

The Effect of Problem Based Learning-STEM on Students' 21st Century Skills in Indonesia: A Meta-Analysis

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Abstract. 21st century skills are skills that must be possessed by students. Students' 21st century skills are still relatively low. Problem-based learning is a learning model that encourages students to improve 21st century skills. Problem based learning-STEM in the process of student learning activities has not run optimally. This study aims to determine the effect of the Problem Based Learning-STEM model on students' 21st century skills. This research is a type of meta-analysis research. The data sources in this study came from 6 national and international journals published in 2015-2023. The process of searching for data sources through Google Scholar, ProQuest, ScienceDirect, Wiley and Eric databases. The database for each study must meet the inclusion and exclusion criteria. The heterogeneity of the data taken was analyzed with the help of the Comprehensive Meta-analysis (CMA) version 3.0 application. Meta-analysis showed an effect size value of 1.45 with very high criteria. This finding shows that the Problem Based Learning-STEM model has a significant effect on students' 21st century skills. This model needs to be applied in every school so that students have 21st century skills.

Keywords: Problem Based Learning, STEM, Learning, 21st Century Skills, Meta-Analysis

INTRODUCTION

21st century skill is an ability possessed by students to think critically, creatively, innovatively, problem solving, communication and collaboration in a teaching and learning activity (Lolanessa et al., 2020; Öztürk, 2023; Razak et al., 2022; Santosa & Sepriyani., 2020). The 21st century skills are better known as 4C skills or Critical thinking, Creative, Collaborative and Communication (Atabey & Topçu, 2020). 21st century skills really help students understand concepts and subject matter (Turhan & Demirci, 2021; Mirici & Ataberk, 2014; Zulkifli et al., 2022; Ichsan et al., 2023; Alzahrani & Nor, 2022; Oktarina et al., 2021). students who have 21st century skills will find it easier to understand lessons (Akçay et al., 2022; Karatas & Arpacı, 2021; Rahman et al., 2023; Supriyadi et al., 2023). In addition, these 21st century skills encourage students to master future educational technologies (Erol, 2021; Semilarski et al., 2021; Yang & McKenzie, 2018).

21st century skills are still a major problem in the world of education (Laar et al., 2020; Göksün & Kurt, 2017). Students' 21st century skills in Indonesia are low (Widodo & Wardani, 2020; Santosa et al., 2021; Suharyat et al., 2022; Zulyusri et al., 2020; Apra et al., 2021; Ichsan et al., 2023). Based on the 2018 PISA results, students' scientific literacy in 21st century learning obtained a score of 398, which is still relatively low compared to other countries. (Putranta et al., 2021; Ichsan et al., 2022; Sofianora et al., 2023). In addition, the learning process is still centered on the teacher (Suhaimi et al., 2022), lack of opportunity for students to think critically and lack of teacher assistance in encouraging students' 21st century skills (Munawwarah et al., 2020; Muzana et al., 2021; Santosa & Yulianti, 2020; Winarni, 2022; Suharyat et al., 2022; Rahman et al., 2023). Menurut Dewi et al., (2021) Teachers are not yet optimal in applying material towards students' 21st century skills.

Problem based learning is a learning model that can encourage students to improve their 21st century skills (Baran et al., 2021; Novitra et al., 2021; Manuaba et al., 2022; Komasaawa et al., 2018). Problem based learning is a learning model that is centered on students in the process of solving a problem (Farisi et al., 2017; Apra et al., 2021; Chaidam & Poonputta, 2022). The problem-based-learning model is able to improve students' critical thinking, creative and problem solving skills (Simanjuntak et al., 2021; Sousa & Costa, 2022; Thorndahl & Stentoft, 2020; Sari et al., 2021; Fradila et al., 2021). The problem base learning model encourages students to be more active in teaching and learning activities (Alfares, 2021; Laksmi et al., 2021). Furthermore, the problem based learning model encourages students to encourage 21st century skills in learning activities. The problem based learning model is effectively combined with STEM.

