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A Meta-Analysis Study: The Effect of Problem Based Learning Integrated with STEM on Learning Outcomes

Dola Suciana, Hartinawati, Inas Sausan, and Meliza

ABSTRACT

The purpose of this study was to determine the effect of problem-based learning integrated with STEM on learning outcome. In this study, reanalysis of the data from previous studies regarding the effect of the problem-based learning integrated with STEM on learning outcomes. This research used a systematic review method with quantitative techniques (meta-analysis). The results of previous studies related to the effect of the PBL integrated with STEM on learning outcomes that have been published in a journal were analyzed using meta-analysis techniques. The data were collected using an instrument in the form of a meta-analysis coding sheet. There are 21 articles analyzed. The technique used is to measure the value of the effect size from experimental results in these scientific articles. Based on the research that has been done, it is known that the PBL integrated with STEM has an effect on improving learning outcomes. This can be seen from the average effect size value of 1.28 with a high effect category. In addition, from the acquisition of this effect size value, it is known that PBL with STEM also has an effect on improving learning outcomes in terms of education levels (elementary school, junior high school, senior high school or college levels) and subjects (mathematics, chemistry, physics biology, science for elementary and junior high school). Based on this research, it can be concluded that the PBL integrated with STEM has an effect on improving student learning outcomes at various levels of education and various subjects.

Keywords: learning outcomes, problem-based learning, STEM.

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I. Introduction

Education is an important component in supporting the progress of a nation. The quality of good education is directly proportional to the improvement of the quality of its human resources, besides that education also plays an important role in determining the future direction of a nation. Currently the development of technology and science is happening so rapidly, especially when entering the era of the industrial revolution 4.0. Education in this era is very challenging for the teacher (Rachamtullah, 2020). Therefore. The Indonesian nation needs to prepare a good education for the next generation, so that they are not left behind and can compete with other nations in the world. This is in line with the mandate contained in the 1945 Constitution, which states that the Indonesian nation's national education in general aims to improve the quality of its human resources. Based on the 2018 PISA score, it was found that the Indonesian state's PISA score was in a fairly alarming ranking, the State of Indonesia was ranked 74th, which puts it in the bottom six positions of all countries participating in the test. The higher order thinking skills of students are still relatively low and need to be improved (Hewi, 2020).

In improving higher order thinking skills, it can be done by implementing a student-centered learning process, as well as training thinking skills in dealing with various everyday problems. One of the learning models that can train student's problem-solving skills is the problem-based learning (PBL) model (Birgili, 2015). Problem based learning model is a pedagogical approach based on problems. In this learning model the opportunity is given to students to have problem solve skill in collaborative setting (Yew, 2016). Students are introduced to a case or problem related to the learning material being studied, then students are asked to find solutions to these problems. In this PBL model, learning activities begin with giving a problem, then students identify the problem and determine its relationship to the learning material, then establish a hypothesis. Then after the identification process is complete, data collection, data processing, and then checking the truth of the hypotheses that have been formulated (Adiwiguna, 2019).

The application of the PBL learning model in the learning process is not only able to improve students' critical thinking skills, but can also increase students' creativity, communication skills, motivation, and social attitudes (Birgili, 2015). There are three types of learning contained in PBL, including cognitive, collaborative, and content learning. Cognitive learning is learning that focuses on the ability to

think critically, innovatively and creatively. Collaborative learning means learning that is focused on the skills to collaborate and communicate. Content learning is more focused on interdisciplinary knowledge such as STEM (science, technology, engineering, and mathematics) (Dotimineli, 2021).

The application of the PBL model in learning activities can be integrated with the STEM approach. This is because the PBL model has similarities with the STEM approach. The components contained in STEM namely science, technology, engineering and mathematics can be applied to learning activities with problem-based learning (Ramadhani, 2017). With this integration, it can not only improve students' critical thinking skills but also be able to improve scientific literacy skills and the character of students (Putri, 2020). Learning with the STEM approach means combining two or more fields of knowledge contained in STEM, namely science, technology, engineering and mathematics. This is because these four fields of science are an important foundation in the development of science and technology, so it is hoped that students will have the provision and readiness to face future world developments with the ability to think critically, innovatively, creatively and have the ability to collaborate and communicate (Winarni, 2016).

