# The Effect of Project Based Learning (PjBL) on Physics Learning: A Meta-Analysis

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***Abstract*** *- Ideally education should prepare students to be able to face challenges in the future. The physics learning process implemented by teachers in the classroom should be able to encourage the growth of 21st century skills in students. In reality, the learning process still uses conventional methods and teacher-centered, so that the ability of students is low. For this reason, PjBL is implemented to improve students' abilities in physics subjects. The purpose of this study is to analyze the influence of similar research that use PjBL. The type of research used is meta-analysis research with a quantitative approach. The results of this research are the first, namely the impact of similar research from PjBL which indicates that PjBL has a positive impact on physics learning. Second, based on grade level, similar study effects of PjBL showed that grade X had a more significant effect. Thirdly, based on the learning materials, the impact of similar studies of PjBL shows that the topic of simple harmonic motion has a significant impact. Fourth, based on the learning media that has a more significant effect on similar research, namely LKS media. Fifth, based on the aspects reviewed, the impact of similar studies of PjBL indicated that the aspect of problem-solving ability has a more significant impact. This research can be used as a reference to develop PjBL at school levels, different materials, various interactive media, and aspects reviewed.*

***Keywords****: Meta-analysis; Project Based Learning; Physics Learning*

## INTRODUCTION

Ideally education should prepare students to be able to face challenges in the future. In this connection, education and learning system should always be refined according to the needs of the times. Likewise with physics learning. Physics learning at school has a central role in equipping students with 21st century skills (Jayadi et al., 2020). The physics learning process applied by teachers in the classroom must stimulate the growth of 21st century skills in students, namely critical thinking skills, creative, innovative, collaboration and communication skills. Based on this, physics learning process must be modified in ways that give freedom to students to actively choose and explore all learning resources. So that learning can run more fun and learning outcomes can be achieved better.

The reality found by previous researchers shows that students' abilities in learning physics are still low (Nurfa & Nana, 2020; Yunus et al., 2016) and the scores obtained are still below the KKM (Yance et al., 2013). It is because the physics learning process that happens still uses conventional methods or the lecture method (Nurfa & Nana, 2020; Turnip & Sinaga, 2016; Manik & Syahwin, 2018; Khoiri et al., 2016). Another researchers found that in learning physics the learning process is still dominated by the teacher (Permata, et al., 2018), the learning model applied by the teacher is not appropriate (Suranti et al., 2016) and has not been effective (Roziqin et al., 2018 ), and there are also teachers who do not use any learning model (Asra, 2018). This certainly causes the abilities possessed by students to be low. Responding to this

problem, the previous researcher said that the PjBL is a good solution to overcome this problem.

The PjBL is a learning method that has been developed in many developed countries such as the United States. The PjBL is a more innovative learning method that focuses on contextual learning with complex activities. The PjBL is a learning method that gives learners the freedom to plan learning activities, conduct projects collaboratively, and develop work products that will be presented to others (Mahendra, 2017). The PjBL is an innovative learning where the learning process is student centered and sets the teacher as a facilitator and motivator (Al-Tabany, 2014). According to Daryanto (2014), the PjBL has the advantages of increasing motivation, improving problem-solving skills, increasing collaboration, improving resource management skills, improving students' skills in managing learning resources, encouraging students to develop and practice communication skills, providing learning experiences that involve students that are more complex and designed to develop in accordance with the reality, and making learning fun.

The research results previously conducted have limitations. The limitations are, 1) the results have not explained how much influence the PjBL in physics learning, 2) only applying PjBL model in one grade level, 3) only using one learning material that applies PjBL model, 4) only applying PjBL model assisted by one learning media, 5) only reviewing one aspect of ability. According to these limitations, the researcher aims to integrate all existing relevant research to see the impact of PjBL model in physics learning using meta-analysis method.

Meta-analysis is a statistical method for merging quantitative results from several studies to summarize the overall empirical knowledge on a specific topic. Meta-analysis is used in analyzing central tendencies and variations in study outcomes, and correcting errors and biases in research (Littell et al., 2018). Meta-analysis is able to solve various problems of different research findings or hard to collect, and finally becomes more systematic with the existence of meta-analysis. Meta-analysis provides findings in the form of an effect size which is then used to obtain a summary effect size value.

