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Effectiveness of Problem-Based Learning Model in Science Learning: A Meta-Analysis Study

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Abstrak

This study aims to determine the effect and impact of the overall research on the Problem-based learning model in science learning. This type of research is a meta-analysis. The data sources in this study are 17 national and international journals published from 2017-2022. Searching for data sources through Google Scholar, ScienceDirect, Wiley, ProQuest, and Eric Journal. Inclusion criteria are research on problem-based learning models with experimental or quasi-experimental methods and measurement of learning outcomes to evaluate Problem-Based Learning learning models. The results showed that all studies' average effect size value (ES = 1.40) was very high. This finding explains that the Problem-Based Learning model provides a very high positive impact on science learning. In addition, the Problem-Based Learning learning model can effectively be applied to students' science learning at school. Effect measurement in this study is influenced by the level of education, year of publication, learning outcomes, and sample size. Overall, the Problem-Based Learning model is instrumental in increasing students' potential in facing the 21st century.

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INTRODUCTION

Science learning is a compulsory subject that must be mastered by students in facing the 21st century (Ulfa et al., 2017; Elfira et al., 2023; Razak et al.., 2021; Fradila et al., 2021; Oktarina et al., 2021). Science learning is essential for students to stimulate critical thinking skills (Rahman et al., 2023; Suharyat et al., 2022; Zulkifli et al., 2022). According to Rahayu et al. (2012), Science learning is a subject that studies phenomena about living and non-living things. In addition, science learning leads students to study themselves with the surrounding nature (Listyawati, 2016). In learning science, students must be able to develop scientific and systematic thinking skills in solving a problem (Suendarti & Virgana, 2022; Rahman et al., 2023; Suharyat et al., 2023; Santosa et al., 2021); however, students experience much control in science learning.

The results of the 2018 PISA survey (Sofianora et al., 2023; Ichsan et al., 2022); Supriyadi et al., 2023; Karim, 2023) show that Indonesian students' science learning is still low, only obtaining a score of 396, ranked 71 out of 78 members. The process of learning science at school still needs to be more active (Kusnandar, 2019; Aydede, 2022), so students are less interested in learning (Ferdyan et al., 2021). Taupik & Fitria (2021) stated that the teaching and learning process has yet to include students being active in learning. Students find it challenging to understand the science learning material provided by the teacher (Putri et al., 2018; Santosa et al., 2021; Ichsan et al., 2022; Santosa & Yulianti, 2020), The learning model is still conventional, and the learning process has not directed students to think scientifically (Ejin, 2017; Zulyusri et al., 2022; Santosa, 2021). Therefore, there is a need for a learning model that can improve the student learning process.

Problem-based learning is a learning model that involves students more actively in learning to solve a problem (Bayram & Deveci, 2022; Şenyiğit & Yüzüncü, 2021; Suharya et al., 2022; Putra et al., 2023; Murdiyah et al., 2020; Alfares, 2021). The problem-based learning model is a learning model that presents students with a problem and then directs students to solve the problem (Paradina et al., 2019; Mustofa & Hidayah, 2020; Suhirman & Yusuf, 2019). Problem-based learning model can increase students' independence in learning (Dewi et al., 2013; Zulyusri et al., 2022; Theabthueng et al., 2022). Research results by Kasuga et al. (2022) stated that the problem-based learning model encourages students to think critically and creatively in learning. In problem-based learning, students understand concepts and focus on solving problems (Phasa, 2020; Çeliker & Dere, 2022; Marthaliakirana et al., 2022).

Previous research by Yulianingtias et al. (2016) stated that the problem-based learning model can improve learning outcomes and problem-solving skills. Research results in Amin et al. (2020) The problem-based learning model can improve students' critical thinking skills and motivation in learning. Students with critical thinking skills will find it easier to understand concepts and learning content

(Rahman et al., 2023). Research results Montejo, (2019) problem based learning dapat mendorong kecerdasan emosional siswa dalam belajar sehingga siswa lebih percaya diri. Research oleh Saputro et al. (2020) Problem-based learning can increase students' confidence and critical thinking. Therefore, the problem-based learning model is one of the solutions to improve the quality of student learning. Based on the above problems, this study aims to determine the effect and impact of the whole research of the Problem-based learning model in science learning.