Utilization of PBL-STEM learning is not only able to support the learning process at the elementary and secondary levels, but it can also even be used for learning at the university level (Arikunto, 2010). The main purpose of implementing the STEM approach in the learning process is as an effort to demonstrate holistic knowledge between STEM subjects. Learning with the STEM approach can be said to be successful if there are all aspects of STEM in the learning process (Laisnima, 2020). The PBL-STEM-learning approach can have a great impact and benefit on students, including improving problem-solving skills, encouraging students to have inventors, innovators, increasing independence, logical thinking, being able to use technology well for their progress (Pourshanazari, 2013).

Based on previous research with the research title "Integration of STEM-problem based learning through online on the critical thinking skills of biology education students," shows that there is an effect of implementing the PBL model that is integrated with the STEM approach on learning outcomes and student's thinking skills. The application of the STEM-PBL model showed results in the form of increasing learning outcomes and students' critical thinking skills. This is because the PBL model with integrated STEM can help students master science and technology learning and students are required to be actively involved in solving the problems presented (Fadhilah *et al*., 2022).

In another study with the research title "problem-based learning in the covid-19 pandemic era to improve students' critical thinking skills," the results showed that by implementing the PBL-STEM based learning process there can increase student's learning outcomes and students' critical thinking skills. Students can design several tools related to problems in material and business subjects. In addition, students also have high enthusiasm for the implementation of PBL-STEM learning activities. This of course can make students more active during the learning process and familiarize them to be more creative, innovative, and critical in dealing with and solving problems (Putri *et al*., 2020).

From the background described above, this article will discuss a meta-analysis study of previous studies to see how much influence of the problem-based learning model integrated with STEM on learning outcomes.

II. Research Method

Meta-analysis research is a type of literature review research by combining two or more similar research results to obtain a quantitative blend of data. Based on the characteristics of the meta-analysis research, a search was carried out on articles with research results that were in accordance with the topics studied in this study, namely the influence of teaching materials with the STEM approach on learning outcomes. The search was conducted through Google Scholar, Portal Garuda, Science Direct and other journal provider sites available on the internet. Meta-analysis research requires calculation of effect sizes taken from learning outcomes data on the application of the problem-based learning models integrated with the STEM approach on learning outcomes, that has been studied by previous researchers in articles.

Coding sheets for meta-analytical research instruments are important in making it easier for researchers to collect and then analyze the data obtained. the variables used in coding will produce the information needed to calculate the effect of teaching materials with the STEM approach on learning outcomes in chemistry subjects, among the coding include the name of the researcher, the year of research, the title of the study, the education level of the research subject and others.

In the meta-analysis research procedure, the following steps are carried out:

1) The first step is for the researcher to determine and study the research theme to be summarized.
2) The second step, the researcher searches for and collects research with a predetermined theme and then makes a selection. Searching for sources or research literature can be done manually or through literature available on trusted and quality sources on the internet.
3) The third step, the researcher will calculate the effect size with the method in the meta-analysis.
4) The fourth step, researchers identify whether or not there is heterogeneity of the effect size in the model at this stage.
5) Concluding and interpreting the results of meta-analysis research. (DeCoster *et al*., 2009)

Analysis of meta-analysis research data is to measure the effect size of experimental data in scientific articles. The following is the statistical formula for processing effect size data in Table I.

The results of calculating Cohen's Effect Size values are interpreted with Cohen's criteria as follows in Table II.

TABLE I: CALCULATION OF EFFECT SIZE VALUE

Data Statistic	Equation
Mean and deviation standar 1 group	$\frac{\bar{x}\ postest - \bar{x}\ pretest}{SD\ pretest}$
Mean and deviation standar 2 postest group	$\frac{\bar{x}\ eksperiment - \bar{x}\ control}{SD\ control}$
Mean and deviation 2 postest-pretest group	$\frac{\left(\overline{x_{postest}} - \overline{x_{pretest}}\right)_{control} - \left(\overline{x_{postest}} - \overline{x_{pretest}}\right)_{eksperin}}{\frac{SD_{pretest\ control} + SD_{pretest\ eksperiment} + SD_{postes\ contro}}{3}}$
If given t value	$t\sqrt{\frac{1}{n\ eksperiment} + \frac{1}{n\ control}}$ n =number of samples

(Becker & Park, 2011).