Meta-analysis research was selected as the research method for some reasons. First, there have been many articles that discuss the impact of PjBL in physics learning. Second, no research on the influence of similar studies on PjBL in physics learning. Third, it is unknown which influence of similar research on PjBL in physics learning has a significant influence based on grade level, learning materials, learning media, and aspects reviewed. In this case, many researchers have verified it, but produced different conclusions.

This research paper analyzes the impact of PjBL on physics learning as a whole. In addition, this research paper will describe the impact of PjBL in physics learning based on grade level, learning materials, learning media, and reviewed aspects included research limitations and research implications for future research.

## RESEARCH METHODS

The method used is a meta-analysis with a quantitative approach. This research examines some similar articles from national and international journals. The criteria for the articles analyzed are the latest published articles in the range of 2013 to 2022, have information that complements meta-analysis such as independent variables, dependent variables and moderator variables, and there

is descriptive statistical information to determine effect size and summary effect size.

The variables in this research consisted of 3 types, namely independent variables, dependent variables and moderator variables. The independent variable in this research is PjBL. The dependent variable of this research is physics learning. Moderator variables used in this research are based on grade level, learning materials, learning media and aspects reviewed.

**Table 1.** Effect Size Categories

| ES | Category |
|---|---|
| ES ≤ 0,15 | Ignore |
| 0,15 < ES ≤ 0,40 | Low |
| 0,40 < ES ≤ 0,75 | Medium |
| 0,75 < ES ≤ 1,10 | High |
| 1,10 < *ES* ≤ 1,45 | Very High |
| *ES* > 1,45 | Superlative |

The collected articles were categorized using meta-analysis techniques. The articles collected were searched online using the stages proposed by David B. Wilson and George A. Kalley (Komalasari et al., 2021), namely determining the problem or topic to be researched, specifying the period and article criteria used, collecting articles relating to the research topic, focusing the research, classifying each article obtained, collecting article data, and determining the effect size of each article. The data processing technique used to calculate the effect size using the Cohen's d equation, and to calculate the summary effect size using the random effect model and the fixed effect model. Effect size is interpreted according to the following categories (Dincer, 2015) (Table 1).

## RESULTS AND DISCUSSION

### Results

#### *Analysis of the effect of similar research on physics learning*

According to the results of heterogeneity testing, it is found that the random effect model is most appropriate for calculating the summary effect size of the influence of the project-based learning model on physics learning. The calculation of the summary effect size on students can be seen in Table 2 below.

Based on Table 2, the result was that the 23 articles used indicated that the project-based learning model had an influence on students' physics learning outcomes. The result of the summary effect size obtained is 1.544 which indicates that the PjBL is in the very high category, with a lower confidence interval of 1.011 and an upper confidence interval of 2.076. The hypothesis testing results show that the p value < a, which indicates that the H0 hypothesis testing is rejected. The rejected H0 result shows that there is an effect of PjBL on students' physics learning in general.

**Table 2.** Effect of Similar Research on Physics Learning for Students

| Article Code | $Y_i$ | $V_{Yi}$ | $T^2$ | $V_{Yi} + T^2$ | $W_i^*$ | $W_i^* Y_i$ |
|---|---|---|---|---|---|---|
| A1 | 0.69 | 0.06 | 1.39 | 1.45 | 0.69 | 0.48 |
| A2 | 0.58 | 0.06 | 1.39 | 1.45 | 0.69 | 0.40 |
| A3 | 0.55 | 0.06 | 1.39 | 1.45 | 0.69 | 0.38 |
| A4 | 0.69 | 0.07 | 1.39 | 1.46 | 0.68 | 0.47 |
| A5 | 0.69 | 0.07 | 1.39 | 1.46 | 0.68 | 0.47 |
| A6 | 0.64 | 0.10 | 1.39 | 1.49 | 0.67 | 0.43 |
| A7 | 0.79 | 0.04 | 1.39 | 1.43 | 0.70 | 0.55 |
| A8 | 2.22 | 0.10 | 1.39 | 1.49 | 0.67 | 1.49 |
| A9 | 0.00 | 0.03 | 1.39 | 1.42 | 0.71 | 0.00 |
| A10 | 53.46 | 51.07 | 1.39 | 52.46 | 0.02 | 1.02 |