STEM is a learning model that combines Science Technology Engineering and Mathematics in teaching and learning activities (Kulakoglu & Kondakci, 2023; Çeliker, 2020; Rahman et al., 2023; Hite & Spott, 2022). STEM is able to improve students' 21st century thinking skills. According to (Waters & Orange, 2022; Drew et al., 2015) STEM in the world of education can prepare students to be competitive and pursue fields according to their potential. STEM can not only improve students' 21st century skills (Wilson et al., 2022), but also able to improve student learning outcomes (Darsani, 2019).

Previous research Maghfiroh et al., (2016) by the Problem based learning- STEM model is able to improve science process skills in science students. The problem based learning model can improve students' scientific literacy (Wong et al., 2021). According to research (Amaral & Fregni, 2021) Problem based learning model helps students to improve critical thinking skills in learning. The problem-based learning model is effective for increasing learning outcomes and students' creative thinking abilities (Hamzah et al., 2022). Furthermore, research by (Hadi, 2021) the problem-based learning-STEM model is able to improve students' thinking skills in learning mathematics. So the application of the Problem Based Learning –STEM model needs to be implemented in the education system in Indonesia. According to (Putri et al., 2020) problem based learning-STEM is very effective in improving student learning outcomes and thinking skills. Based on the problems above, this study aims to determine the effect of the Problem Based Learning-STEM model on the skills of the 21st century Indonesian students.

METHODS RESEARCH

This research is a kind of meta-analysis research. Meta-analytic research is a type of research that analyzes studies that can be calculated using statistics (Suharyat et al., 2022; Supriyadi et al., 2022; Razak et al., 2021; Kaçar et al., 2021; Ridwan et al., 2021; Karim et al., 2022). Meta-analysis was used to determine the effect of the problem based learning-STEM model on students' 21st century skills. The population in the study came from educational journals published from 2017-2023. The sample for this study were 16 national and international journals that met the inclusion criteria with the PRISMA model which can be seen (Figure 1.). Data collection techniques through direct observation through the Google Scholar database, Eric, Wiley, ScienceDirect and ProQuest.

(Aspiranti & Larwin, 2021) meta-analysis steps, namely 1) formulating the problem, 2) collecting related studies; 3) make improvements and correct statistical information; 4) determine the average obtained by each study; 5) determine the effect size variations. Data analysis in this study was a quantitative statistical analysis by calculating the effect size of each study with the help of the Comprehensive Meta-analysis (CMA) version 3.0. The effect size criteria can be seen in Table 1.

Tabel 1. Effect Size category

Effect Size		Category
-0.15	0.15	Ignored
0.15 < ES	0.40	Small
0.40 < ES	0.75	Medium
0.70 < ES	1.10	Hight
1.10 < ES	1.45	Very Hight
1.45 > ES		Hight Inluence

Source: (Musna et al., 2021; Suparman et al., 2021; Ichsan et al., 2022; Santosa et al., 2021; Santosa, et al., 2021)