TABLE II: INTERPRETATION OF EFFECT SIZE

Criteria	Interpretation
0–0.20	Very low effect
0.21–0.50	Low effect
0.51–1.00	Medium effect
>1.00	High effect

(Cohen *et al*., 2013).

III. RESULT

Based on the results of article selection from several websites, 21 articles were obtained. The article will be analyzed, and the effect size calculation will be carried out. The result of this research shows that the average effect size is 1.28, in the high category that is shown in Table III below.

The effect size of the influence of problem-based learning model integrated with STEM on learning outcomes seen from the level of education, including elementary, junior high school, senior high school and university, are shown in Table IV.

The next category to be analyzed is the influence of the PBL-STEM model on learning outcomes based on the subjects taught in schools/colleges. From the articles obtained, there are five groups of subjects, that is mathematics, chemistry, physics, biology, and science, are shown in Table V.

TABLE III: RECAPITULATION OF THE EFFECTS OF THE PBL-STEM ON LEARNING OUTCOMES

No	Author	Education Level	Subject	Effect Size Value	Category
1.	Inpinit, J., *et.al*. (2016)	Senior high school	Mathematic	1.25	High
2.	Putri, Y., *et.al*. (2021)	Senior high school	Physic	0.36	Low
3.	Fadhilah, N, *et.al*. (2022)	College Student	Biology	2.21	High
4.	Amalya, C, *et.al*. (2021)	Senior high school	Biology	0.21	Low
5.	Pratika, F., *et.al*. (2021)	Senior high school	Chemistry	0.31	Low
6.	Clarissa *et.al*. (2020)	Senior high school	Science	2.27	High
7.	Adiwiguna, P., *et.al*. (2019)	Elementary school	Science	0.69	Medium
8.	Mostafa, M., *et.al*. (2021)	Junior high school	Science	1.6	High
9.	Parno *et.al*. (2018)	Senior high school	Physic	1.75	High
10.	Kulsum, U., *et.al*. (2018)	Senior high school	Biology	1.71	High
11.	Yujun Lee *et.al*. (2019)	Junior high school	Mathematic	0.96	Medium
12.	Parno *et.al*. (2020)	Senior high school	Physic	1.92	High
13.	Hasanah, Z., *et.al*. (2021)	Senior high school	Biology	1.23	High
14.	Winda, Z., *et.al*. (2019)	College Student	Chemistry	1.84	High
15.	Ariyatun *et.al*. (2020)	Senior high school	Chemistry	0.85	Medium
16.	Nurazmi *et.al*. (2021)	Senior high school	Physic	2.9	High
17.	Ningsih, F., *et.al*. (2018)	Junior high school	Science	0.75	Medium
18.	Hadi, F., *et.al*., (2021)	Elementary School	Mathematic	0.69	Medium
19.	Umi, K., *et.al*. (2020)	Senior high school	Biology	1.72	High
20.	Hasanah, Z., *et.al*. (2021)	Senior high school	Biology	0.48	Low
21	Setyorini, A., *et.al*. (2021)	Junior high school	Science	1.31	High
	Mean of Effect size			1.28	High

TABLE IV: THE EFFECT OF THE PBLL-STEM ON LEARNING OUTCOMES BY EDUCATIONAL LEVEL

Level	Number of articles	Effect Size	Category
Elementary School	2	0.69	Medium
Junior High school	4	1.15	High
Senior High school	13	1.30	High
University	2	2.02	High

TABLE V: THE EFFECT OF THE PBL-STEM MODEL ON LEARNING OUTCOMES BASED ON SUBJECTS

Subject	Number of articles	Effect Size Value	Category
Mathematic	3	0.96	Medium
Chemistry	3	1.00	Medium
Physic	4	1.73	High
Biology	6	1.26	High
Science (For elementary school/junior high school)	5	1.32	High

