The third result shows no effect on the teaching materials used, namely digital teaching materials. Based on the summary effect size of the implementation effect

of the PBL model on the physics PSA of students based on teaching materials of 0.331 in the low category. This means that in PBL the role of teaching materials is not too dominant. Of the four teaching materials obtained are digital teaching materials. This means that problem solving will be more effective by using digital teaching materials because using it will help teachers visualize problems to students in the form of images, literature, and illustrations (Apriliasari et al., 2019; Noviatika et al., 2019; Simanjuntak et al., 2021).

This result is supported by other studies that digital learning on physics problem solving ability obtained a low level of effectiveness. This is because physics learning cannot be done without directly involving real life for students (Nadhifah et al., 2021).

Conclusion

Based on the research, it can be concluded that the effect of PBL model on students' physics PSA as a whole is 1.985 with a very high category. The effect of PBL model on physics PSA of students based on subject matter, giving the most effective effect on temperature and heat material unit of 4.135 with very high category. The effect of PBL model on students' physics PSA based on teaching materials is 0.315 with a low category.

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