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Effectiveness of the Flipped Classroom Model on the Problem-Solving Abilities of Science Education Students: A Meta-analysis Study

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Abstract: A concise the purpose of the study was to determine the effectiveness of the flipped classroom model on the problem solving skills of science education students. A total of 950 studies were analyzed obtained from six databases consisting of ScienceDirect, Education Resources Information Center (ERIC), Wiley Journal, Springer; ProQuest and IEEE aim to get relevant articles published in 2020-2023. From the analyzed studies, 21 studies were selected for meta-analysis. Data analysis with JSAP software. The results showed that the flipped classroom model provides high effectiveness on the problem solving skills of science education students (r_{RE} = 0.97; 95 % CI [0.840; 1.111]; $p < 0.001$). This finding provides information for teachers to apply the flipped classroom model to improve students' problem solving skills in learning.

Keywords: Effect Size; Flipped Classroom; Meta-analysis; Problem Solving; Science education

Introduction

Natural Sciences (Science) is a subject that trains students to have critical and scientific thinking skills in learning (Akcay, 2019; Puspita et al., 2023). According to Fahrezi et al., (2020) science is a science helping students to study the phenomena of the universe through scientific observation. In the science learning process, students are not only required to have knowledge but students also have direct learning skills with nature (Tenenbaum &; Van Herwegen, 2023; Kho & Chen, 2017; Dorph et al., 2018). Students who study science can implement subject matter in everyday life (Wahyuni &; Gianyar, 2021; He et al., 2020; Suendarti & Virgana, 2022; Han et al., 2023). Science learning encourages students to have problem-solving skills in learning (Poonputta &; Prasitnok, 2022; Daniel, 2016; Hong & Diamond, 2012).

Problem solving ability is an ability possessed by students to provide a solution in solving a problem (Sudarsono et al., 2022; Yunus et al., 2021; Hulaikah et al., 2020). According to Allwood & Montgomery (2015) said that the problem-solving ability of a student in analyzing a problem to get a solution. In science learning, students must have problem-solving skills in order to solve various phenomena that occur in life (Sumiantari et al., 2019). Students who have problem-solving skills in science learning are more creative and able to find learning concepts holistically (Yapatang &; Polyiem, 2022; Fitriani et al., 2020).

However, the problems that occur in students' problem-solving abilities in science learning are still relatively low (Hestiana &; Rosana, 2020; Fitri et al., 2022; Saputri &; Febriani, 2017; Surur et al., 2020). In the learning process, students memorize a lot of material and formulas so that students have not been able to

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apply concepts to solve problems (Sinaga &; Sihombing, 2018). Furthermore, the low problem-solving ability can be seen from PISA (Programme for International Student Assessment) research conducted by the Organization for Economic Cooperation and Development (OECD) In 2018 the science literacy ability of Indonesian students obtained a score of 396 lower than the OECD which was 486 (Zulyusri et al., 2023; Suharyat et al., 2023; Hariyadi et al., 2023). This result is supported by the *International Mathematics and Science* (TIMSS) Trends Research, Indonesian students obtained a score of 397, ranking 61 out of 64 countries (Rahman et al., 2023). In learning activities, teachers apply inappropriate models to encourage students' problem-solving abilities.

The flipped classroom model is a learning model that effectively encourages students' problem-solving abilities (Nurtamam et al., 2023; Nguyen et al., 2021; Ariani et al., 2022). *Flipped* classroom model is a learning model for students to learn through a video from home before classroom learning activities begin (Diningrat et al., 2023; Ajmal et al., 2021; Aslan, 2022). According to Sengul (2021) that *the* flipped classroom model can grow students to be more active in learning. The teacher's flipped classroom model presents learning through a video to students from home when students discuss the material in class (Pratiwi et al., 2022).

The flipped classroom model can improve the ability to understand concepts and solve problems in students (Khofifah et al., 2021). Flipped classroom model can increase self-confidence, motivation and perception of students in learning (Sirakaya &; Ozdemir, 2018; Guo, 2019). Furthermore, *the* flipped classroom model can encourage students to have critical and collaborative thinking skills (Chang et al., 2022; Paristiowati et al., 2019; Princess et al., 2021). This research gap, many studies related to the flipped classroom model have not found the effect of the *size* of the flipped classroom model and the problem-solving ability of students in science learning. Based on this, this study aims to determine the effectiveness of the flipped classroom model on the problem-solving ability of science education students.

Method

Research Design

This study is a type of meta-analysis research. Meta-analysis is a type of research that searches data, collects and analyzes primary data quantitatively (Kaçar et al., 2021; Öztürk et al., 2022 ; Santosa et al., 2021; Aybirdi, 2023). The study aims to analyze research quantitatively before related to the flipped classroom model on the problem-solving ability of science education students.

Data Collection Procedural

This study collected quantitative data sourced from reputable international journals and proceedings. Data tracing database through ScienceDirect, ScienceDirect, Education Resources Information Center (ERIC), Wiley Journal, Springer; ProQuest and IEEE. Data search keywords are "Flipped Classroom Model", "Problem Solving", "The effect of Flipped Classroom model on problem solving ability" Flipped classroom in science learning". The data selection process through the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method consisting of identification, schreening, eligibility and included can be seen in Figure 1.