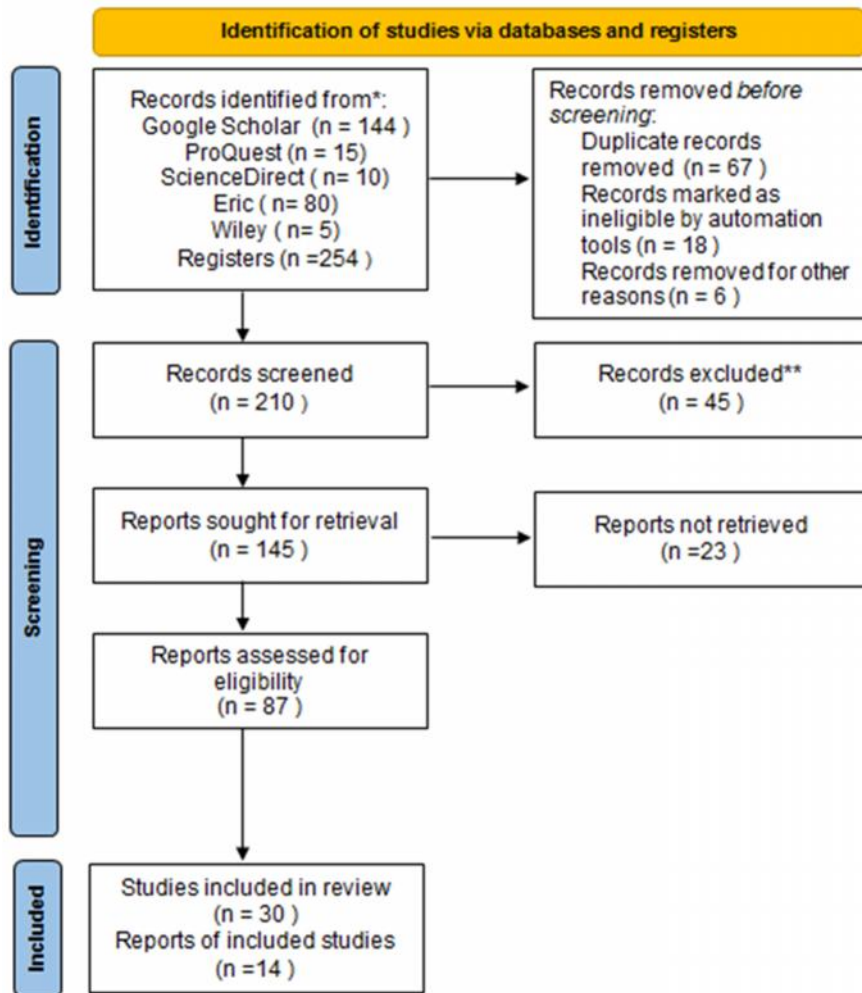


Figure 1: PRISMA Selection Process for Each Study

RESULT AND DISCUSSION

From the results of an analysis of 16 national and international journals related to the influence of problem-based learning-STEM on students' 21st century skills in Indonesia, each study met the inclusion criteria. The effect size of each study can be seen in (Table.2).

Table 2. Effect Size of Each Study

No	Author	Tahun	Journal Type	Hedge's	Category
1	Adiwiguna <i>et al.</i> ,	2019	National	0.56	Medium
2	Ariyatun & Octavianelis,	2020	National	0.90	Hight
3	Ardiansyah <i>et al.</i> ,	2021	National	0.61	Medium
4	Putri <i>et al.</i> ,	2020	National	1.20	Very Hight
5	Parno <i>et al.</i> ,	2019	International	1.35	Very Hight
6	Setyaningsih <i>et al.</i> ,	2022	International	0.64	Medium
7	Febrianto <i>et al.</i> ,	2021	National	1.10	Very Hight
8	Hujjatusnaini <i>et al.</i> ,	2022	National	0.88	Hight
9	Arisa & Sitinjak	2022	National	2.20	Hight Influence
10	Shamdas <i>et al.</i> ,	2023	National	0.52	Medium
11	Isatunada & Haryani	2021	National	0.34	Small
12	Salikha <i>et al.</i> ,	2021	International	0.52	Medium
13	Akcanca,	2020	International	0.81	Hight
14	Perdana <i>et al.</i> ,	2021	International	0.94	Very Hight
15	Rizaldi <i>et al.</i> ,	2020	International	1.31	Very Hight
16	Baran <i>et al.</i> ,	2021	International	0.77	Hight
Nilai Rata-rata Effect Size				0.915	Hight

Based on Table 2. Shows an average effect size value of 0.915 with high criteria. This shows that the problem based learning – STEM model has a significant influence on the 21st century skills of Indonesian students. This is in line with research Benek & Akcay (2022) the problem based learning-STEM model has a positive influence on 21st century thinking skills. The problem-based learning-STEM model can encourage critical, creative thinking and problem-solving skills in students (Rais *et al.*, 2021; Ok & Kaya., 2021). According to Budiarti *et al.*, (2021) model problem based learning students are more active in providing solutions in solving a problem in learning. The problem-based learning-STEM learning model makes students learn more easily in understanding difficult study material (Noble *et al.*, 2020; Dare *et al.*, 2021; Çeliker, 2020). Therefore, the problem based learning-STEM model needs to be developed in student learning activities in Indonesia.