IV. DISCUSSION

Based on the results of article selection from several websites, 21 articles were obtained. The article will be analyzed, and the effect size calculation will be carried out. The articles then analyzed based on 2 categories, the first is to see learning outcomes with the problem based learning model integrated with STEM based on education level (elementary school, junior high school, senior high school and college student), then the second category is to see the effect of the problem based learning model integrated with STEM on learning outcome seen from the subject (mathematic, chemistry, physic, and science for elementary and junior high school). The results of the effect size data described in the table above, show that there are 11 articles with high effect category, five articles are in the medium category, and four articles are in the low category. From the calculation, the average effect size value is 1.28 in the high category. This means that in general, from the 21 articles analyzed, the application of the STEM integrated problem-based learning model has a high influence on improving learning outcomes. This is in line with research conducted by Arifin, which states that the integration of STEM in the problem-based learning model has an effect on improving student learning outcomes because it improves problem-solving abilities (Arifin, 2020). In addition, the application of the STEM integrated problem-based learning model in learning activities is able to encourage students to be independent in learning activities and direct them to think more creatively (State, 2014). Problem-based learning is able to increase students' learning activities, so that learning outcomes or students' scientific attitudes also increase. The learning process that is integrated with the STEM approach is able to develop student skills in the 21st century which tends to continue to change (Anazifa, 2017). STEM makes learning more meaningful for students. The aspects contained in STEM namely Science, Technology, Engineering and Mathematics are a harmonious unity between problems that occur in the real world and problem-based learning (PBL). The collaboration of these two things certainly makes learning better (Selisne, 2019)

The articles studied are in the 2016–2022 range of the 21 articles collected, the most articles are in 2021 as many as 9 articles. While in 2017 the author has not been able to find an article about the effect of the problem-based learning model integrated with STEM on learning outcomes. The year of publication shows the update of research results and updates on the results of previous or ongoing research within the last 6 years. generally, there is an increase in the number of publications related to research effect of the problem-based learning model integrated with STEM on learning outcomes between 2016–2021, but in 2022 only a few studies have been found on the effect of the problem based learning model integrated with STEM on learning outcomes. The increasing number of publications indicates the importance of research related to the PBL-STEM learning model to be studied because it is so related to the 21st century skills need of students (Anazifa, 2017). PBL-STEM learning activities allow students to be able to develop their thinking skills to produce innovative solutions in problem solving. The following will describe effect size data based on several categories:

A. Effect of Problem Based Learning Model Integrated with STEM on Learning Outcomes on Education Level

Based on the articles that the author obtained, the most articles were found at the high school level with 13 articles, then junior high school with 4 articles, 2 articles for elementary school and also 2 articles for college. From the effect size value data, it is also known that the highest effect size value is university level, which is 2.02 with the high category, the senior high school level is 1.30 with the high category, the junior high school level is 1.15 with the high category and the elementary level is 0.69 with the medium category. These results indicate that learning by applying the STEM integrated problem-based learning model is good for application at the university level. This is because in this STEM integrated problem-based learning activity it requires critical thinking skills and high-level thinking to solve complex and global problems, this will be easy for students to carry out at the university level (Khoiri, 2019).

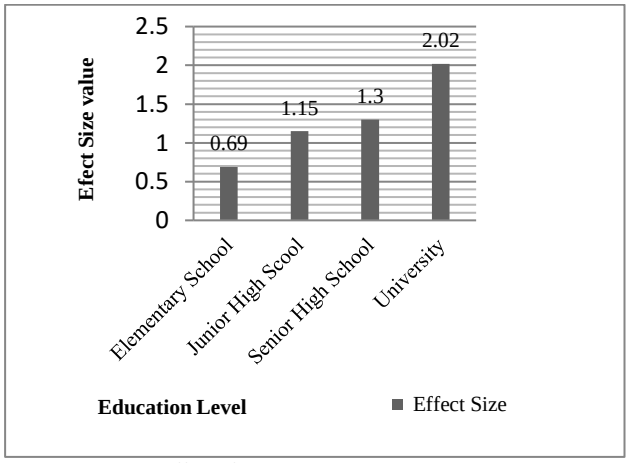

Fig.1. Graphic the Effect of PBL-STEM Model on Learning Outcomes Based on Educational Level.