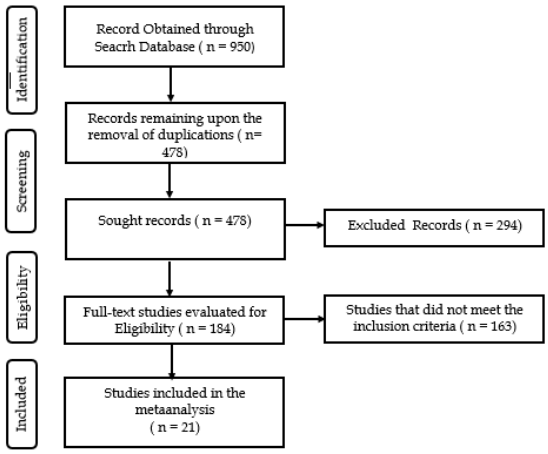

Figure 1. Data Selection Process Through PRISMA Method (Baysal et al., 2023)

Eligibility Criteria

The eligibility criteria for articles collected in this meta-analysis research consist of: 1) research published in 2020-2023; 2) research data in the form of international journals or proceedings indexed by Scopus; Web of Science; Thomson Routers and SINTA; 3) the research method should be a flipped classroom experimental model and a conventional control class; 4) research related to science education; 5) The study reported complete data to calculate the effect size.

Data coding

The coding process in meta-analysis is very necessary. Data coding serves to facilitate research data analysis. Encoding based on data characteristics consists of 1) author; 2) Publicas year, 3) sample size, correlation value (r) and 4) Research indexation.

Data Analysis

Data analysis in meta-analysis studies calculated the value of effect size (Glass, 2015; Chamdani et al., 2022). According to Borenstein et al., (2009) statistical

analysis in meta-analysis research consists of 1) calculating the effect size value of primary research; 2) conduct heterogeneity tests and determine estimation models; 3) check publication bias and 5) calculate the p-value to test the hypothesis. For data analysis in this study with JSAP 0.8.4 software. Mneurut Cohen et al., (2007) effect size criteria can be seen Table 1.

Table 1. Cohen's Effect Size Criteria

Effect Size	Category
0.0 ≤ d ≤ 0.2	Low
0.2 ≤ d ≤ 0.8	Moderate
d ≥ 0.8	High

Result and Discussion

Based on the results of article analysis through an online database, 950 articles related to the flipped classroom model were obtained on the problem-solving ability of science education students. From these searches, only 21 articles met the inclusion criteria to be used as data in the meta-analysis. Data that meet inclusion are analyzed based on the characteristics of the research code, year of publication, sample size (N), effect size, Standard error (SD) and research index can be seen Table 2.

Table 2. Results of Article Characteristics Analysis

Code	Year	Sample Size	Effect Size	Standard Error	Index
Study 1	2021	44	1.15	0.27	Scopus
Study 2	2020	120	1.32	0.33	Scopus
Study 3	2021	60	0.76	0.21	SINTA
Study 4	2022	90	0.95	0.30	Scopus
Study 5	2021	125	1.20	0.28	Scopus
Study 6	2023	50	0.82	0.30	SINTA
Study 7	2021	200	2.05	0.42	Scopus
Study 8	2020	30	0.74	0.20	SINTA
Study 9	2020	48	0.97	0.22	SINTA
Study 10	2019	130	1.26	0.25	Scopus
Study 11	2020	48	0.80	0.37	SINTA
Study 12	2020	100	1.50	0.40	Scopus
Study 13	2023	60	0.92	0.39	SINTA
Study 14	2023	30	0.67	0.16	SINTA
Study 15	2020	80	1.20	0.18	Scopus
Study 16	2020	45	0.81	0.32	SINTA
Study 17	2022	96	0.83	0.27	SINTA
Study 18	2021	60	0.79	0.20	SINTA
Study 19	2020	30	0.63	0.16	SINTA
Study 20	2023	140	2.14	0.40	Scopus
Study 21	2020	56	0.87	0.23	SINTA

Based on Table 2, the results of the analysis of the characteristics of articles published in 2020-2023 and the total number of articles indexed by SINTA and Scopus. The sample size ranges from the smallest 30 and the largest 200, the effect size ranges from 0.63 – 2.05. According to the effect size criteria Cohen et al., (2007) from 21 articles there are four effect sizes (19.04%) medium category and seven effect sizes (80.96%) high category. Next, conduct a heterogeneity test of the 21 effect sizes analyzed. The results of the heterogeneity test can be seen in Table 3.