METHODS

This type of research is meta-analysis research. Meta-analysis reviews previous studies that can be statistically analyzed (Santosa et al., 2021; Suharyat et al., 2022; Yang et al., 2013; Wang & Wang, 2020). The data sources in this study came from 17 national and international journals published from 2017-2022. Search for data sources through Google Scholar, Eric, ScienceDirect, Wiley, and Taylor of Francis using the PRISMA method. According to Aslikhah Nurkamto (2019), The steps of meta-analysis in this study are 1) Determine and summarize the research topics to be studied; 2) collect research results according to the research topic; 3) Determine the effect size value of each article; 4) Draw meta-analysis conclusions.

Furthermore, the keywords for searching data sources are "problem-based learning," "science learning,"; "The Effect of Problem-Based Learning on Science Learning." Data analysis in this research is quantitative statistical analysis with JSAP application. In this research, meta-analysis calculates Effect Size (ES), Standard Deviation (SD), and mean value. Furthermore, the Effect Size criteria can be seen in (Table 1.)

Table 2. Kriteria *Effect Size*

Effect Size	Criteria
$0 \leq ES \leq 0.2$	Low
$0.02 \leq ES \leq 0.8$	Medium
$ES \geq 0.8$	Hight

source: (Perdana, 2021; Yang et al., 2013; Suastra et al., 2021)

FINDINGS AND DISCUSSION

Findings

The results of searching data sources from the Google Scholar, ScienceDirect, Wiley, ProQuest, and Eric databases obtained a total of 145 journals related to the effect of STEM-based e-learning on elementary, junior high, high school, and university students. However, 17 journals have met the inclusion criteria. The effect size value of each journal can be seen in Table 2.

Table 2. Overall Effect Size

No	Article Code	Year	Hedge's	Standard Error	Effect Size Criteria
1	J1	2020	0.77	0.29	Medium
2	J2	2020	1.03	0.63	Hight
3	*J3*	2022	0.54	0.21	Medium

4	J4	2020	0.61	0.39	Medium
5	J5	2022	1.29	0.79	Hight
6	J6	2017	0.91	0.41	Hight
7	J7	2020	0.72	0.32	Sedang
8	J8	2021	1.20	0.70	Hight
9	J9	2020	0.44	0.27	Small
10	J10	2022	0.81	0.49	Hight
11	J11	2022	0.71	0.31	Medium
12	J12	2021	0.80	0.42	Hight
13	J13	2019	1.10	0.62	Hight
14	J14	2018	0.69	0.48	Medium
15	J15	2020	1.35	0.53	Hight
16	J16	2018	0.60	0.28	Medium
17	J17	2022	0.84	0.33	Hight
Average Effect Size value				**0.828**	**Hight**

Based on Table 2. The average value of Effect Size (ES = 0.828) with high criteria shows. This explains that the problem-based learning model significantly affects student learning activities. The next stage is determining the effect size model by conducting a heterogeneity test. The results of the heterogeneity test can be seen in Table 3.

Table 3. Heterogeneity Test Results

Model	n	Hedge's g	Standard Error	95 % CL	Q	P	Keterangan
Fixed	17	0.923	0.068	[0.527;0.912]	52.20	0.00	H1 accepted
Random	17	0.949	0.372	[0.313; 1.623]			

Based on Table 3. Showing the value of the heterogeneity test ($Q = 52.20$; $p = 0.00 < 0.05$), the effect size in the study is heterogeneously distributed. These results explain that the meta-analysis model used in this study is a random effect model. The average effect size value is 0.828. This finding is analyzed based on Cohen's framework in (Table.1), then the Problem-Based Learning learning model positively impacts students' science learning activities with high criteria. Furthermore, it calculates the publication bias by using the Funnel Plot method. Funnel Plot analysis can be seen in Figure 1

Table 4. Rosenthal Fail-Safe N (FSN) test results

Classic Fail-Safe N	
Z-Value for observed studies	14.368
The P-value for observed studies	0.000
Alpha	0.050
Tails	2.000
Z for alpha	1.780
Number of observed studies	17
Number of missing studies that would bring p-value to > alpha	238.000

Figure 1. It shows the analysis results with the funnel plot method from 12 primary studies analyzed in the meta-analysis showing symmetrical effect size data, so it has a slight publication bias. Next, conduct the Rosenthal Fail-Safe N (FSN) test to determine the possibility of publication bias. The results of the Rosenthal Fail-Safe N (FSN) test can be seen in Table 4.