From the Fig. 1 shown, it can be seen that at the junior high school, senior high school and college levels the average effect size value is in the high category, while at the elementary school level it is in the medium category. This is in line with the cognitive development of children, where a child who is at the junior high school, senior high school and university level is in the formal operational phase. According to Piaget's theory of cognitive development, this phase occurs at the age of 11 years until a person is an adult. At this stage a child will have the ability to think abstractly, perform mathematical calculations, and think creatively (Suralaga, 2010).

B. Effect of Problem Based Learning Model Integrated with STEM on Learning Outcomes Based on Subjects

Based on the data in the table above, it can be seen that the problem-based learning model integrated with STEM in physics subjects obtained the highest effect size value, that is 1.73 with a high effect size category. In biology, the effect size value is 1.26 with a high effect category, in chemistry the effect size value is 1.00 in the medium category, in science the effect size value is 1.32 in the high category. Meanwhile, in mathematics the effect size value is 1.23 in the medium category.

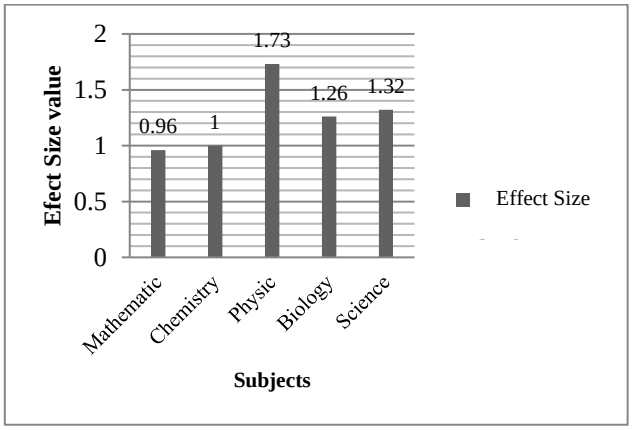

Fig. 2. Graph of the Effect PBL-STEM Model on Learning Outcomes Based on Subjects.

From the graph above, it can be seen that the effect size values obtained in each subject indicate that learning in the fields of science (chemistry, physics, biology and science) has higher effect size value than mathematics. This is in line with research conducted by Amin, 2022 which states that the STEM approach is most effective in the field of science focus. Learning in the field of science is a unity of facts, concepts, principles, procedures or theories, so that with the integration of STEM in learning activities, these aspects can be achieved properly (Usmeldi, 2019). Learning in the field of science using the STEM integrated PBL learning model will focus students on the problems that have been given so that students do not only learn concepts related to the given problem. But also understand the scientific method in solving existing problems. With the application of this scientific method can inadvertently improve the critical thinking skills of their students.

V. Conclusion

Based on a meta-analysis study conducted on 21 articles about the effect of the problem-based learning model integrated with STEM on learning outcomes, the results showed: 1) In general, from the 21 articles analyzed, the average effect size value was 1.28 with the high category. This means that the application of the problem-based learning model integrated with STEM has an effect on improving learning outcomes. 2) Based on the year of publication, the most articles regarding the application of the problem-based learning model integrated with STEM on learning activities at most in 2021, in general there was an increase in publications from 2016 to 2021. 3) Based on level of education of the 21 articles analyzed, the most articles were found at the senior high school level, the highest effect size value is at the university level, with the effect size value is 2.02 (high category) and the lowest is at the elementary school level with the effect size value is 0.69 (medium category). This shows that PBL-STEM learning is very suitable to be applied at the higher education level. 4) Based on the type of subject, it is known that from the 21 articles analyzed, the fields of science (chemistry, physics, biology, science) obtained a high effect size value compared to mathematics. The highest effect size value is in physics at 1.73 (high category) and the lowest is 0.96 in mathematics (medium category).

Conflict Of Interest

Authors declare that they do not have any conflict of Interest.

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