Table 3. Heterogeneity Test Results

	Q	Df	p
Omnibus Test of Model Coefficients	199.022	1	< 0.001
Test of Residual Heterogeneity	3 4,106	20	< 0.001

Note: p-values are approximate

Table 3 explaining the results of the heterogeneity test obtained the value Q = 199.022. This value is greater than that of 34.106 with a confidence level of 95% and a p value of < 0.001. This finding can be concluded the distribution of 21 heterogeneously distributed effect sizes. So, a suitable random effect model was used to analyze 21 articles. Next, check the publication bias of the 21 articles analyzed. Checking publication bias can be done with a funnel plot and calculating the Rosenthal Fail Safe N (FSN) value (Diah et al., 2022; Çevik &; Bakioğlu, 2022 ; Suparman et al., 2020; Uluçinar, 2023). The results of checking publication bias with funnel plots can be seen in Figure 2.

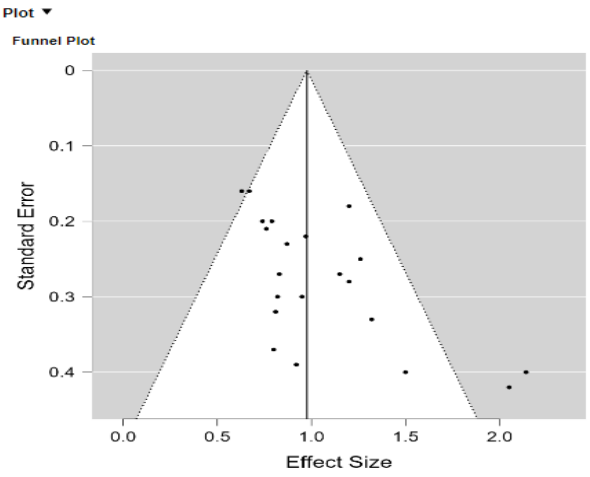

Figure 1. Funnel Plot Standard Error

Based on figure 1, checking publication bias with funnel plots is difficult to know whether the funnel plot is symmetrical or asymmetric, so it is necessary to do a *Risenthal Fail Safe N* (FSN) test. *Rosenthal Fail Safe N* (FSN) test results can be seen in Table 4.

Table 4. Rosenthal Fail Safe N (FSN) Test Results

File Drawer Analysis	Fail Safe N	Target Significance	Observed Significance
Rosenthal	2455	0.050	< 0.001

Based on Table 4, the value of k = 21 then 5k + 10 = 115. Furthermore, the safe N file value is 2455 with a target significance of 0.050 and p < 0.001. The value of Fail safe N > 5k + 10 can be concluded that the data in this meta-analysis is resistant to publication bias and no data is added or discarded. Next, calculate the summaty effect size or mean effeck size to find out the p-value. The summary effect size test results can be seen in Table 5.

Table 5. Summary Effect Size Test Results

	Estimate	SE	Z	p	95% Confidence Interval	
					Lower	Upper
Intercept	0.976	0.069	14.108	<0.001	0.840	1.111

Table 5, shows the analysis of effeck size with random effect model at an intervel level of 95%, a lower limit of 0.840 and a limit of 1.111 and a summary effect size value of 0.976, this effect size is in the high category. The Z-test value is 14.108 and the p significance value < 0.001. These results conclude that the application of the flipped classroom model has a significant influence on the problem-solving ability of science education students.

This research is in line with Lin (2018) the application of the flipped classroom model can improve student achievement, perception and problem-solving abilities. This finding is in line with Mudhofir, (2021) the flipped classroom model can encourage students' problem-solving abilities. The flipped classroom model trains students to learn more actively and creatively in understanding the material provided by the teacher (Schiller &; Herreid, 2013; Baytiyeh, 2017; Hwang & Chen, 2023), so as to improve problem-solving abilities. *The flipped classroom model* makes it easier for teachers to provide material so that the learning process is more interesting. Flipped classroom model of students learning through videos that have been given by teachers can train students to learn independently (Elmaadaway, 2018).

The flipped classroom model increases student motivation and learning outcomes and fosters science literacy (Rahayu et al., 2022; Paristiowati et al., 2019; Indah et al., 2020). In addition, the flipped classroom model can encourage students to think critically and creatively in solving a problem (Asmara et al., 2018; Rahmatan et al., 2022; Listiqowati, 2022; Etemadfar et al., 2020). Flipped classroom model students learn without limits by utilizing technology (Al-zoubi, 2021; DeRuisseau, 2016). The flipped classroom model trains students to have problem-solving skills in learning (Mirlanda et al., 2020).

Conclusion

From this meta-analysis research, it can be concluded that the flipped classroom model provides high effectiveness on the problem-solving ability of science education students (rRE = 0.976; 95% CI [0.840; 1.111]; P < 0.001. These findings provide information to teachers to apply the flipped classroom model to improve students' problem-solving skills in learning. The flipped classroom model can encourage students to learn actively and innovatively in utilizing technology. Flipped classroom models can help teachers interact with students on a personal level.

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In completing the research, nine authors contributed, namely Tomi Apra Santosa, Dian Purnama Ilahi, Lisa Utami contributed in collecting, screening and analyzing research data, while Festiyed, Desnita, Asrizal, Skunda Deliarosta, Yerimadesi and Fitri Arsih checked and made corrections to this article.

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Conflicts of Interest
The authors declare no conflict of interest.

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