| Article Code | $Y_i$ | $V_{Yi}$ | $T^2$ | $V_{Yi} + T^2$ | $W_i^*$ | $W_i^* Y_i$ |
|---|---|---|---|---|---|---|
| A11 | 3.58 | 0.25 | 1.39 | 1.64 | 0.61 | 2.19 |
| A12 | 224.09 | 836.96 | 1.39 | 838.35 | 0.00 | 0.27 |
| A13 | 46.99 | 36.83 | 1.39 | 38.22 | 0.03 | 1.23 |
| A14 | 0.79 | 0.04 | 1.39 | 1.43 | 0.70 | 0.55 |
| A15 | 1.02 | 0.06 | 1.39 | 1.45 | 0.69 | 0.70 |
| A16 | 0.31 | 0.08 | 1.39 | 1.47 | 0.68 | 0.21 |
| A17 | 1.78 | 0.11 | 1.39 | 1.50 | 0.67 | 1.19 |
| A18 | 1.38 | 0.06 | 1.39 | 1.45 | 0.69 | 0.95 |
| A19 | 2.56 | 0.13 | 1.39 | 1.52 | 0.66 | 1.68 |
| A20 | 2.44 | 0.06 | 1.39 | 1.45 | 0.69 | 1.68 |
| A21 | 0.00 | 0.03 | 1.39 | 1.42 | 0.71 | 0.00 |
| A22 | 4.63 | 0.37 | 1.39 | 1.76 | 0.57 | 2.64 |
| A23 | 2.92 | 0.12 | 1.39 | 1.51 | 0.66 | 1.93 |
| Total | | | | | 13.547 | 20.914 |
| M* | | | 1.544 | | | |
| SEM* | | | 0.272 | | | |
| LLM* | | | 1.011 | | | |
| ULM* | | | 2.076 | | | |
| Z* | | | 5.68 | | | |
| *p value* | | | 0.000 | | | |

***Analysis of the effect of similar research based on grade levels***

According to the results of the heterogeneity test, it can be explained that at 2 grade levels the Q value > df, then the estimate of the variance of the articles is quite large and heterogeneous. The appropriate model used at grade level is the random effect model. The summary effect size calculation can be viewed in Table 3 below.

**Table 3.** Effect of Similar Research Based on Grade Levels

| Grade Level | Article Code | $M^*$ | $SE_M$ | $LL_M$ | $UL_M$ | *P* |
|---|---|---|---|---|---|---|
| X | A2<br>A3<br>A4<br>A5<br>A7<br>A9<br>A10<br>A11<br>A12<br>A13<br>A15<br>A16<br>A19<br>A22 | 1.794 | 0.433 | 0.945 | 2.642 | 0.000 |
| XI | A1<br>A6<br>A8<br>A14<br>A17<br>A18<br>A20<br>A21<br>A23 | 1.410 | 0.330 | 0.763 | 2.057 | 0.000 |

Based on Table 3, it shows that both grade levels show an influence on students' physics learning. Class X shows that the effect of PjBL is in the very high category

because it has a summary effect size of 1.794, while class XI shows that the effect of PjBL is in the very high category because it has a summary effect size of 1.410. The results of testing the hypothesis at both grade levels show that the value of $p < a$, which shows that at both grade levels it influences student learning.

***Analysis of the effect of similar research based on learning materials***

The calculation of the summary effect size based on learning materials is carried out using 2 different models. 3 learning materials, namely static fluids, dynamic fluids, and work and energy using the random effect model. 9 other learning materials, namely optical devices, momentum and impulses, Bernoulli's law, elasticity and simple harmonic motion, Newton's law of gravity, dynamic electricity, harmonic motion, Kepler's law, and straight motion using the fixed effect model. The calculation summary effect size based on learning materials can be viewed in Table 4 below.