Next, determine the heterogeneity test of each study using the Q statistic and determine the estimation model. Table 3. Describes the results of the comparison of meta-analyses based on the estimation model.

Table 3 Meta-Analytic Comparison Results Based on Estimation Models

Estimation model	n	Q _b	df(Q)	p-value
Fixed effect models	16	98.120	15	0.000
Random effect models	16			

Based on Table 3. Shows a Q_b value of 98,120 greater than 21,010 with 15 degrees of freedom in table X2. It can be concluded that each study is heterogeneous with a p-value <0.05. The next step is to calculate the usual publications based on random effect models. It aims to see whether the journal that publishes only significant studies that appear to be higher than the actual effect size (Suparman *et al.*, 2021). To see publication bias, you can do Rosenthal's fail-safe N (FSN) test which can be seen (Table.4). The test is used because the effect size is not completely symmetrical in the vertical line. Therefore it is necessary to examine Rosenthal's fail-safe N (FSN) test.

Table 4. Hasil Uji Rosenthal's Fail-Safe N (FSN)

Bias Condition	
Z value for the observed study	8.45012
P value for the observed study	0.00000
Alpha	0.05
Tails	3
Z value for Alpha	1.02310
Number of Observed Studies	16
FSN	970

Based on Table 4, the Rosenthal's Fail-Safe N Test (FSN) value is 970. With a calculation result of $970 / (5.16 + 10)$ it is $10.78 > 1$. It can be concluded that each study analyzed is resistant to publication bias. Hence, no research studies were lost in research. The next stage is to test the research hypothesis by calculating the p-value that can be seen (Table.5).

Table 5. Hypothesis Test Results Based on Random Effect Size Models

Estimation Model	n	Z	P	Effect Size	Standard Error	95% Confidence Interval	
						Low Limit	Upper limit
Random effect Model	16	4.01	0.00	0.915	0.015	0.341	1.235

Based on Table 5. Shows an effect size value of 0.915 with a degree of confidence of 95%, namely the lower limit of 0.341 and the upper limit of 1.235. So, the effect size has a high criterion. In addition, the standard error is 0.015 and the p-value < 0.001 . This shows that the problem-based STEM learning model has a positive impact on students' 21st century skills in Indonesia. 21st century skills are very important to help them solve various problems in learning. According to (Dare et al., 2021) the problem-based learning-STEM model is able to shape student careers in facing the 21st century.

The application of the problem based learning-STEM model in improving students' 21st century thinking skills needs to be applied to schools (Puspitasari, 2020; Suharyat et al., 2023; Elfira & Santosa, 2023). In the Indonesian education system, the Problem based learning-STEM model is an effective model in improving 21st century thinking skills, better known as 4C (Erol, 2021; Worapun et al., 2022; Sumarni et al., 2020). 21st century skills encourage students to think critically, innovatively, creatively, collaboratively and communicatively in a learning process activity. The problem-based learning-STEM model forms the personality of students who have competitiveness (Viro et al., 2020; ahin, 2021). Therefore, the problem based learning-STEM model is a breakthrough in improving students' 21st century skills in Indonesia.

CONCLUSION

Based on the research above, it can be concluded that the effect size value (ES = 0.915) is high. This shows that the Problem Based Learning-STEM model has a significant influence on students' 21st century skills. This model needs to be applied to every school so that students have 21st century skills. Problem based learning-STEM models help students and teachers learn more effectively and efficiently. Furthermore, the application of the problem based learning-STEM model encourages the potential of students who think at a higher level.

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