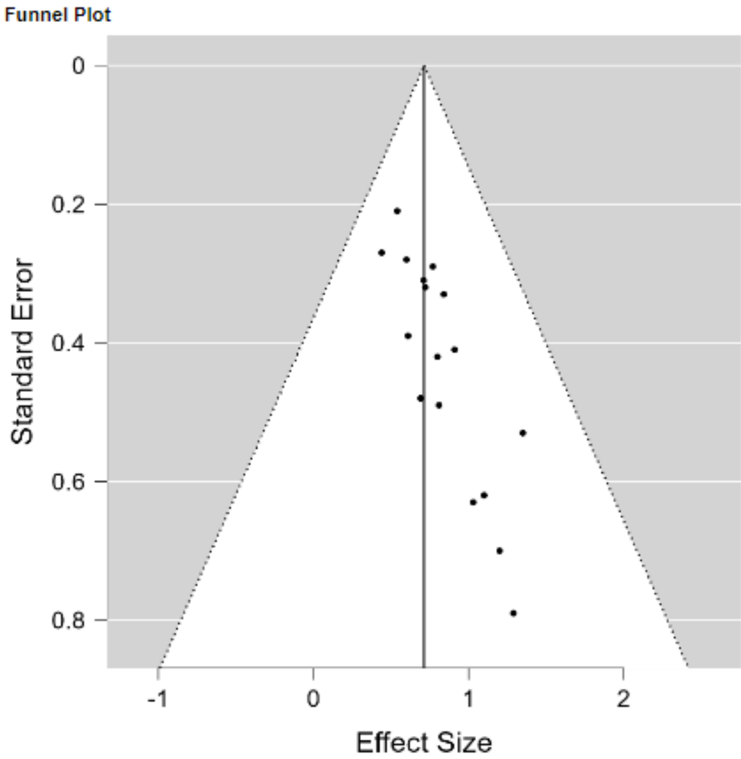

Figure 1. Funnel Flot of Hedge's Standard Error

Based on Table 3. Shows that the Rosenthal Fail-Safe N (FSN) value is 238, then 238 (5.17 + 10) = 2.50 > 1 means that the research in the meta-analysis is resistant to publication bias. The next step is to calculate the p-value to test the hypothesis. This is to determine whether Problem-Based Learning positively impacts students' overall science learning activities based on random effect models. The overall analysis results based on random effect models can be seen in Table 5.

Based on Table 5. The overall effect size value (ES = 0.837) with high criteria. Furthermore, the z value = 6.327 with p-value = 0.000 <0.5 means that the application of Problem-Based Learning is more effective in improving students' science learning outcomes than conventional learning classes.

Table 5. Overall analysis based on random effect models

Estimation Model	n	Z	p	Effect size	Standard Error	95 % CL
Randon effect model	17	6.327	0.000	0.828	0.372	[0.313; 1.623]

Discussion

The application of the problem-based learning model has a significant impact on student learning activities. This can be seen from the average effect size value (ES = 0.828) high criteria. Problem-based learning can encourage critical thinking skills and student learning outcomes (Mulyanto et al., 2018; Saputro et al., 2020; Razak et al., 2022). The problem-based learning model makes students more active in the learning process and more courageous in expressing their ideas (Seyhan & Türk, 2022; Sr & Ray, 2019; Fitriani, 2020). According Aidoo & Ofori's (2016) problem-based learning model students are more creative and innovative in solving a problem.

In teaching and learning activities at school, teachers are guided to be able to apply learning models that encourage students to be more active. According to (Hastuti et al., 2016) Problem-based learning model can improve students' understanding of concepts in science learning. Science learning students are led to be more active and creative in learning (Kodariyati & Astuti, 2016; Janah & Widodo, 2013; Tiarini et al., 2019). Not only that, in learning, a student must be able to think scientifically and critically in solving a problem (Tosun, 2013; Winarti et al., 2022; Festiyed et al., 2022).

Mokambu (2021) stated that the problem-based learning model could improve creative thinking skills in science learning. The problem-based learning model is very effective to be applied to science learning. This can be seen from the value (z = 6.327 or p-value <0.05), so the problem-based learning model must be applied to students' science learning. Problem-based learning model can stimulate students' critical thinking in science learning (Devi & Bayu, 2020; Setiawan, 2013). Students with critical thinking skills in science learning can apply the subject matter to their environment. (Supratman et al., 2021; Nwazota & Institute, 2018; Yustiana el al., 2022). So, the problem-based learning model can support students' thinking skills in learning science (Suhaimi et al., 2022; Ichsan et al., 2022).

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