**Table 4.** Effect of Similar Research Based on Learning Materials

| Learning materials | Article Code | $M^*$ | $SE_M$ | $LL_M$ | $UL_M$ | *p* |
|---|---|---|---|---|---|---|
| Static Fluid | A8 | 1.780 | 0.420 | 0.957 | 2.604 | 0.000 |
| | A18 | | | | | |
| Dynamic Fluid | A1 | 1.564 | 0.879 | -0.158 | 3.286 | 0.038 |
| | A20 | | | | | |
| Work and Energy | A10 | 27.124 | 25.837 | -23.517 | 77.765 | 0.147 |
| | A17 | | | | | |
| Optics | A3 | 0.55 | 0.249 | 0.062 | 1.038 | 0.014 |
| Momentum and Impulse | A4 | 0.693 | 0.272 | 0.160 | 1.226 | 0.005 |
| Bernoulli's law | A21 | 0.000 | 0.167 | -0.328 | 0.328 | 0.500 |
| Elasticity and Simple Harmonic Motion | A6 | 0.644 | 0.316 | 0.024 | 1.264 | 0.021 |
| Newton's Laws About Gravity | A23 | 2.921 | 0.349 | 2.236 | 3.606 | 0.000 |
| Dynamic Electricity | A7 | 0.787 | 0.205 | 0.385 | 1.189 | 0.000 |
| Harmonic Motion | A11 | 3.583 | 0.497 | 2.609 | 4.557 | 0.000 |
| Kepler's law | A14 | 0.79 | 0.192 | 0.413 | 1.167 | 0.000 |
| Straight Motion | A16 | 0.309 | 0.285 | -0.249 | 0.867 | 0.138 |

Based on Table 4, it showed an effect on students' physics learning. The results of the summary effect size calculation show that there are 5 learning materials in the very high category, 2 learning materials in the high category, 3 learning materials in the medium category, 1 learning material in the low category, and 1 learning material in the negligible category. Testing the hypothesis obtained the result that 9 learning materials showed value of $p < a$, while the other 3 learning materials show value of $p > a$. The results of testing this hypothesis show that only 9 out of 12 learning materials that implement the PjBL have an impact on student learning.

***Analysis of the effect of similar research based on learning media***

The calculation of summary effect size based on learning media is done using fixed effect model, because the population is the same. The 4 learning media are virtual laboratory media, posters, aeromodelling, and worksheets. The calculation of summary effect size based on learning media can be seen in Table 5.

**Table 5.** Effect of Similar Research Based on Learning Media

| Learning Media | Article Code | M* | SE$_M$ | LL$_M$ | UL$_M$ | *P* |
|---|---|---|---|---|---|---|
| Virtual Lab | A3 | 0.55 | 0.249 | 0.062 | 1.038 | 0.014 |
| Poster | A19 | 2.56 | 0.366 | 1.843 | 3.277 | 0.000 |
| Aeromodelling | A21 | 0.000 | 0.167 | -0.328 | 0.328 | 0.500 |
| LKS | A22 | 4.629 | 0.605 | 3.443 | 5.815 | 0.000 |

Based on Table 5, it is known that 2 learning media are in the very high category, 1 learning media is in the medium category, and 1 learning media is in the negligible category. The hypothesis testing conducted on the four-learning media shows that the three-learning media have value $p < a$, while 1 other learning media has value $p > a$. The results of testing this hypothesis indicate that only 3 out of 4 learning media have an influence on students' physics learning when using the PjBL. The three-learning media are virtual laboratory media, posters and worksheets.

***Analysis of the effect of similar research based on the aspects reviewed***

According to the results of heterogeneity testing on the 5 aspects reviewed when implementing PjBL, the results shows that the Q value > df, then the estimation of the variance between articles is quite large and the data is heterogeneous. A suitable model is used to calculate the summary effect size for the four aspects, namely the random effect model. The other 3 aspects reviewed were not tested for heterogeneity because the population was the same, so the model that was suitable to use was the fixed effect model. The summary effect size calculation based on the aspects reviewed can be seen in Table 6 below.

Based on Table 6, it shows that 4 aspects reviewed are in the very high category, 1 aspect is in the high category, 1 aspect is in the medium category, and 2 aspects are in the low category. Hypothesis testing was carried out on the 8 aspects reviewed, giving the result that 6 aspects have value p < a, while the other 2 aspects have value p > a. Testing this hypothesis shows that of the 8 aspects, only 2 do not have an effect on students' physics learning when applying the PjBL.

**Table 6.** Effect of Similar Research Based on The Aspects Reviewed

| Aspects Reviewed | Article Code | M* | SE$_M$ | LL$_M$ | UL$_M$ | *P* |
|---|---|---|---|---|---|---|
| Learning outcomes | A6 | 2.338 | 0.605 | 1.152 | 3.524 | 0.000 |
| | A7 | | | | | |
| | A10 | | | | | |
| | A11 | | | | | |
| | A16 | | | | | |
| | A17 | | | | | |
| | A19 | | | | | |
| | A22 | | | | | |
| Critical Thinking Ability | A1 | 0.693 | 0.100 | 0.497 | 0.889 | 0.000 |
| | A2 | | | | | |
| | A4 | | | | | |
| Creative Thinking Ability | A8 | 1.657 | 0.865 | -0.039 | 3.353 | 0.027 |
| | A12 | | | | | |
| | A14 | | | | | |
| | A18 | | | | | |

| Aspects Reviewed | Article Code | M* | SEM | LLM | ULM | P |
|---|---|---|---|---|---|---|
| Concept Mastery | A3 / A21 | 0.244 | 0.273 | -0.291 | 0.779 | 0.187 |
| Interest in Learning | A5 / A9 | 0.309 | 0.341 | -0.360 | 0.978 | 0.184 |
| Problem Solving Skill | A20 / A23 | 2.620 | 0.230 | 2.168 | 3.071 | 0.000 |
| Science Process Skills | A13 | 46.987 | 6.069 | 35.092 | 58.882 | 0.000 |
| Communication Skills | A15 | 1.021 | 0.247 | 0.537 | 1.505 | 0.000 |

**Discussion**

Based on the results of testing the hypothesis on the PjBL, it shows that there is a positive and significant influence on learning physics. The summary effect size results show that the PjBL has a value of 1.544 and is included in the very high category. The PjBL has an impact on students' knowledge, because through the PjBL students are actively involved in the learning process, and students can develop their thinking and problem-solving skills. The results of this test are in line with those proposed that PjBL has a significant effect on students in the cognitive, affective and psychomotor domains (Yance et al., 2013). The results of other studies also state that the PjBL provides significant changes in physics learning (Turnip & Sinaga, 2016). This is also in line with other studies and indicates that PjBL has a positive effect on learning physics rather than when using conventional models (Yunus et al., 2016; Chasanah et al., 2016).

Based on Table 3 indicate that grade X has a greater effect on students' knowledge. The summary effect size of class X shows that the PjBL has an effect of 1.794 and is in a very high category. This shows that the implementation of the PjBL in grade X provides an increase in students' knowledge in learning physics. This is in line with the results of the research which states that the PjBL has a positive and significant impact when applied to grade X (Yunus et al., 2016; Asra, Azmi., 2018; Manik & Syahwin, 2018).

Based on Table 4, it shows that the PjBL which is applied to the material of harmonic motion has a more significant impact on students' knowledge. The summary effect size value for harmonic motion material is 3.583 and is in the very high category. This shows that in the material of harmonic motion students are more active in the learning process when the PjBL applied. The results of this study are in line with those conducted by Rosviana Manik and Syahwin (2018) which stated that by implementing the PjBL on harmonic motion material can improve student learning outcomes by 65.93%.

Based on Table 5, it shows that the PjBL gives a very good effect on students' knowledge when using LKS media. The effect value on LKS media shows 4.629 and is in the very high category. This shows that with the help of LKS media students become more active in exploring the learning process and produce higher knowledge than when using other media. The test results are in line with the results of the study which stated that there was a significant effect on the application of LKS-based the PjBL on the competence of knowledge, attitudes, and skills possessed by students (Sari et al., 2015).

Effect of similar research based on the aspects reviewed show that when the PjBL used to review aspects of problem solving ability produces an effect value of 2.620 and

is in the very high category. The results of this research are in line with other researchers who state that there is an influence the PjBL on students' problem-solving skills (Makrufi et al., 2018). The results of other research also state that the PjBL makes students' problem-solving abilities better (Dewi et al., 2017).

## CONCLUSION

Based on the results of the analysis conducted, five conclusions can be drawn from this study. First, the impact of similar research from PjBL which shows that PjBL has a significant impact in physics learning. Second, based on grade level, similar study effects of PjBL showed that grade X had a more significant impact. Thirdly, based on the learning material, the similar study effect of PjBL shows that the topic of simple harmonic motion has a significant impact. Fourth, based on the learning media that has a more significant impact on similar studies, namely LKS media. Fifth, based on the aspects reviewed, the effect of similar studies of PjBL shows that the aspect of problem-solving ability has a more significant impact. This research can be used as a reference to develop PjBL at school levels, different materials, various interactive media, and aspects reviewed.

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